A STUDY OF THE EFFECTIVENESS OF ACTIVATED CARBON FILTER FOR REMOVAL OF HALOTHANE IN THE OPERATING ROOM

LIEUTENANT ANEK PANLAEM

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF SCIENCE
(INDUSTRIAL HYGIENE AND SAFETY)
FACULTY OF GRADUATE STUDIES
MAHIDOL UNIVERSITY
2006

ISBN 974-04-7668-6

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Lt. A. Panlaem
....
Lt. Anek Panlaem
Candidate

....
Assoc. Prof. Chompusakdi Pulket
Ph.D.(Industrial Hygiene & Env.H.)
Major-Advisor

Vichai Pruk.
....
Assoc. Prof. Vichai Pruktharathikul
M.Sc.(Industrial Hygiene and Safety)
Co-Advisor

V. Singhakajen
....
Assoc. Prof. Vajira Singhakajen
M.A.(Demography)
Co-Advisor

....
Prof. M.R. Jisnuson Svasti,.
Ph.D.
Dean
Faculty of Graduate Studies

....
Assoc. Prof. Chompusakdi Pulket
Ph.D.(Industrial Hygiene & Env.H.)
Chair
Master of Science Program in
Industrial Hygiene and Safety
Faculty of Public Health

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was submitted to the Faculty of Graduate Studies, Mahidol University
for the degree of Master of Science (Industrial Hygiene and Safety)
on
September 29, 2006

Lt. A. Panlaem
……………………………………………
Lt. Anek Panlaem
Candidate

……………………………………………
Assoc. Prof. Chompusakdi Pulket
Ph.D.(Industrial Hygiene & Env.H.)
Chair

Vichai Pruk.
……………………………………………
Assoc. Prof. Vichai Pruktharathikul
M.Sc.(Industrial Hygiene and Safety)
Member

……………………………………………
Assoc. Prof. Jitrapun Pusapukdepob
M.Sc.(Industrial Hygiene and Safety)
Member

V. Singhakajen
……………………………………………
Assoc. Prof. Vajira Singhakajen
M.A.(Demography)
Member

……………………………………………
Prof. M.R. Jisnuson Svasti, Ph.D.
Dean
Faculty of Graduate Studies
Mahidol University

C. Chaikittiporn
……………………………………………
Assoc. Prof. Chaermchai Chaikittiporn
Dr.P.H.(Epidemiology)
Dean
Faculty of Public Health
Mahidol University

ACKNOWLEDGEMENT

I wish to express my sincerest gratitude to my advisor, Associate Professor Dr. Chompusakdi Pulket for invaluable advice and encouragement given throughout my study. I am also gratefully indebted to my co-advisor: Associate Professor Vichai Pruktharathikul., Associate Professor Vajira Singhakajen and Associate Professor Jitrapun Pusapukdepob for their inspiration and valuable suggestion.

I would like to extend my gratitude to my friends and the staff of the Division of Preventive Medicine, Department of Naval Medical for their full cooperation, encouragement during the whole period of my study.

I would to express my deepest appreciation and sincere gratitude to my beloved family.

Lieutenant Anek Panlaem

A STUDY OF THE EFFECTIVENESS OF ACTIVATED CARBON FILTER FOR REMOVAL OF HALOTHANE IN THE OPERATING ROOM.

LIEUTENANT ANEK PANLAEM 4437091 PHIH/M

M.Sc. (INDUSTRIAL HYGIENE AND SAFETY)

THESIS ADVISORS: CHOMPUSAKDI PULKET.,Ph.D. VICHAI PRUKTHARA-THIKUL.,M.Sc. VAJIRA SINGHAKAJEN., M.A.

ABSTRACT

The objective of this research was to study the relationships between the activated carbon adsorption rate of halothane and the rate of air changes in operating rooms. This study used filters made from local activated carbon for removal of halothane. The experiment was designed using activated carbon with the combination of air change to reduce halothane concentration in order to control the concentration at 50 ppm which corresponded to the threshold limit value (TLV). The experiment was conducted in a 1 m^3 chamber, equipped with activated carbon filter size 0.1 x 0.25 m^2. The concentration of halothane, velocity and weight of activated carbon was controlled at 50 ppm, 0.97 m/s and 50 g respectively. The rate of air change was set at 7 levels (i.e.: 15, 20, 25, 30, 35, 40, 45 air changes per hour) and replicated 5 times for each air change. This experimental data was collected in order to find the correlation between activated carbon adsorption rate of halothane and the rate of air change.

This research showed that 1.) There were relationships between air change rates, the percentage of halothane adsorption, time duration and halothane concentration i.e.: when the air change rate increased, the percentage of halothane adsorption and time duration increased, (r = 0.75, p-value = 0.01) while the concentration of halothane after adsorption decreased (r = -0.76, p-value = 0.01) 2.) The percentage of halothane adsorption varied according to the air change rate and concentration of halothane before adsorption (r = 0.80, p-value = 0.05) illustrated by the regression equation $Y = -51.099 + 0.382 X_1 + 1.537 X_2$. When Y= percentage of halothane adsorption. X_1 = air change rate. X_2 = concentration of halothane before adsorption. 3) As the air change rate increased, the efficiency of activated carbon adsorption increased at a certain rate but the efficiency of activated carbon adsorption did not change (p-value = 0.05). This point was the saturated adsorption of activated carbon.

The recommendation was that the limitation of using activated carbon would concern particularly the storage and maintenance of the material in order to meet the efficiency criteria.

KEY WORDS : ACTIVATED CARBON / ADSORPTION / AIR CHANGE RATE / HALOTHANE

77 P. ISBN 974-04-7668-6

การศึกษาประสิทธิภาพของตัวกรองชนิดแอ็คติเวเตตคาร์บอนที่ใช้กำจัดฮาโลเทนในห้อง ผ่าตัด

(A STUDY OF THE EFFECTIVENESS OF ACTIVATED CARBON FILTER FOR REMOVAL OF HALOTHANE IN THE OPERATING ROOM.)

เรือเอก เอนก แป้นแหลม 4437091 PHIH / M

วท.ม. (สุขศาสตร์อุตสาหกรรมและความปลอดภัย)

คณะกรรมการควบคุมวิทยานิพนธ์ : ชมภูศักดิ์ พูลเกษ, Ph.D.(Industrial Hygiene and Environment Health)., วิชัย พฤกษ์ธาราธิกุล, M.Sc.(Industrial Hygiene and Safety)., วชิระ สิงหะคเชนทร์, M.A.(Demography).

บทคัดย่อ

วัตถุประสงค์ของการศึกษาวิจัยครั้งนี้ เป็นการศึกษาหาความสัมพันธ์ระหว่างอัตราการดูดซับฮาโลเทนของแอ็คติเวเตตคาร์บอนกับอัตราการหมุนเวียนอากาศในห้องผ่าตัด การศึกษาเป็นการนำตัวกรองอากาศที่ทำจากแอ็คติเวเตตคาร์บอนในท้องตลาดมาใช้กำจัดฮาโลเทน การทดลองได้ถูกออกแบบให้ใช้แอ็คติเวเตตคาร์บอนร่วมกับการไหลเวียนของอากาศเป็นตัวดูดซับฮาโลเทนที่ระดับความเข้มข้น 50 พีพีเอ็ม ตามข้อกำหนดค่ามาตรฐานที่ยอมให้ได้รับหรือสัมผัส การทดสอบได้สร้างเป็นห้องทดลองขนาด 1 ลูกบาศก์เมตร, แผ่นตัวกรองอากาศขนาด 0.1x0.25 ตารางเมตร, กำหนดค่าความเข้มข้นของฮาโลเทน ความเร็วลม และน้ำหนักของแอ็คติเวเตตคาร์บอนที่บรรจุในแผ่นกรองอากาศเป็นค่าคงที่ที่เท่ากันทุกครั้งคือ 50 พีพีเอ็ม 0.97 เมตรต่อวินาที และ 50 กรัมตามลำดับ ใช้อัตราการหมุนเวียนอากาศ 7 ระดับคือ 15, 20, 25, 30, 35, 40, 45 การหมุนเวียนอากาศต่อชั่วโมง และทุกการหมุนเวียนอากาศจะทำซ้ำ 5 ครั้ง นำข้อมูลจากทดลองมาหาความสัมพันธ์ระหว่างอัตราการดูดซับของแอ็คติเวเตตคาร์บอนต่อฮาโลเทน และอัตราการหมุนเวียนอากาศ ผลการวิจัยสรุปได้ว่า 1). มีความสัมพันธ์ระหว่างอัตราการหมุนเวียนอากาศ เปอร์เซ็นต์ในการดูดซับฮาโลเทนของแอ็คติเวเตตคาร์บอน ระยะเวลา และระดับความเข้มข้นของฮาโลเทน คือ เมื่ออัตราการหมุนเวียนอากาศเพิ่มขึ้น เปอร์เซ็นต์ในการดูดซับฮาโลเทนและระยะเวลาจะเพิ่มขึ้น (r= 0.75,p-value = 0.01) ขณะที่ระดับความเข้มข้นของฮาโลเทนหลังการดูดซับจะลดลง (r =-0.76,p-value=0.01) 2). เปอร์เซ็นต์การดูดซับฮาโลเทนของแอ็คติเวเตตคาร์บอนจะขึ้นอยู่กับอัตราการหมุนเวียนอากาศและระดับความเข้มข้นฮาโลเทนก่อนการดูดซับ (r=0.80,p-value=0.05)โดยแสดงเป็นสมการถดถอย $Y = -51.099 + 0.382X_1 + 1.537X_2$ เมื่อ Y = เปอร์เซ็นต์การดูดซับฮาโลเทน, X_1 = อัตราการหมุนเวียนอากาศและ X_2 = ระดับความเข้มข้นของฮาโลเทนก่อนการดูดซับ 3). เมื่ออัตราการหมุนเวียนอากาศเพิ่มขึ้นจะทำให้ประสิทธิภาพในการดูดซับฮาโลเทนของแอ็คติเวเตตคาร์บอนเพิ่มขึ้น และเมื่ออัตราการหมุนเวียนอากาศถึงระดับหนึ่งประสิทธิภาพในการดูดซับฮาโลเทนของแอ็คติเวเตตคาร์บอนจะไม่มีความแตกต่างกัน (p-value=0.05) ซึ่งเป็นจุดอิ่มตัวในการดูดซับของแอ็คติเวเตตคาร์บอน ข้อเสนอแนะในการวิจัยนี้คือ ต้องมีความเอาใจใส่ในการใช้แอ็คติเวเตตคาร์บอนโดย เฉพาะเรื่องการเก็บและการบำรุงรักษา เพื่อให้คงสภาพการใช้งานของสารอย่างมีประสิทธิภาพตามมาตรฐาน

77 หน้า. ISBN 974-04-7668-6

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CHAPTER I
INTRODUCTION

1.1 STATEMENT OF THE PROBLEM

Work environment for physicians, nurses, or any one else who works in the operating room was risk to contacted the contamination or disease from patients or even work areas. This factor was important to prevent the problem and should have the constraints to control for the operators who work not less than 8 hours in the operating room. Especially, Waste Anesthetic Gases: (WAGs) (17) is nitrous oxide and halothane that substitute chloroforms in the operation. In case to become unconscious, there are two main factors cause from leaks such as the equipment connectors and patient expiration. The air ventilation is one important factor that can reduce the leak from anesthetic gases. Therefore, there are two ventilation systems in the operation room such as central air system and split type. For the spilt system, the anesthetic gases were accumulated more than the central air system. It would be affecting the health in visualization, audition, nerves systems, liver, and kidney (1, 3, 4, 12, 15, and 19) even though a childless abortive program. It cannot be avoid of the leaks when works in the operation room. Most of the operation rooms in Thailand do not have the leak detector on anesthetic gases such like other countries due to the expensive cost. Operators are not aware of the dangerous effects on health because it was not shown symptom in the short period of time. It is difficult to detect amount of anesthetics gases unless measure it. In case of contacting or perceiving the leaks of anesthetic gases in the long period of time, it will affect the persistent health. So that it should restrict or control anesthetic gases not be more than Time Weight Average: TWA standard (32).

This research was selected anesthetic gases that only were halothane. Researcher studies the possibility of activate carbon to adsorb it that gives the good results due to non-polar substance. The gas concentration was a method used to measure by Gas Chromatography: GC (48). A method of destroy or reduce the anesthetic gases pollution was typical use to called the ventilation system by scavenging system but adsorption method. The adsorption method was usually using the porosity solid material that can adsorb gas molecular into the surface. There were many factors related to an adsorption capacity and adsorption duration e.g. gas concentration, flow rate, temperature, and relative humidity. Therefore, the activate carbon has adsorption characteristic that gas can be adsorbed.

1.2 GENERAL OBJECTIVE

This objective was to study the efficiency of the designed and constructed halothane adsorption equipment.

1.3 SPECIFIC OBJECTIVE

1. The research objective was to study the air change rate conditions in order to the efficiency of halothane adsorption. and
2. A study of the relationship between the activated carbon adsorption rate of halothane and air change rate conditions.

1.4 RESEARCH HYPOTHESIS

1. At the different rate of the air change condition, the activated carbon can reduce the halothane concentrations in the different levels.
2. The efficiency of halothane adsorption by activated carbon would be reduced when the time consumption increased.

1.5 RESEARCH VARIABLE

Initial variable

Air change

Halothane concentration (PPM)

Time duration (minute)

Activated carbon (gm)

Dependent variable

Halothane concentration (PPM)

Control variable

Temperature (˚C)

Pressure (atm)

Relative humidity (%)

1.6 SCOPE AND LIMITATION OF RESEARCH

This study was conducted in the controlled chamber at temperature of 22-24 degree Celsius, pressure 1.00-1.02 atmosphere, and humidity at 45-55 %. Initially, this study was set up the concentrations of halothane to be constant. Then, give the air pass through the activated carbon at the different air change rate. This experiment was replicated 5 times at each rate of air change. Additionally, the initial halothane concentrations could not be prepared at the same level all the time.

1.7 DEFINITION OF KEYWORDS

Activated Carbon

The charcoal from woods, coconut shell, fruit peel, or coal that burn down and then dip into water and dry. Then, the charcoal was burned at temperature 1000 degree Celsius on vacuum state.

Adsorption

The process of gas molecule or vapor gas adsorb at surface of adsorption material. The adsorption process occurs at the inner surface of adsorption material called Vander Valve tension. The Vander Valve tension is more or less depending on the gas type and gas characteristic and adsorption material.

Air change rate

The quantity of air in the times of room air volume would be changed due to leaks or supply air within 1 hour. For example, 3 air changes, 1000 cubic feet means fresh air change is equal to 3000 cubic feet per hour.

Halothane

A general anesthetic drug; a colorless, nonflammable liquid that was widely used as an inhalation anesthetic and that takes effect rapidly and could be rapidly counteracted. These drugs were generally administered by an anesthesiologist or anesthetist in order to induce or maintain general anesthesia to facilitate surgery. Its systematic name is 2-bromo-2-chloro-1, 1, 1-trifluoroethane.

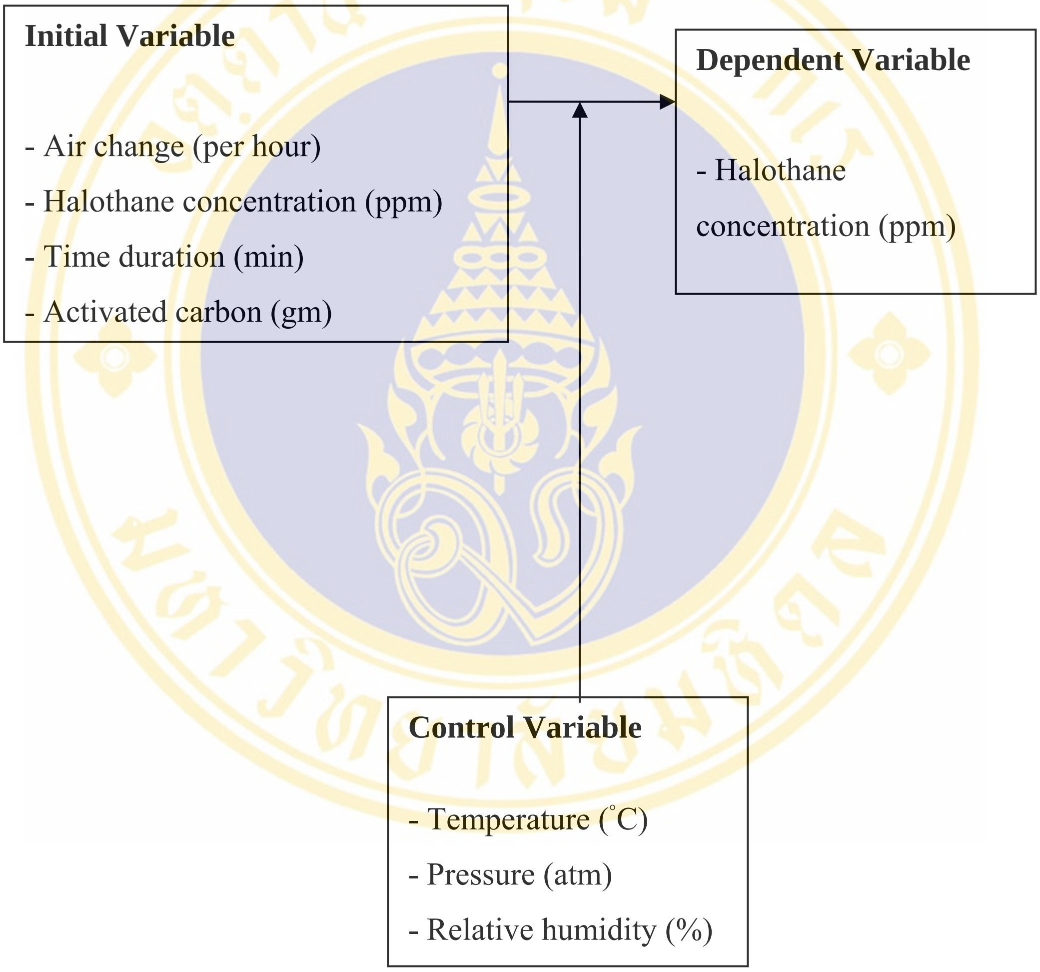
1.8 RESEARCH ADVANTAGES

1. To apply use of the design filter made from activated carbon in air ventilation system of the operating room that convenient to buy in market. It could control amount of activated carbon, air flow, time duration, air change rate and halothane concentrations due to less halothane concentrations to be standardization.

2. To be able to find the proper rate of air change to reduce halothane concentration by using activated carbon as an experiment. The rate of air change can be adjustable for controlled factors.

3. To be able to calculate for the efficiency of the halothane adsorption activated carbon. Due to the efficiency of activated carbon would be reduced and saturate at a point of time, so it’s very important to maintain the efficiency of adsorbents.

1.9 CONCEPTUAL FRAMEWORK



CHAPTER II

LITERATURE REVIEW

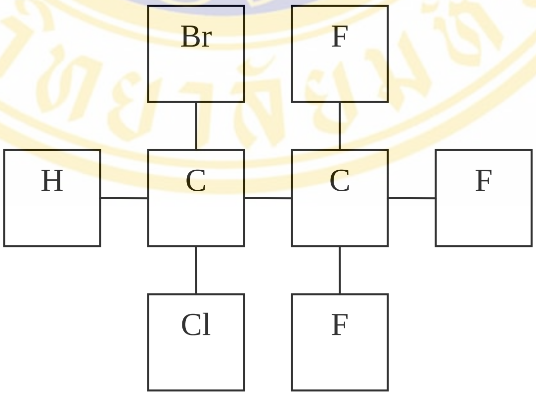
2.1 THE INFORMATION OF HALOTHANE (2, 17)

Halothane is halogenated hydrocarbon; it was made by Raventos in 1956. After discovered fluroxene 5 years, it's popular using to be chloroform until now.

1. Substance identification

Formula C_2BrClF_3H

Structure



Synonyms	Fluothane 2-Bromo-2-chloro-1, 1, 1,-trifluoroethane Rhodialothan

2. Chemical and physical properties

Physical data

2.1 Molecular weight	197.39
2.2 Boiling point (at 760 mmHg.)	50.2 degrees C (122.4 degrees F)
2.3 Specific gravity (water=1)	1.871 at 20 degrees C (68 degrees F)
2.4 Vapor density	Data not available
2.5 Melting/Freezing point/ Decomposition temperature	Data not available
2.6 Vapor pressure at 20 degrees C (68 Degrees F)	243 mmHg.
2.7 Solubility	Slightly soluble in water; miscible in petroleum ether and other fat solvents
2.8 Evaporation rate	Data not available

Reactivity data

1. Conditions contributing to instability: Halothane is sensitive to light but could be stabilized with 0.01 percent thymol. Contact with light causes decomposition.

2. Incompatibilities: Contact of halothane with light should be avoided. Contact with acids, acid fumes, heat, or flame causes toxic fume emissions.

3. Hazardous decomposition products: Toxic gases (such as bromine, chlorine, and fluorine) may be released in a fire involving halothane.

4. Special precautions: Halothane attacks some coatings and some forms of plastic and rubber.

Flammability

The National Fire Protection Association has not assigned a flammability rating to halothane.

1. Flash point: Not applicable.
2. Autoignition temperature: Not applicable.
3. Flammable limits in air: Not applicable.

4. Extinguishant: Use an extinguishant that was suitable for the materials involved in the surrounding fire.

Fires involving halothane should be fought upwind from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Firefighters should wear a full set of protective clothing and self-contained breathing apparatus when fighting fires involving halothane.

3. Exposure limits

OSHA Permissible exposure limit

The Occupational Safety and Health Administration (OSHA) do not currently regulate halothane.

NIOSH Recommended exposure limit

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 2 parts per million (ppm) parts of air (16.2 milligrams per cubic meter (mg/m^3) for halothane (as a waste anesthetic gas) as a 60-minute ceiling limit that should not be exceeded during any part of the workday (NIOSH 1992).

ACGIH Threshold limit value

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned halothane a threshold limit value (TLV) of 50 ppm (404 mg/m^3) as a TWA for a normal 8-hour workday and a 40-hour workweek (ACGIH 1994, p. 22).

4. Routes of exposure

Exposure to halothane can occur through inhalation, ingestion, and eye or skin contact.

5. Signs and symptoms of exposure

1. Acute symptoms: The signs and symptoms of acute exposure to halothane in humans may include redness and tearing of the eyes and central nervous system effects (dizziness, a sense of fatigue, headache, sleepiness, slurred speech, reduced respiratory rate).

2. Chronic symptoms: The signs and symptoms of chronic exposure to halothane may include jaundice, enlarged and tender liver, and reproductive effects (spontaneous abortion, infertility, premature delivery, and congenital abnormalities).

6. Health hazard information

Halothane is very popular using in operation room, especially halothane and nitrous oxide, these two gases effect human health if takes long time. Therefore, operators such as doctor, nurse can be taken the dangerous effect on their health.

Effects on animals

Halothane causes eye irritation and liver and kidney damage. This substance may also be a reproductive toxin in animals (1, 33). Instilled into the eyes of rabbits, halothane caused severe eye irritation (33). The LC_{50} in rats is 29,000 ppm for an unspecified duration, and the oral LD_{50} in rats is 5,680 mg/kg (NIOSH 1993). Guinea pigs repeatedly given anesthetic doses of halothane developed hepatic lesions and necrosis of the liver (1). Other studies in rabbits and rats exposed subchronically showed dose-dependent increases in liver-to-body weight ratios in these animals (1). The offspring of rats exposed daily during gestation to 10 ppm of halothane showed reduced learning ability and, at autopsy, liver damage (1). Daily exposure of pregnant mice to 500 ppm halothane caused only a small decrease in maternal and fetal weight gain (1). The International Agency for Research on Cancer (IARC) has determined that the evidence for the carcinogenicity of halothane in animals is inadequate (1, 25).

Halothane was tested for carcinogenicity by inhalation in mice and rats. When mice were exposed in utero and then three times weekly for 78 weeks at the maximum tolerated dose (4) or 24 times at several dose levels (16), no treatment-related neoplasm was observed. No carcinogenic effect was seen in rats exposed to a low level of halothane alone or in combination with nitrous oxide.

Effects on humans

Halothane causes central nervous system depression, affects the cardiovascular system, may cause hepatitis, and has reproductive effects in humans. When used as a clinical anesthetic, halothane induces amnesia, analgesia, anesthesia, and respiratory depression (22). Anesthetic doses range from 5000 to 30,000 ppm (1). During anesthesia, cardiac output may be reduced and arrhythmias may occur (22). A syndrome called "halothane hepatitis" occurs in 1 in 10,000 halothane-induced anesthesia patients; this syndrome involves fever, anorexia, nausea, and vomiting and may progress to hepatic failure and death (22). This syndrome usually occurs in patients who have been anesthetized with halothane more than once in a short period of time (1, 22). Volunteers exposed to 4,000 ppm halothane exhibited amnesia for word pairs and impaired manual dexterity, while those exposed to 1,000 ppm showed no effects (1). A number of epidemiological studies of occupationally exposed populations, primarily operating room personnel, have shown increased risks of spontaneous abortion, premature delivery, involuntary infertility and cancer, diseases of the liver and kidney, and congenital abnormalities in their children (22). Some authors point out that the populations in these studies were exposed to other potential reproductive toxins, such as cigarette smoke and other anesthetic gases (1).

Most studies conclude that there was a significant correlation between reproductive toxicity and exposure to waste anesthetic gases (5, 23, 27, and 31). The major toxicities identified were spontaneous abortion and infertilities (42, 20, and 40). Nitrous oxide and halothane have been shown to cause fetal anomalies and increased fetal death rates in experiments on animals (41). Epidemiologic studies have shown that exposure to trace levels of nitrous oxide and halothane is associated with an increased number of miscarriages, compared to numbers in women employed outside the operating room (8). Other studies have documented genetic damage in operation room personnel who have been exposed to isoflurane and nitrous oxide (10, 24). It has been concluded that exposure even to trace concentrations of waste anesthetic gases may cause dose-dependent genetic damage (35). Changes in genetic material may interfere with mechanisms controlling cellular growth, thereby giving rise to cancer or to congenital malformations (23).

A study of Karl A Poterack, MD. (28) For the effect of halothane related to liver function. He found that, there are 2 major types of hepatic toxicity associated with halothane administration. The 2 forms appear to be unrelated. They were termed type 1 and type 2. Type 1 hepatic toxicity was benign, self-limiting, and relatively common (up to 25-30% incidence). It was not characterized by jaundice or clinically evident hepatocellular disease, and type 2 was associated with massive centrilobular liver cell necrosis that leads to fulminant liver failure. It is characterized clinically by fever, jaundice, and grossly elevated serum transaminase levels. The result of studied, type 1 is transient, self-limiting, and usually subclinical. It was often only detected if liver function tests are done and type 2 has a mortality rate of approximately 50%, and rises to 80% when hepatic encephalopathy is present.

Peelen et al. (37) studied the effects of exposure to anesthetic gasses on time to pregnancy, spontaneous abortions, preterm birth, low birth weight and congenital anomalies in operation personnel. An increased risk for spontaneous abortion (OR (odds ratio) = 1.3), preterm birth (OR=1.9) and congenital abnormalities (OR=1.6) was observed. After correction for alcohol use, work circumstances and other environmental exposure on the working place, the OR for preterm birth was 1.4 and the OR for congenital abnormalities was 1.8. In this study, the concentration of anesthetic gasses was measured; the maximal halothane concentration measured was 135 mg/m3 (~16ppm). However, operation personal was exposed to a mixture of anesthetic gasses. For that reason, it was not clear if halothane caused the slight increases in reproductive effects.

Cote et al. (13) detected halothane concentrations of 2 ppm in breast mill of one lactating, practicing anesthetist. This concentration was consistent with the operating room environment. For analytical and methodological reasons, the concentrations measured in breast milk were regarded as an underestimated rather than an overestimated value. An earlier study indicated that respiratory excretion of halothane by operating room personnel may continue for up to 72 hours after routine exposure.

2.2 GAS CHROMATOGRAPHY (39, 48)

Chromatography was the science of separation which uses a diverse group of methods to separate closely related components of complex mixtures. During gas chromatographic separation, the sample was transported via an inert gas called the mobile phase. The mobile phase carries the sample through a coiled tubular column where analytes interact with a material called the stationary phase. For separation to occur, the stationary phase must have an affinity for the analytes in the sample mixture. The mobile phase, in contrast with the stationary phase, is inert and does not interact chemically with the analytes. The only function of the mobile phase is to sweep the analyte mixture through the length of the column. Gas chromatography can be divided into two categories: (1) gas-solid and (2) gas-liquid chromatography. gas-liquid GC, developed in 1941, was the primary GC technique used for environmental applications. gas-solid GC was not widely used for environmental applications.

The stationary phase is chosen so that the components of the sample distribute themselves between the mobile and stationary phase to varying degrees. Those components that are strongly retained by the stationary phase move slowly relative to the flow of the mobile phase. In contrast, components that have a lower affinity for the stationary phase travel through the column at a faster rate. As consequence of the differences in mobility, sample components separate into discrete bands that can be analyzed qualitatively and quantitatively.

The theory of operation of gas chromatograph

The theory of separation by GC is relatively simple and understanding the factors that affect separation allows more effective applications of GC analysis in the field. The purpose of separation is to allow identification and quantitation of individual components of a mixture and the theory of separation was detailed below. In addition to separation, detection of analytes after separation, which is an essential but separate aspect of chromatography, was presented in the section describing system components. Basic components of a complete gas chromatographic system include: (1) a carrier gas supply, (2) a syringe for sample introduction, (3) the injection port, (4) the column and oven, (5) the detector and data collection system.

Before separation occurs in the chromatographic column, the mixture of components in the sample was introduced into the chromatograph through the injection port with a syringe. At this point, the analytes were vaporized (if not already in the gas phase) by the high temperature maintained in the injection port. The analytes were kept in the gaseous state by maintaining all elements of the instrument at a temperature above the boiling point of the analytes. The gas phase analytes were then immediately swept onto the chromatographic column by the mobile phase. The mobile phase was comprised of an inert carrier gas, which usually is nitrogen, helium, or hydrogen.

As the analytes were swept through the column by the mobile phase, separation occurs based on the affinity of each analyte for the stationary phase. The gas chromatographic column was composed of a coiled, tubular column and the stationary phase within the tube. GC columns were either packed or open-tubular. Early GC columns were packed with carbon or diatomaceous earth based solids which acted as the stationary phase. In modern open-tubular columns, the stationary phase is a liquid organic compound that was coated on the internal surface of the fused silica column. Polarities of the analytes dictate the choice of stationary phase. Components of the mixture with a high degree of affinity for the stationary phase were strongly retained while components with low affinity for the stationary phase migrate rapidly through the column. As a consequence of the differences in mobility due to affinities for the stationary phase, sample components separate into discrete bands that could be qualitatively and quantitatively analyzed.

As individual components of the mixture elute the chromatographic column, they were swept by the carrier gas to a detector. The detector generates a measurable electrical signal, referred to as peaks, that is proportional to the amount of analyte present. Detector response was plotted as a function of the time required for the analyte to elute from the column after injection. The resulting plot was called a chromatogram. Detector response was generally a Gaussian shaped curve representative of the concentration distribution of the analyte band as it elutes from the column. The position of the peaks on the time axis may serve to identify the components and the area under the peaks provide a quantitative measure of the amount of each component.

2.3 THE MECHANISM AND STRUCTURE OF ACTIVATED CARBON (9, 15)

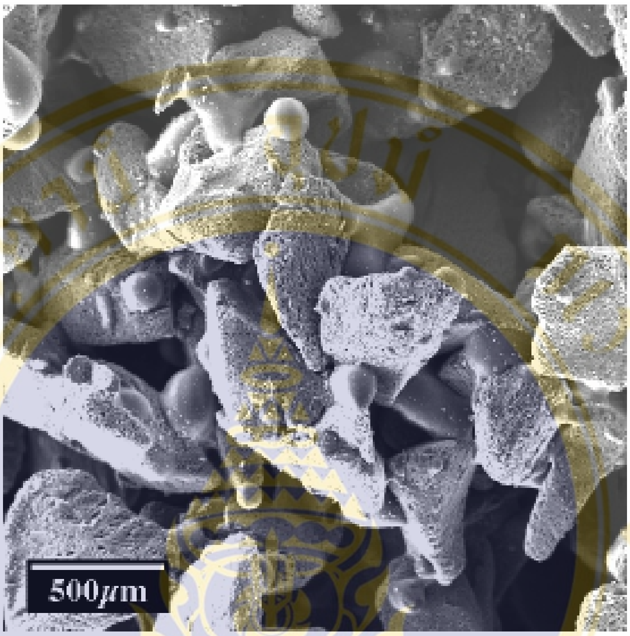


Figure 2-1. Surface area and porosity of activated carbon

Activated charcoal or activated carbon is an amorphous form of carbon. This means that it has no regular atomic structure, unlike the other forms (allotropes) of elemental carbon: diamond, graphite, fullerenes or nanotubes. Activated carbon is a micros porous carbonaceous material which was produced from various raw-materials, such as peat, wood, lignite, anthracite, fruit pits or shells. The raw materials were converted into activated carbon using steam (temperature above 900°C) or acid (temperature above 450 °C). The activation process creates pores in the carbon, whose surface area may exceed 1,500 m^2/g. It is by far the most important adsorptive media due to its wide range of pore sizes.

The adsorption affinity of the internal surface (V/d Waals adhesion forces) together with the pore size distribution (cohesion forces), constitute an activated carbon's purification capability. Physical adsorption forces are not always sufficient to adsorb a component, and in these circumstances, the internal surface may be used as a carrier for an active component, or chemical compound.

Harruff, Lewis G and a team (21), has success on the research of a get rid of hydrocarbon in acid – gas with activated carbon. This experiment had been tested in Saudi Arabia that can reduce the concentration 95 % of gasoline, toluene, xylene.

Lodewyckx, P; Vansant, EF (30) had cachiated with wheeler – Joans fomular to predict organic gas breakthrough time on activated carbon absorption without any humidity. The major factor was absorption capacity that be measured over 200 breakthrough times in 7 different gas on 3 different activated carbon, The result is successful and discover the humidity affect to an absorption capacity .

Lee, Poshin, Davidsan, Jane (29) has evaluated the activated carbon absorption efficiency in ozone concentration elimination. The result is that activated carbon is efficiency to eliminate ozone. Eventhough, and chemical interaction was occurred between ozone and carbon, carbon would be deformed. For structural analysis, and carbon composition with electron microscopy and photoemission spectrometry, carbon structure would be changed permanently and reduced the surface area. Therefore, Humidity also affects to the test the lower humidity, the more absorption efficiency.

Vahdat and team (46) had an experiment to predict the absorption of chemical interaction between m- xylene and acetane, and acetane and styrene in a mask and charcoal tube and calculate with wheeler formula and create breakthrough graph that calculations result is close to the experiment.

Adsorption mechanism (36, 38, 43)

Adsorption is the process by which molecules of a liquid or gas contact and adheres to a solid surface. In this course we focus exclusively on gas adsorption. Adsorption was used for dehydration in addition to a variety of air pollution control problems. Adsorption may not be advisable if the process gas contains significant concentrations of particles or other contaminates that will clog or “use up” the adsorbent. When removing organic compounds it is necessary to ensure that gas concentration does not exceed 25% of the lower explosion limit (LEL). Incineration is an alternative to adsorption for VOC control. As with condensation, adsorption is always exothermic; heat was liberated. The solid substrate on which adsorption occurs was called the adsorbent, or sorbent. The adsorbing species is the adsorptive, and the adsorbed material was the adsorbate, or simply the sorbate.

Adsorbents are very porous materials that contain many miniscule internal pores. The total surface area is enormous 0.1 to 1.0 km^2/kg or 20 to 200 football fields per kilogram. Pore sizes are as small as nanometers. The most common configuration for industrial adsorbers involves the use of fixed bed adsorption systems. A schematic diagram of a typical fixed bed system is shown below:

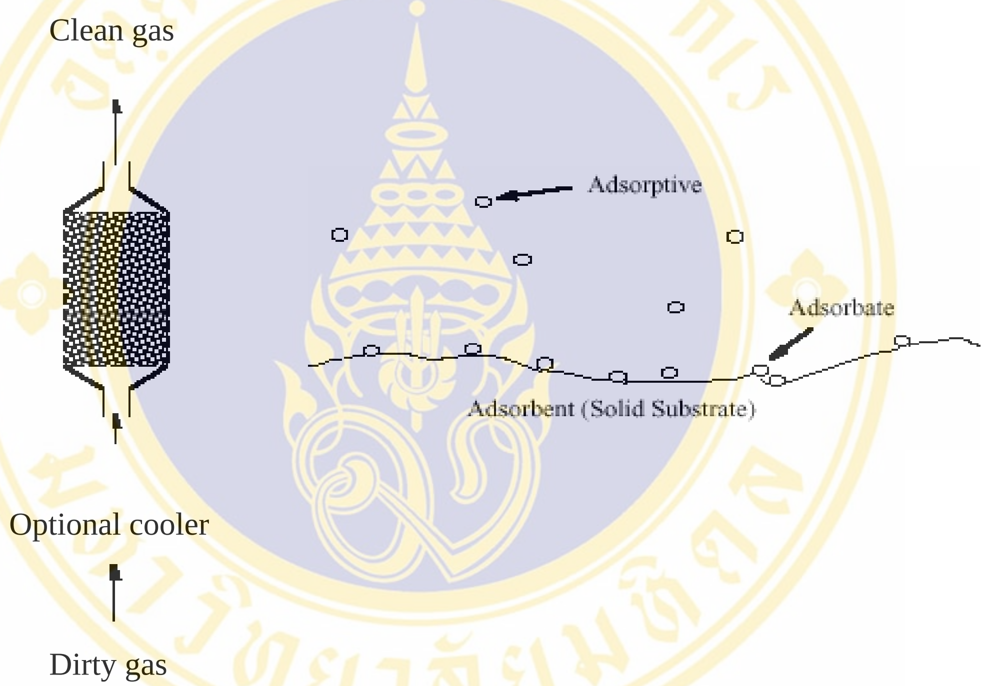


Figure 2-2. Adsorption mechanism

Adsorption mechanisms (15, 19)

Adsorption processes were classified as either physical or chemical. The dominant mechanism depends on the adsorbent and the adsorbate(s).

Physical adsorption occurs when London-van der Waals forces bind the adsorbing molecule to the solid substrate; these intermolecular forces are the same ones that bond molecules to the surface of a liquid. It follows that heats of adsorption are comparable in magnitude to latent heats (10 to70 KJ/mole). Species that were physically adsorbed to a solid could be released by applying heat (much the same as a liquid could be readily volatilized by heating); the process is reversible. An increase in temperature causes a decrease in adsorption efficiency and capacity. Almost all adsorption processes pertinent to air pollution control involve physical adsorption.

Chemical adsorption occurs when covalent or ionic bonds were formed between the adsorbing molecules and the solid substrate. This bonding leads to a change in the chemical form of the adsorbed compounds, and is therefore not reversible. An example of a chemical adsorption process is the formation of CO_2 when O_2 gas adsorbs to a carbon substrate. The bonding forces for chemical adsorption are much greater than for physical adsorption. Thus, more heat was liberated. For many applications the adsorbent was chemically impregnated with a substance that encourages chemical reactions with particular adsorbates. With chemical adsorption, higher temperatures can improve performance.

Adsorbents (15, 34)

There were several adsorbents commonly used. The most common is activated carbon. While activated carbon can be made from nutshells, wood, and petroleum, most of the activated carbon that was used for pollution control was manufactured from bituminous coal. "Activation" is the process that produces the porous structure essential for effective adsorption. It involves heating in the absence of oxygen to dehydrate and carbonize, followed by heating in the presence of oxygen to obtain the porous structure. Activated carbon attracts non-polar molecules such as hydrocarbons. Typical surface areas are 300 to1500 m^2/g. Factors that affect the capacity of an adsorbent include its surface area, its pore size, and its polarity.

Table 2-1. The specific surface areas and other physical properties of commonly used adsorbents.

Adsorbent	Internal porosity, %	Bulk dry density, g/cm^3	Average pore diameter, $\mathring{A}$	Surface area, m^2/g
Active alumina	25-30	0.8	35-45	235
Active bauxite	35	0.85	50	

Table 2-1. The specific surface areas and other physical properties of commonly used adsorbents (Cont.)

Adsorbent	Internal porosity, %	Bulk dry density, g/cm^3	Average pore diameter, A$^\circ$	Surface area, m^2/g
Silica gel	Various	0.43-0.73	Various	300-800
Shell-based carbon	50-80	0.32-0.57	20-30	800-1500
Wood-based carbon	30-75	0.14-0.56	5-100	600-1500
Peat- based carbon	55	0.24-0.50	5-40	500-1600
Coal-based carbon	55-80	0.32-0.60	5-65	600-1500
Petroleum-based carbon	65-85	0.48	18-20	800-1100

Table 2-2. Comparison between the surface areas of unit density spheres

Sphere diameter, mm	Surface area, m^2/g
0.001	6
0.01	0.6
0.1	0.06
1.0	0.006

Dynamic adsorption (7, 15, 38)

Adsorption for the control of indoor air contaminants is a dynamic process which depends on

1) The physical and chemical properties of the adsorbent, including material composition, particle size, media thickness, total surface area, and pore volume.

2) The concentration and physical and chemical properties of the gases to be removed (adsorbate).

3) The concentration of other adsorbable gases and vapors, including water vapor.

4) Temperature of the ambient air.

5) The residence time of the adsorbate in the filter.

The gas filtration process of diffusion, mass transfer, physical adsorption /desorption and chemical reaction is complex, but we can use several simplified models to predict dynamic and equilibrium behavior.

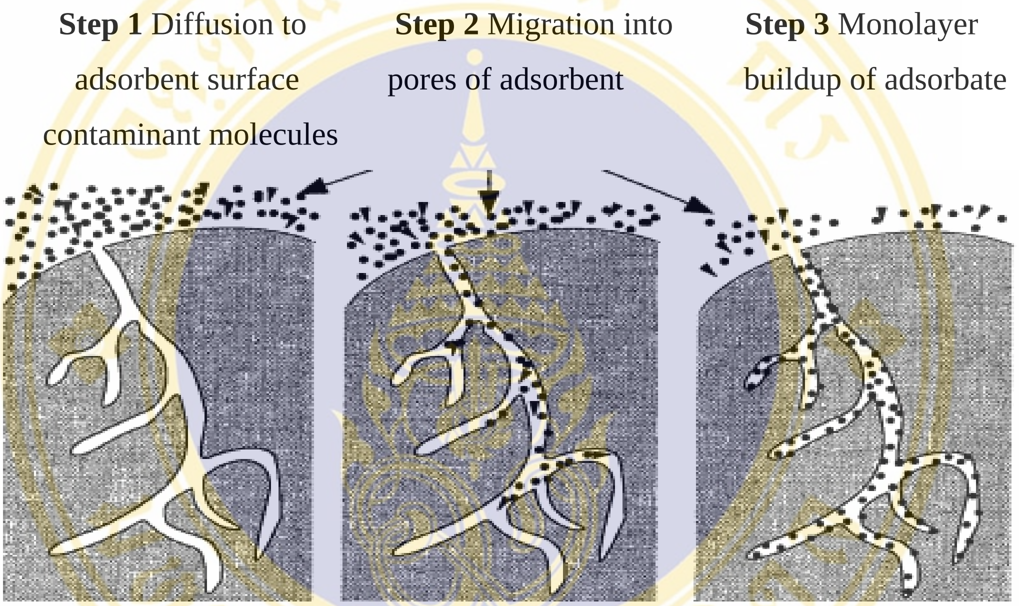


Figure 2-3. The steps of gas adsorption

In a fixed bed adsorption system, the adsorbent located closest to the pollutant gas inlet was the first to become saturated (i.e., to reach equilibrium). The pollutant gas rapidly becomes depleted, and therefore there is very little adsorption further through the system.

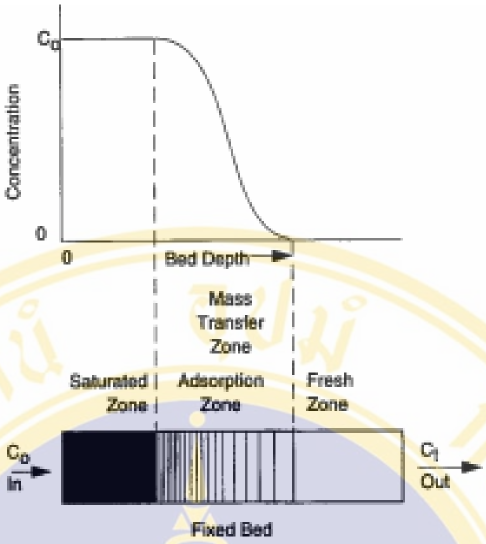


Figure 2-4. Height of bed and adsorption

2.4 THE RELATION OF ADSORPTION EQUILIBRIUM (14, 15, 34, 38)

Adsorption equilibrium was the state of the molecules that reached the adsorption surface equal to the number of molecules that escape from the adsorption surface. We call this as “Saturated vapor “and we can not get rid of this vapor from the wasted gas stream forever. The condition of equilibrium will control the maximum quantity of vapor, which could be adsorbed at the assign working state. Although, there are several variables that will affect efficiency of adsorption but only 2 variables are most important to control the equilibrium of the assign system, which are temperature and pressure. Equilibrium graph that use to explain adsorption system is isotherm graph at stable temperature, iso-bar graph at stable pressure and iso–tear graph at stable adsorption vapor.

Adsorption Isotherm

The data at equilibrium state of adsorption that usually used is the adsorption isotherm data. Isotherm graph is the graph between the ability to adsorb and the sub-pressure of gas molecules that have been adsorbed at one stable temperature. Normally, the ability of adsorption unit will have a unit in percentage as weight of gas molecule in gram that has been adsorbed per 100 gram of adsorption unit.

Dynamic of Adsorption Process

Dynamic is the movement, it is the movement of air through adsorption bed and also the change of intensity of vapor while pass through the bed. Bringing the air stream that we want to treat, be able to contact with adsorption unit can be done in several characteristics. The characteristic that we often meet is to let the air flow pass through adsorption bed of pass through the adsorption unit at stable quantity in the downward direction.

Gas stream that has an concentration of toxic substance from the beginning at C_o pass through adsorption bed which do not have any toxic in the downward direction, most of the toxic would be adsorbed at the top of the bed and left a little amount of toxic in the rest of the bed . Therefore, gas stream that come out from the bottom of the bed is non-toxic gas and assign as C_{t1}.

After that for a while, the top of the bed would be saturated with toxic substance. The most adsorption (about 95 %) happen at the narrow part of the bed underneath that saturated area. This narrow part calls “Mass Transfer Zone” (MTZ). When the vapor of toxic gas continue pass through the bed, it will increase the saturated area and MTZ will keep move downward according to the height of adsorption unit. Normally, the actual height of MTZ is quite stable while pass through adsorption bed. There still is an adsorbing process when vapor pass the non use part, so the concentration of toxic substance at the exit “C_{t2}” equal to zero. According to there still have some part of bed that not saturated, then adsorbing process is keep continue until the bottom of MTZ contact the base of bed. The concentration of toxic substance at exit of adsorption unit will increase dramatically and we call this point as “breakthrough”, which is the point that un-treated vapor also pass through. And if we not change a new bed, the intensity of toxic substance will increase rapidly until equal to the beginning intensity as shown at the point C_{t3} in the picture.

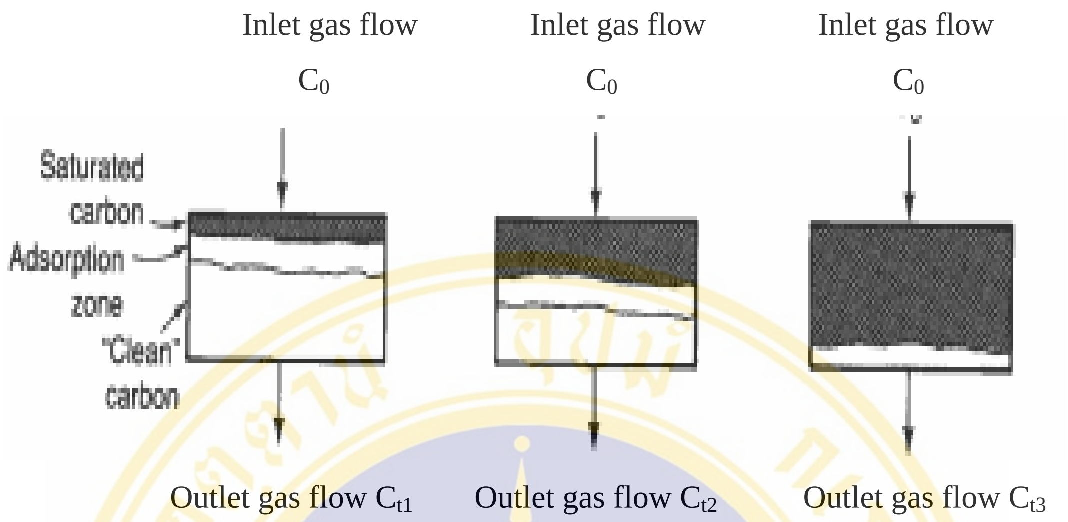


Figure 2-5. Dynamic adsorption (1)

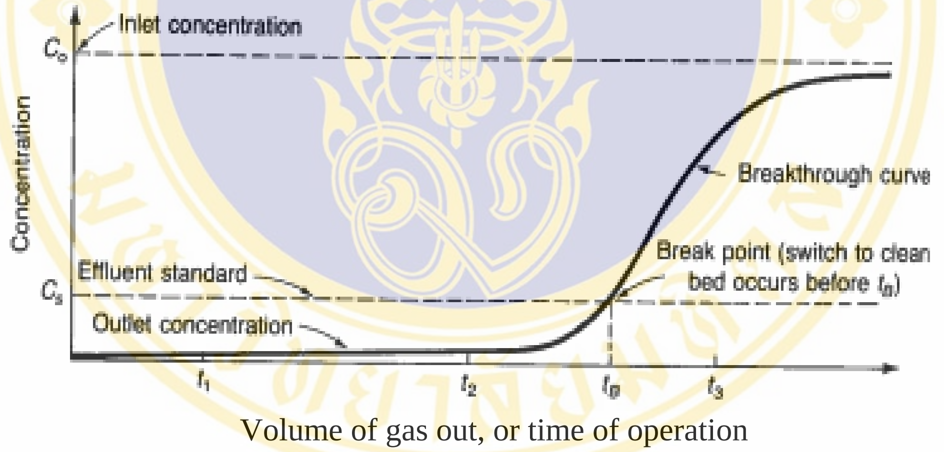


Figure 2-6. Dynamic adsorption (2)

2.5 ADSORPTION FACTORS (6, 12, 15, 38)

1. Temperature

For the physical adsorption, the ability to adsorb would be decreased when the temperature increase. This is because when the temperature getting higher, vapor pressure of the substance, that would be adsorbed, also gets higher. This will increase the energy level of the molecules that we want to adsorb and cause them to have enough energy to get rid of the surface tension "Van der Waals" and be able to change to gas phase. Those molecules, which already in the gas phase will keep staying in its phase. Because of this high vapor pressure, so it is general rule that the temperature of adsorption unit should be lower than 55 ^{o}C. This can be done by release heat to the gas stream that we want it to be treated and / or adsorb bed

2. Pressure

The adsorption ability will increase when sub-pressure of adsorbed substance was increased. The adsorbed substance very directly to the pressure of the whole system. Therefore, if system pressure has been increase that means increasing the adsorption ability .The increasing of the ability to adsorb came from a reduction in Mean Free Path of vapor that we want to adsorb at higher pressure. Simply, adsorbed molecule substance has a large compression, therefore, it's possible to have more interaction between molecule and adsorption material.

3. Gas velocity

The period of time to contact between the toxic gas stream and adsorption substance was limited by the velocity of the gas stream that pass through the adsorption unit. The contacting time results directly to the efficiency of the adsorption unit. To have 90 % efficiency, most of the activated carbon adsorption systems were designed to have the maximum velocity at 30 meter per minute (100 feet per minute) and lowest velocity at 6 meter per minute (20 feet per minute). That avoid gas flow pass through adsorption unit is the functional of diameter of adsorption unit. For the given toxic gas volume, with maximum velocity, we can identify the minimum diameter of adsorption unit by using the following formula,

$$Q = AV$$

When Q = Flow rate (m^3/sec)
A = Cross Section Area of Adsorption Unit (m^2)
V = Velocity of gas stream (m/sec)

The flow rate of air that pass through adsorption unit will influence to pressure drop , which means increasing flow rate will also increase pressure drop. Within this range of maximum and minimum flow rate above normally, means a diameter and pressure drop of depending or the height of adsorption substance.

4. Height of bed

A suitable height of the bed is very important. For the efficiency of toxic gas disposal, if the height of adsorption bed less than "Mass Transfer Zone" (MTZ) it will reach the "Breakthrough Point" This will decrease the efficiency of the adsorption system. To calculate the height of MTZ is very difficult because it depends on a lot of factors. Therefore, we can estimate the height of bed by the formula of "Kovach";

$$MTZ = \frac{1}{1-X_a} \quad D \left(\frac{1-C_a}{C_b} \right)$$

When D = Height of bed, m
C_b = Break through Capacity, %
C_a = Saturation capacity, %
X_a = Saturation level within MTZ, %
(Normally use 50 %)
MTZ = Height, m

From the above formula, we will normally check that a design height of bed is more than MTZ height. Normally, the actual height of bed is set higher than MTZ height for the enough working time and the overall a required quantity of adsorption substance can be read from the isotherm graph of adsorption.

5. Humidity

To have a good adsorption efficiency of activated carbon; should have relative humidity not over than 50 %. Because if the relative humidity gets higher than 50 %, it will increase the molecules of water and these water molecules will take over the position of surface adsorption.

6. Type of Toxic substance

According to that we have dust particle, liquid drop and organic compound, which have a very high boiling point can cause a reduction in efficiency of adsorption unit. Because these will cover the surface area of adsorption substance then reduce the adsorption area and cause the bed block up or deactivation.

2.6 THE OPERATING ROOM (44, 45, 50)

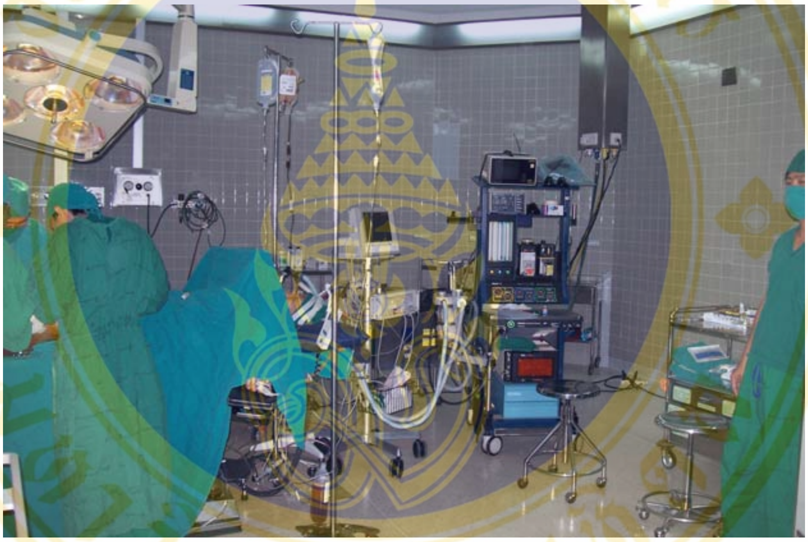


Figure 2-7. The operating room

The operating room is the place where most surgery takes place. The operating room may be inside a hospital, a same day surgery_facility, or even a doctor's office. The design of operating room for was separated 4 zones; Outer zone (rest of hospital & theatre reception), Clean zone (theatre complex up to the theatre doors), Aseptic zone and Disposal zone. The standard room size of the operating room is 400 sq, and the flooring should be one-piece linoleum without seams although all tile floors made out of non-porous tile is a more expensive option. The flooring should go up the wall about four inches or so. The goal was to prevent infectious material from being wedged into seams or crevices and provide an easy to clean surface. The ceiling and walls should be painted with washable paint that is amenable to cleaning. Hanging tile ceiling is also fine but the tiles must be non-porous washable and arranged so that dust does not shower the surgical field. Wall paper was not suggested.

The ability to monitor, maintain and control temperature, humidity, and ventilation is important. This does not necessarily mean expensive Heating, Ventilation and Air Conditioning (HVAC) units. The temperature of operating room should be 24-26^{o}C and humidity should be 40-60%.Tempperature & Humidity was best controlled by adjusting the ventilation. The source of air for ventilation is from roof level of operating room, drawn through a series of fans through filters capable of removing bacteria carrying particles. The air was also humidified & warmed or cooled. High Efficiency Particulate Air (HEPA) filters are commonly used - filter particles of 0.5 microns with 99.97% efficiency. Light source for surgery should produce > 40 000 luxs at the incision site.

1. Dimension

The operation room shall not be too large. It might cause staking time to grape the equipment. Additionally, it shall not be too small due to the difficulty of aseptic preventive state. The proper size should be 20x20 ft^2, 18x20 ft^2 and not less than 14x16 ft^2.

2. Pipe line

The operating room should have the pipeline. But the gas tank should be outside the room or the building.

3. Temperature and Humidity

Temperature and Humidity in hot zone country should set an air conditioning unit at temperature 65-70 ^{o}F. Do not use ventilation fan because of air borne infection. Humidity shall set between 50-60% that can reduce the germs or disease in an operation room and reduce the static electricity.

Table 2-3. The air change per hour of out door air condition and total air for other rooms in the hospital (1999 ASHRAE Application Handbook)

Area	ASHRAE Handbook (1999)		
	Min.OA; ACH	Min.Total air; ACH	Pressure relationship
Operating rooms (all outdoor air system)	15	15	P
Operating rooms (recirculating air system)	5	25	P
Delivery rooms (all outdoor air system)	15	15	P
Delivery rooms (recirculating air system)	5	25	P
Recovery	2	6	E
Nursery suite	5	12	P
ICU	2	6	P
Patient rooms	2	4	+/-
Medical procedure / Treatment rooms	2	6	+/-
Autopsy rooms	2	12	N
Physical therapy	2	6	N
Positive isolation rooms	2	15	P
Negative isolation rooms	2	6	N

ACH = air change per hour, P = positive, N = negative, E = equal, +/- = continuous directional control not required and OA = Out door Air condition.

2.7 AIR CONDITION SYSTEM (18,26,47,49)

This air conditioning system could be decided according to a refrigerant capacity as follows:

1. Small residential air condition, this is a house hold appliance that use for residential or small stores. The capacity is 1- 2 Tons, not more than 3 Tons. Window type and split type are selected for small stores which is not more than 6 Tons.

2. An air conditioning unit capacity is 6 Tons up to 20 Tons or more selected for medium residents.

3. An air conditioning unit capacity is 20 Tons up to100 Tons or more selected for large residents or commercial building.

The factors of air conditioning system

1. Heat

In the room, heat gain is from electrical devices, which transform electrical energy to heat energy. Approximately 90%, called sensible heat. The electrical heat gain will affect the overall sensible heat in a room. Therefore, the sensible heat is typically 60-70% only. Additionally, heat gains from human mostly cause the sensible heat to 60-70% due to latent heat. Therefore, it shall consider to the humidity of human in calculating cooling capacity.

2. Temperature

Temperature sensor is computer equipment that is the most effective at 72 ^{o}F. Normally, the most suitable temperature for human is 76 ^{o}F that cause the different load.

3. Relative humidity

Typically, the relative humidity is around 50-60% of outside air. Even the change of relative humidity would not much affect to human. Therefore, it would not have to control the humidity in a room. Otherwise, humidity affects to computational equipment.

If the relative humidity is high, it will condense and affect to the electrical circuit, or it will occur iron rust. In case of low humidity, that can destroy the electrical circuit.

4. Temperature and humidity control

For human, air conditioning is not necessary to control temperature because can adapt the temperature to an environment. So that, the range of temperature can be adjust ± 5 °F. and humidity relation can be set 40-60%

5. Air filter

Air filter normally used in a room has low efficiency, but a control room or operation room need to air purifying filter for high efficiency.

6. Fresh air

Fresh air is typically ventilate or circulate an air to get rid of the adore or smoke or less. For clean room, a special control room need very cleaning room which need only fresh air for build up positive pressure in order to the leakage of air.

7. Operating hour

The normal operating for fan air conditioning unit is around 8 hours. But for control room such as computer room must operate 24 hours that will be considered for cost effectiveness.

Air distribution.

The conventional air conditioning system, split type, or window type has a return air to a unit. The central air conditioning system has ducting work that allows fresh air only 10-15% of circulation air. Fresh air can be getting through an air condition to a room, or installing the ventilation fan to let fresh air pass through window or door gap. However, this method will have higher dust and humid than filling a fresh air (fresh air 1 m^3/min will increase load 80 BTU/hr.)

The installation of an air conditioning unit should not be blocked to the discharge (supply air) and return air. If not, it will affect the cooling system.

Air condition system in the operating room (44, 45, 50)

An air conditioning system in an operation room is special system. Due to the life safety fan physicians, nurses and operation officer. Therefore, the effective air conditioning system shall consider as follow:

1. Pressure

The air inside a room is purity (no germs and disease) that was more cleaned than outside. An operation room was designed inside pressure higher than outside pressure called, positive pressure, Therefore, if there are some holes or gap from windows or door, air will leak to gaps, and outside air cannot reverse to a room. On the other hands in case of negative pressure from a lot of ventilation fans , air will leaks to a inside room from door gaps or openings to be an accuracy measurement , a differential pressure sensor shall be measure the difference between inside and out side air not less than 2.5 Pa with closed door.

2. Relative humidity

The relative humidity ratio in on operation room shall be 45 – 55% (reference: 1999ASHRAE Application Handbook) and not over than 60 % in any times high relative humidity ratio will cause the high growth speed of bacterias. If relative humidity ratio is grater than 80 %, condensation in room such as ceilings and walls will occur fungus. Moreover, the high relative humidity ratio will effect to the accuracy of medical equipments and shorten life times. If it was discovered high relative humidity ratio in a room, it should check the source of the leakage such as water pipes or drainage and fix it. Mosts of problems come from a coil design not suitable for a cooling load in an operation especially split type units.

3. Air filters

The important principle for cleaning air control in an operation room is circulation air pass the air filter in an air conditioning unit. High efficient air filters used in an operation room must be 2 layers, first layer efficiency not less than 25 % (ASHRAE standard 52.1) and second layers efficiency not less than 90 % (ASHRAE standard 52.1) .For the extremely cleaned room , e.g. Orthopedics room or Transplantation must be used 3 layers filter , 99.97% efficiency , call HEPA filter at an air discharge.

It is necessary to get rid of or reduce concentration of halothane in an operation room. In order to the short term an health effects are not obvious ,but concerns in long term effects, So that , a researcher has designed concepts of reducing halothane in an operation room less than 50 ppm (TLV) with focus on the air change system by using activated carbon. According to activated carbon properties, numbers of researcher were satisfied in an adsorption property that leads to this research study.

CHAPTER III

RESEARCH METHOD

3.1 Research Model

This research model is a simulation study for time duration for each air change level and measure halothane concentrations before and after experiment. The adsorbent material selected in this experiment was the coconut activated carbon.

Research chart

O_1---------------------- X -------------------- O_2

When; O_1 = Value before experiment

O_2 = Value before experiment

X = Activated carbon

3.2 Experimental equipment design

The air conditioning unit used in the operation room was split type unit. The fan coil unit was inside the room and a condensing unit was outside. The supply air velocity could be adjusted into 3 speeds. However, this experiment was set up at one speed only all the experiment time. This experiment was built as a chamber with dimension width x length x height = 1 x 1 x 1 cubic meter and the activated carbon was put at the discharge air to adsorb halothane.

1. Designed equipment

1.1 Chamber

The chamber size 1 x 1 x 1 m^3 and put a box of fan size 0.55 x 0.17 x 0.30 m^3 were built in the laboratory of division of preventive medicine. The activated carbon was installed on the top of chamber with a rectangular channel size 0.1 x 0.25 m^2. Also, the channel size 0.1 x 0.25 m^2 was cut in front of a chamber for air outlet and 2 holes with corks for keep air and wiring.

Figure 3-1. The designed chamber for experiment.

1.2 Filter

An activated carbon was filled equally in between two layers of synthetic fiber and put wire screen cover it for moving protection. Activated carbon weight must be equal weight for each experiment.

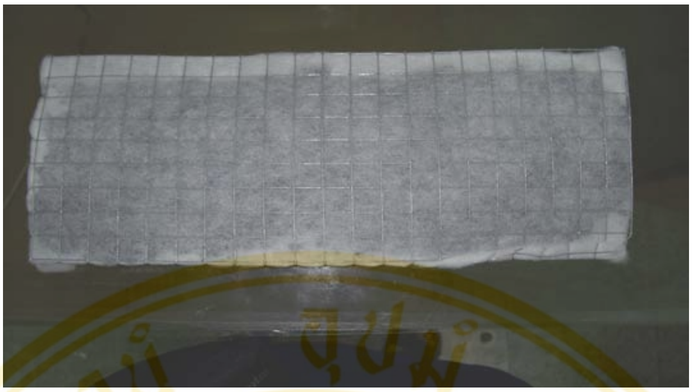


Figure 3-2. Illustration of filter used in this study

1.3 Velocity

The mean of velocity from air conditioning unit was constantly controlled at 0.97 meter/sec.

1.4 Centrifugal fan

The centrifugal fan was used in the system of air conditioning.

1.5 Air change rate

This experiment set up the rate of air change is 7 levels i.e.: 15, 20, 25, 30, 35, 40, and 45 air change per hour.

2. Air velocity and temperature instrument

Figure 3-3. Air velocity and temperature instrument

3. Weighting instrument (digital scale)

Figure 3-4. Weighting instrument (digital scale)

4. Relative humidity instrument

5. Barometer instrument

6. Gas Chromatograph with Flame Ionization Detector

3.3 Sampling and analysis

1. Air sampling

Collecting air sample equipment:

The 500 micro liter syringes was used to collect air sample and inject into gas chromatograph. (Real time)

Figure 3-5. Gas type syringe for gas chromatograph GC-14B.

2. Sampling analysis

2.1 Gas chromatograph standard setting

2.1.1 Temperature setting

Temp. Oven	90	°C
Temp. Injector	150	°C
Temp. Detector	200	°C

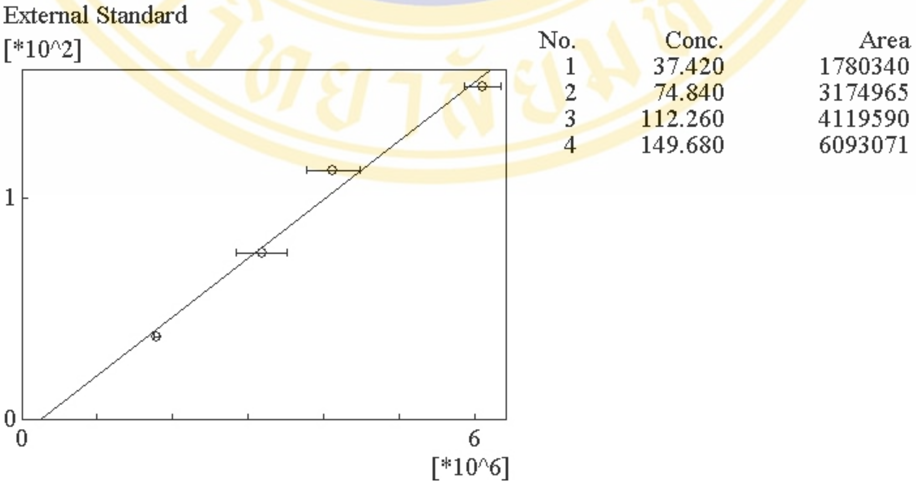
2.1.2 Gas flow rate

Carrier (He)	25	ml. /min
Hydrogen	23	ml. /min
Air	250	ml. /min

Figure 3-6. Gas chromatograph model SHIMADZU GC-14B

2.2 Calibration curve

The reference tests were set up at 4 points calibration curve and repeat 2 times for each point; put 2 set of halothane 4 concentrations: 1, 2, 3 and 4 micro liter respectively into a bottle totally 8 bottles and put in the oven at 60 °C 5 min. The samples from the chamber were injected directly real time into the gas chromatograph to quantify amount of gas.



No.	Conc.	Area
1	37.420	1780340
2	74.840	3174965
3	112.260	4119590
4	149.680	6093071

Figure 3-7. The calibration curve of halothane

2.3 Sample analysis

The samples were analyzed by using gas chromatograph model SHIMADZU No.10733102927 YSGC-14B. The Flame Ionization Detector (FID) was used to determine the halothane concentrations. The chemical substance into a column and oxidize between oxygen and hydrogen. Gas chromatogram will detect oxidation and convert into the peak data in a computer.

3.4 Materials for experiment

1. Coconut shell activated carbon properties

Type	Coconut shell activate carbon
Surface	> 1,100 m^2 /g.
Particle size	+ 8(2.36 mm) less than 5 %
	8x16 (2.36 – 1.18 mm) more than 90 %
	and – 16 (1.18 mm) less than 5 %
Porosity	55-75 %
Porosity volume	> 0.48 m^3 cm. /g.
pH	9-11
Iodine number	1050 mg/g

2. Halothane USP grade 99 %

3. Dust filter

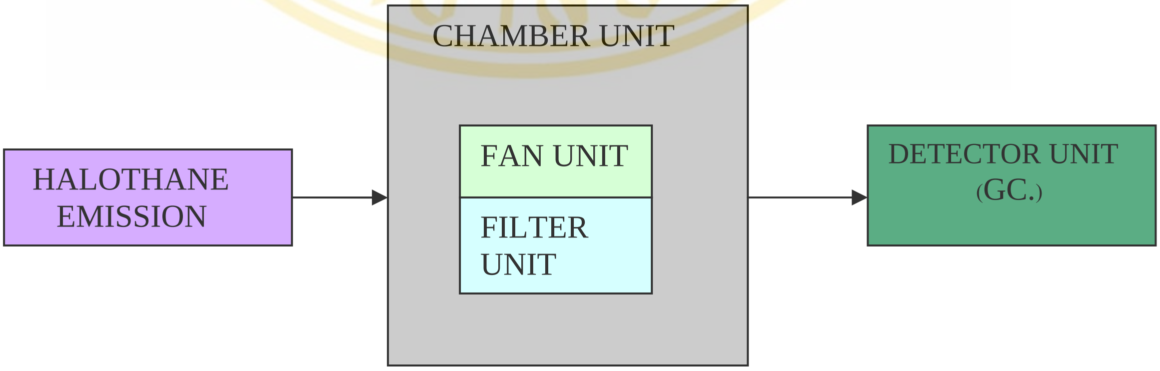


Figure 3-8. Process of halothane experiment

3.5 Research process

The experimental process was carried out as the following steps**:**

1. Calculate and record time duration of each air change rate.
2. Prepare 35 activated carbon filters in equal weight at 50 g.
3. Prepare 50 ppm of halothane in chamber.
4. Put the activated carbon filter into a box of fan in the chamber.
5. Switch on the fan unit and time record each of air change rate; 7 different air change rate i.e.: 15, 20, 25, 30, 35, 40, 45 and replicate 5 times / air change total 35 times**.**
6. Take air pass through filter according to calculate time each of air change rate.
7. Analyze the concentration by gas chromatograph instrument.

3.6 Research Statistics

The descriptive of statistics; average means and standard deviation was used to analyze the data. The multiple regression was used to find relationship between initial variables and dependent variables. The t-test and Chi-square test were used to compare the efficiency of halothane adsorption rate.

CHAPTER IV

RESEARCH RESULT

This study was controlled at temperature 22-24 degree Celsius, pressure 1.00-1.02 atmosphere, and humidity at 45-55%. The study was designed from the ventilation system of the operating room. A chamber size 1x1x1 m^3 contain exhaust ventilation system with activated carbon filter. In this experiment would be set up weight of activated carbon 50 grams, velocity 0.97m./sec and halothane concentration 50 ppm. There are 7 difference air change rates i.e.:15, 20, 25, 30, 35, 40, 45 and replicate 5 times at each rate of air change.

4.1 Calculate suitable time for each air change rate.

Volume of chamber = 1 m^3
Velocity = 0.97 m/s
Filter area = 0.025 m^2
Formula $Q = AV$
When Q = Flow rate; m^3
A = Area; m^2
V = Velocity; m/s

Ex. 1 Air change rate is 15 air changes / hr.
Air flow = 1 x 15 m^3/hr
= 15 m^3/hr.
$V = 0.97$ m/s and $A = 0.025$ m^2
Q = 0.025 x 0.97 m^3/s
= 87.3 m^3/hr
Air flow 87.3 m^3 time = 60 min.

If air flow 15 m^3 time = $\frac{15 \text{ x } 60}{87.3}$ min.

= 10.31 min.

Therefore, the air pass through filter 10.31 min. at 15 air changes.

Ex. 2 Air change rate is 20 air changes / hr.

Air flow = 1 x 20 m^3/hr

= 20 m^3/hr.

V = 0.97 m/s and A = 0.025 m^2

Q = 0.025 x 0.97 m^3/s

= 87.3 m^3/hr

Air flow 87.3 m^3 time = 60 min.

If air flow 20 m^3 time = $\frac{20 \text{ x } 60}{87.3}$ min.

= 13.74 min.

Therefore, the air pass through filter 13.74 min. at 20 air changes.

Ex. 3 Air change rate is 25 air changes / hr.

Air flow = 1 x 25 m^3/hr

= 25 m^3/hr.

V = 0.97 m/s and A = 0.025 m^2

Q = 0.025 x 0.97 m^3/s

= 87.3 m^3/hr

Air flow 87.3 m^3 time = 60 min.

If air flow 25 m^3 time = $\frac{25 \text{ x } 60}{87.3}$ min.

= 17.18 min.

Therefore, the air pass through filter 17.18 min. at 25 air changes.

Ex. 4 Air change rate is 30 air changes / hr.

Air flow = 1 x 30 m^3/hr

= 30 m^3/hr.

V = 0.97 m/s and A = 0.025 m^2

Q = 0.025 x 0.97 m^3/s

= 87.3 m^3/hr

Air flow 87.3 m^3 time = 60 min.

If air flow 30 m^3 time = $\frac{30 \times 60}{87.3}$ min.

= 20.62 min.

Therefore, the air pass through filter 20.62 min. at 30 air changes.

Ex. 5 Air change rate is 35 air changes / hr.

Air flow = 1 x 35 m^3/hr

= 35 m^3/hr.

V = 0.97 m/s and A = 0.025 m^2

Q = 0.025 x 0.97 m^3/s

= 87.3 m^3/hr

Air flow 87.3 m^3 time = 60 min.

If air flow 35 m^3 time = $\frac{35 \times 60}{87.3}$ min.

= 24.05 min.

Therefore, the air pass through filter 24.05 min. at 35 air changes.

Ex. 6 Air change rate is 40 air changes / hr.

Air flow = 1 x 40 m^3/hr

= 40 m^3/hr.

V = 0.97 m/s and A = 0.025 m^2

Q = 0.025 x 0.97 m^3/s

= 87.3 m^3/hr

Air flow 87.3 m^3 time = 60 min...

If air flow 40 m^3 time = $\frac{40 \times 60}{87.3}$ min.

= 27.49 min.

Therefore, the air pass through filter 27.49 min. at 40 air changes.

Ex. 7 Air change rate is 45 air changes / hr.

Air flow = 1 x 45 m^3/hr

= 45 m^3/hr.

V = 0.97 m/s and A = 0.025 m^2

Q = 0.025 x 0.97 m^3/s

= 87.3 m^3/hr

Air flow 87.3 m^3 time = 60 min.

If air flow 45 m^3 time = $\frac{45 \times 60}{87.3}$ min.

= 30.93 min.

Therefore, the air pass through filter 30.93 min. at 45 air changes.

4.2 General Information of experiment

This experiment was set up the concentration of halothane to be 50 ppm. Then, give the air pass through the activated carbon at the different air change rate in their times. This experiment is replicate 5 times at each rate of air change.

Table 4-1. The information of mean and standard deviation of halothane concentrations before adsorption and percentage of halothane adsorption.

Air change rate	Time duration (min.)		Halothane concentration before adsorption (ppm)		Percentage of halothane adsorption	
		n	Mean	Std.	Mean	Std.
15	10.31	5	47.12	0.83	22.26	1.47
20	13.75	5	49.38	1.56	33.82	1.18
25	17.18	5	48.94	0.41	36.30	1.61
30	20.26	5	48.40	0.69	38.27	0.83
35	24.05	5	48.62	0.78	38.01	0.88
40	27.49	5	48.70	0.79	37.94	1.10
45	30.93	5	48.52	0.54	38.05	1.13
		35				

4.3 Statistic analysis

4.3.1 Test relationship between variable by Pearson Correlation

Table 4-2. The relation of air change rate, time duration, halothane concentrations before and after adsorption and percentage of halothane adsorption.

Relation		r	p-value
- Air Change rate (Air change/hr)	-Halothane concentration after adsorption (ppm)	-0.76	<0.001
	-Percentage of halothane adsorption. (%)	0.75	<0.001
	-Time duration (min.)	1.00	<0.001
- Halothane concentration before adsorption (ppm)	-Percentage of halothane adsorption. (%)	0.41	0.015
- Halothane concentration after adsorption (ppm)	-Percentage of halothane adsorption. (%)	-0.97	<0.001
	-Time duration (min.)	-0.76	<0.001
	-Air Change rate	-0.76	<0.001
- Percentage of halothane adsorption. (%)	-Air change rate	0.75	<0.001
	-Halothane concentration before adsorption (ppm)	0.41	0.015
	-Halothane concentration after adsorption (ppm)	-0.97	<0.001
	-Time duration (min.)	0.75	<0.001
- Time duration (min)	Air Change rate	1.00	<0.001
	Halothane concentration after adsorption (ppm)	-0.76	<0.001

Table 4-2. The relation of air change rate, time duration, halothane concentrations before and after adsorption and percentage of halothane adsorption.(Cont.)

	Relation	r	p-value
-Time duration (min)	Percentage of halothane adsorption. (%)	0.75	<0.001

However, this experiment could be summarized the relations as the followings:

1. The air change rate has a relation between concentrations of halothane after adsorption, percentage of halothane adsorption and time duration; when air change rate was increased the percentage of halothane adsorption and time duration would be increased too, while the concentrations of halothane after adsorption would be reduced at 99 % confidence interval. (p-value=0.01)

2. The concentrations of halothane before adsorption has a relation to percentage of halothane adsorption; when the concentration of halothane before adsorption was increased; the percentage of halothane adsorption would be increased too. at 95% confidence interval. (p-value=0.05)

3. The concentrations of halothane after absorption has a relation to percentage of halothane adsorption and time duration; when the concentrations of halothane after absorption was increased; the percentage of halothane adsorption and the time duration would be reduced at 99% confidence interval. (p-value=0.01)

4. The percentage of halothane adsorption has a relation to time duration; when the percentage of halothane adsorption was increased; the time duration would be increased as well at 99% confidence interval. (p-value=0.01)

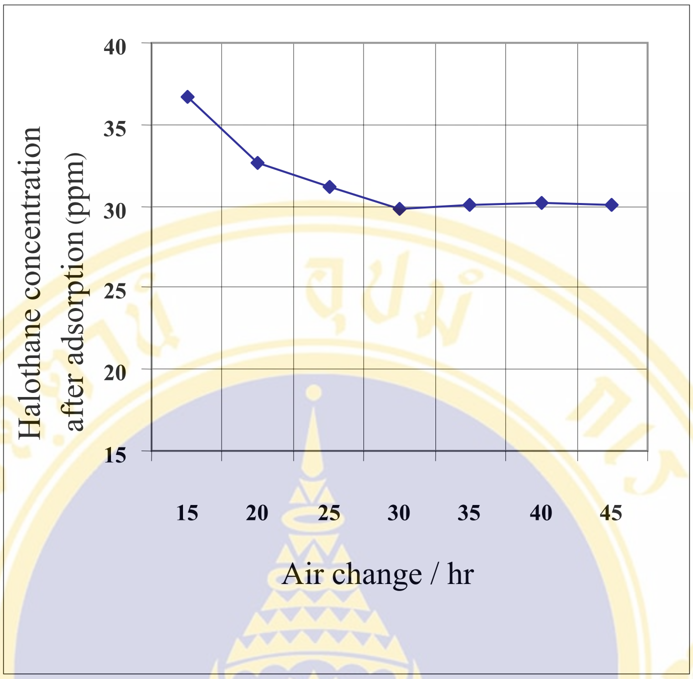


Figure 4-1. The relationship between air change rate and halothane concentrations after adsorption

From graph, halothane concentrations after adsorption would be reduced when air change rate was increased. If air change level was more than 30 air changes, it will have small change for halothane concentrations after adsorption. This point was the saturated adsorption of activated carbon.

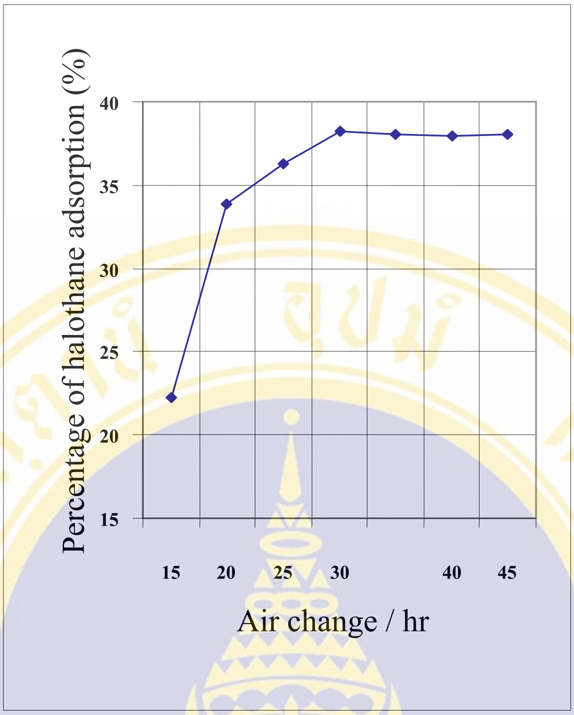


Figure 4-2. The relation between air change rate and percentage of halothane adsorption.

From graph, percentage of halothane adsorption would be increased when air change rate was increased. If air change rate is more than 30 air changes, the halothane concentrations after adsorption will be constant. This point was the saturated adsorption of activated carbon.

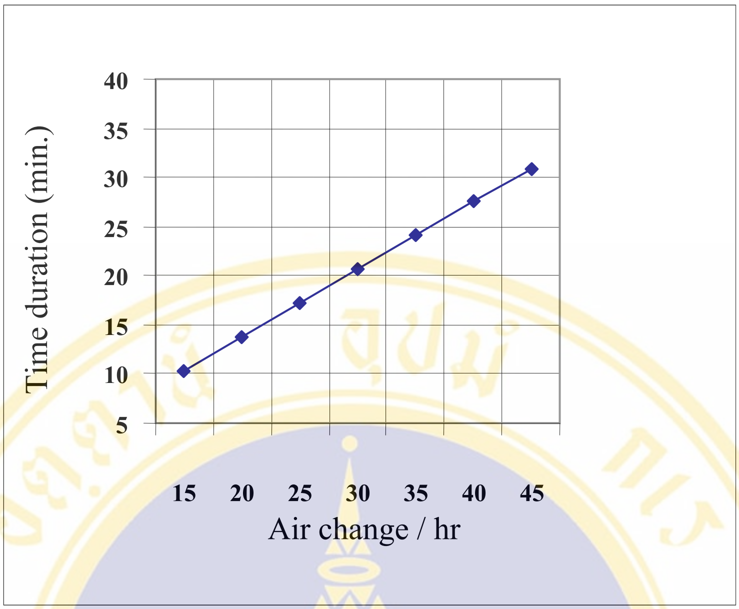


Figure 4-3. The relationship between air change rate and time duration.

From graph, air change rate would be increased when time duration was increased.

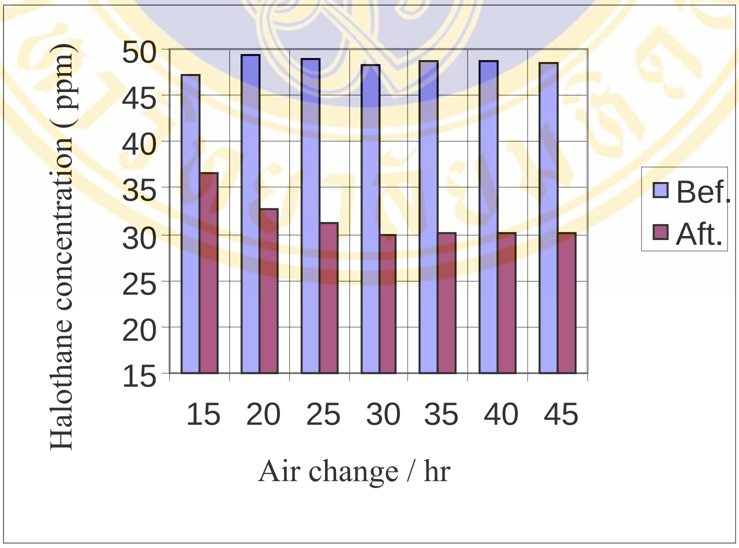


Figure 4-4. The comparison of halothane concentrations and adsorption according to different rate of air changes.

From graph, the comparison of halothane concentrations that before and after adsorption are different .Halothane concentrations would be increased when air change rate was increased, at a stage of air change rate (30 air change); the concentrations of halothane before and after adsorption not significant difference.

4.3.2 The algebraic equation for relationship between the percentage of halothane adsorption, air change rate, concentrations of halothane before and after adsorption and time duration.

Table 4-3.Test a statistic for predicable the relation between variable factors for adsorption.

	Mean.	Std.	n	df	F-test	P-value
1. Air change rate	30.00	10.15	35	2, 32	27.56	<0.001
2. Halothane concentration before adsorption	48.53	1.03	35			
3. Percentage of halothane adsorption	34.95	5.57	35			
4. Time duration	20.62	6.97	35			

The experimental was used the multiple regression by stepwise, 95% to find a relationship of following variations: air change rate, concentrations of halothane before and after adsorption, percentage of halothane adsorption and time duration. We found that percentage of halothane adsorption has related to air change rate and concentrations of halothane before adsorption at 95% Confidence interval (p-value = 0.05) illustrated by the regression equation:

$$Y = -51.099 + 0.382 X_1 + 1.537 X_2$$

When Y = Percentage of halothane adsorption.

X_1 = Air change rate (Air change/hr)

X_2 = Concentrations of halothane before adsorption (ppm)

4.3.3 Compare the efficiency of halothane adsorption.

Table 4-4. Test a statistic for efficiency of the percentage of halothane adsorption by categorized to 3 groups.

Air change rate	Percentage of halothane adsorption					
	n	Mean	Std.	df	F-test	P-value
(1) 15-20	10	28.04	6.22	2, 32	28.013	<0.001
(2) 25-30	10	37.30	1.59			
(3) ≥35	15	38.00	0.96			
	35					

The multiple comparisons dependent variable of percentage of halothane adsorption by LSD found that (1) ≠ (2), (3) while (2) = (3) followed at:

The efficiency of adsorption would be changed in each air change rate stage (15-20), (25-30) and (≥35). The statistic analysis found that the percentage of halothane adsorption of air change rate in group (15-20) has a different form the group (25-30) and (≥35) at the 95 % confidence interval. (p-value = 0.05) while the percentage of halothane adsorption in the group (25-30) and (≥35) were not different, (p-value > 0.05).

Table 4-5. Test a statistic for efficiency of halothane adsorption in each air change

Air change rate	Percentage of halothane adsorption					
	n	mean.	std.	df	F-test	p-value
(1) 15	5	22.26	1.46	6, 28	117.872	<0.001
(2) 20	5	33.92	1.2			
(3) 25	5	36.32	1.61			
(4) 30	5	38.28	0.83			
(5) 35	5	38.02	0.88			
(6) 40	5	37.92	1.09			
(7) 45	5	38.06	1.11			
	35					

The multiple comparisons dependent variable of percentage of halothane adsorption by LSD found that (1) ≠ (2) ≠ (3) ≠ (4) ≠ (5) ≠ (6) ≠ (7)
while (4) = (5) = (6) = (7)

From the experiment that used one-way ANOVA. It could be summarized that; have a difference of the percentage of halothane adsorption in each of air change at 15, 20, 25, 30, 35, 40 and 45 air change at the 95 % confidence interval (p- value = 0.05) while the percentage of halothane adsorption at 30, 35, 40 and 45 were not different, (p-value > 0.05).

CHAPTER V
DISCUSSION

5.1 Discussion of systematic errors and sampling errors

Systematic Error

Personal Error

Skills and techniques were required in this research such as the air change system design and filter design, collect and analysis the sampling, equipment and tools usage (gas chromatograph). Personal error is lead to the research error. However, the researcher did a step by step based on standardization and system in order to reduce the human error.

Method Error

One of the method errors was the method of collected air sampling with real time by using the gas type syringe and directly inject to the gas chromatograph. This sampling was represented to the entire air system that will cause the error. However, the researcher uses a fan to spread the air distribution and keep the same time interval to collect air sampling. The air samples were injected to gas chromatograph. Then, air sampling would be collected at the same place in 5 times replicate.

Instrument Error

Chamber design

The chamber design is square size 1x 1x 1 m^3 by using the hardness and un-adsorb of the halothane. The volumetric space is loss due to the wiring space and filter space. So that fan operation turn on and off will affect to air leak on the edge. However, the researcher used the glue to seal the edge and close the gaps in all areas.

Centrifugal fan box

Centrifugal fan was put inside a box 0.55 x 0.17 x 0.30 m^3 with filter channel and put in a chamber. Therefore, air will not totally pass through the air filter. The amount of air will be leak on the edge, wiring space, or air filter channel. In this case, the researcher would seal the edge and all the holes in order to let the air pass through the filter.

Filters

Filter was designed in rectangular size 0.1 x 0.25 m^2 and contained 50 gram of activated carbon that make less effect to the pressure drop by spread to whole filter area. If the activated carbon is not spread properly, that causes uneven thickness (thick or thin in some areas). This will affect to wind tunnel and early the saturated adsorption. However, to reduce the error, the research would repeat the test for 5 times.

Instrument calibration

The instrument on this research has calibrated from the master calibration company especially gas chromatograph for the external calibration. Therefore, the error could be occurred from this instrument. However, reading in 4 points as a calibration curve at each level of halothane concentrations and replicate 2 times, total 8 times with the same method of collecting and injection for the analysis.

5.2 Discussion on study results

5.2.1 The sample characteristics.

This experiment is study the efficiency of halothane adsorption by activated carbon in the rate of air change. The air change rate could be categorized to be 7 levels i.e.:15, 20, 25, 30, 35, 40 and 45 air change per hour. The experiment will replicate 5 times at each rate of air change. This study can reduce the percentage of halothane concentration as follow: 15 air change (22.26%), 20 air change (33.82%), 25 air change (36.30%), 30 air change (38.27%), 35 air change (38.01%), 40 air change (37.94%) and 45 air change (38.05%)

5.2.2 The efficiency of adsorption of activated carbon

This study was set up the concentrations of halothane to be constant. We found that the percentage of halothane activated carbon adsorption would be increased when air change rate is increase (15-30 air change). If air change rate is more than 30 air change, the percentage of halothane adsorption will be constant; discussion that:

1. The efficiency of halothane activated carbon adsorption.

This research was selected coconut shell activated carbon which has the surface >1,100 m^2/g, particle size +8(2.36mm) less than 5 %, 8x16 (2.36-1.18 mm) more than 90 % and -16 (1.18 mm) less than 5 %, porosity 55-75 %. This kind of material is convenient to find and cheap. It has enough surface and porosity. Medium size and small size were selected for this study that it could be adjusted to appropriate with adsorption property. Porosity of activated carbon will have diameter not over double size of adsorb gas's diameter.

2. Pathway of air flow through the filter

The activated carbon was used in equal quantity and spread into the air filter surface that will not be even thick. Therefore, air will be easier pass through the less density activated carbon (thin) than the more density (thick). This will affect to the efficiency on halothane adsorption and the error of the percentage of halothane concentration.

3. Activated carbon has obstructed

This will reduce the adsorption area that cause from the dust. So that, pre-filter was used before pass air through the activated carbon. In addition, temperature, relative humidity, and atmosphere pressure could not be controlled at the constant 22-24 °C, 45-55% RH., and 1.00-1.02 atm. respectively. These three factors will affect to the halothane adsorption. Especially, the relative humidity decreases the halothane adsorption due to water droplet to the surface and saturate. Temperature and pressure was caused the gas molecule easily exit from the surface.

5.2.3 Test for the relation between halothane concentrations, air change rate and percentage of halothane adsorption.

This research studies the relation of halothane concentrations, air change rate and percentage of halothane adsorption of activated carbon. Air change rate will increase 5 for each incremental. It could be divided into 3 groups of air change rate as 15-20 air change, 25-30 air change and ≥35 air change. It could be found that the concentrations of halothane adsorption were gradually decreased until constant. The efficiency of concentrations of halothane adsorption would be different between air change 15-20, air change 25-30 and ≥35 air change. On the other hand, air change 25-30 and air change ≥35 have not significant changed to the efficiency of concentration of halothane adsorption.

It was found that efficiency of the halothane adsorption is the maximum at air change rate 30 with time duration 20.62 min. on activated carbon 50 ppm. In case of test every air change rate. At this point, the activated carbon was saturated and could not adsorb. So, the filter must be changed to get better performance. Refer to ASHRAE handbook(1999)(45), It was recommended that the recalculating air system in the operating room is not less than 25 air change per hour for the research advantages and application.

5.3 Advantages of research and application.

This research has an objective of selecting material to adsorbed halothane and finds the relationship between air change rate and halothane adsorption. Normally, the ventilation system of the operating room is a recirculating air system and the filter was a pre-filter and HEPA-filter that used for dust protection or germ; but not for the anesthetic drug or aspiration system during anesthesia. Even though, there was a scavenging system in an anesthetic machine.

However, there are some of anesthetic machine that with or without a scavenging system that have not a regular maintenance or other reasons. It could be shown in a case study of Aldo Pacheco-Ferrerisa and team (3) in “Monitoring anesthetic gasses use in operating rooms and estimation of occupational exposure.” In this case found that; in the hospital where the evaluation took place, the results indicate average levels for halothane found that 3.6 ppm without scavenging system and 0.85 ppm with scavenging system, The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 2 ppm part of air for halothane as a 60-minute ceiling limit that should not be exceeded during any part of workday (NIOSH 1992). These results support the opinion that the environment in the operating theatre should be monitored to form part of a program to control residual anesthetic gasses. Another point is to systematize the control of the effectively and maintenance of the scavenging and ventilation system for removal halothane in the operating room, thus preventing any harm to the health of the operating room staff.

Even though, there was a scavenging system in an operating room; but the exposure of halothane to the air circulating system. Therefore, it must be applied the activated carbon that has good characteristic to be an adsorption for removal halothane in the circulating system.

CHAPTER VI
CONCLUSION

6.1 The general characteristic, air change, calibration of instruments and a design of chamber and filter

This research was an experimental study aimed to use the air change conditions to control the efficiency of halothane adsorption and study the relationship between the percentages of halothane adsorption of activated carbon and the conditions of air change rate. This experiment was a simulation of the operation room with the control factors, primary factors, and variable factors. The control factors were temperature set on 22-24 °C, 45-55% relative humidity, and pressure at 1.00-1.02 atm. Primary factors are Halothane concentration (ppm), Air change rate, Time (min), and Activated carbon weight (gm). A variable factor is Halothane concentration (ppm).As a result, the design and equipment are as follows:

1. There were 7 levels of air changes rate; 12, 20, 25, 30, 35, 40, and 45 with velocity at 0.97 m/s. and test 5 replicates; total 35 times.

2. Chamber size is 1 x 1 x 1 m^3 and used plastic material that hardness and un-adsorb halothane. Install the centrifugal fan box inside with dimension 0.55 x 0.17 x0.30 m^3 and cutting rectangular channel to install a filter with dimension 0.1 x 0.25 m^2. The filter size 0.1 x 0.25 m^2 is contained 50 gram of activated carbon which has surface area more than 1100 m2/g, particle size =8(2.36mm) less than 5%, 8x16 (2.36-1.18 mm) more than 90% and 16(1,18 mm) less than 5%, Porosity 55-75%.

3. The instrument was calibrated by the master calibration equipment of the calibration equipment company especially on the Gas Chromatograph model GC-14B.

The internal calibration was a method that adjust the curve of 4 points of halothane concentration with 2 iterations, total 8 points and result of R = 0.9964455 and R^2 = 0.992936.

6.2 The design of experiment

First, prepare 50 ppm of halothane in a chamber (this experiment controls with constant concentration 50 ppm every air change on real time of Gas Chromatograph GC-14B). Second, allow air change rate at 15, 20, 25, 35, 40, and 45 respectively through the design filter and make in 5 iterations and measure halothane concentration with Gas Chromatograph GC-14B.

6.3 The results of experiment

1. General Information

The test results of 7 levels of air changes rate with 5 replicates that was average for each air change rate are in percentage of reduction of halothane concentration by adsorption activated carbon as follows: Air change rate: 15AC (22.26%), 20AC(33.82%), 25AC(36.30%), 30AC(38.27%), 35(38.01%), 40AC (37.94%) and 45 (38.05%).

2. Comparative parameter correlation (Pearson Correlation)

The test results of parameter correlation at 7 air change levels with 5 iterations, total 35 air changes rate are:

2.1 There was the correlation between air change rate and halothane concentrations after adsorption, percentage of halothane adsorption by activated carbon, and time duration. (p-value=0.01)

2.2 There was no correlation between air change rate and halothane concentrations before adsorption (p-value>0.01)

2.3 There was a correlation between halothane concentrations before adsorption and percentage of halothane adsorption by activated carbon. (p-value = 0.05)

2.4 There was no correlation between halothane concentrations before and after adsorption and time duration. (p-value >0.01)

2.5 There was a correlation between halothane concentrations after adsorption and percentage of halothane adsorption by activated carbon and time duration. (p-value =0.01).

2.6 There was a correlation percentage of halothane adsorption by activated carbon and time duration. (p-value =0.01).

3. Compare efficiency of air change rate and percentage of halothane adsorption by multiple regression, Chi-square and LSD

3.1 Compare efficiency by divided into 3 groups of air change rate: (15-20), (25-30), and (≥35). The results are as follows:

3.1.1. There were different efficiency effects among groups of air changes rate (15-20), (25-30), and (≥35) with statistically significant related at (p-value = 0.05)

3.1.2 There were not statistically significant (p-value=0.05) effects between air change rate group (25-30) and (≥35).

3.2 Compare efficiency of air change rate and percentage of halothane adsorption without grouping:

3.2.1 There were affected on efficiency on the vary of air change rate from 15 to 25 with statistically significant related (p-value =0.05)

3.2.2 There were not affected on the efficiency at air change rate from 30 to 45 (not statistically correlation (p-value>0.05)

It can be concluded that the 38% of Halothane adsorption by activated carbon is the best efficiency at 30 air change rate and 20.62 min life time. Then, the efficiency will be decreased unless change the filter for the best efficiency.

4. Factor correlation

Finding the correlation of percentage of halothane adsorption by activated carbon, air change rate, and Halothane concentration before adsorption, and time interval by multiple regression analysis by stepwise, p-value = 0.05 is shown as follows:

It can be written in the correlation equation between the Percentage of Halothane adsorption, Air change rate and Halothane concentration as following equation: $Y = -51.099 + 0.382X_1 + 1.537X_2$ When Y = percentage of halothane adsorption (%), X_1 = air change rate (AC) and X_2 = halothane concentration before adsorption (ppm).

6.4. Recommendation

6.4.1 Recommendation for application

1. This experiment can be recommended as the first prototype design to reduce or eliminate the toxic gases that affect to human especially Anesthetic gas in operation room. This should focus on the filters which concern with the thickness or weight of activated carbon or velocity; that will give a lot of impact.

2. The design filter can be applied to an air conditioning unit or the pollution area that can be direct installed on the return air of conditioning unit.

6.4.2 Recommendation for future study

1. The design of ventilation system in the building was significant and need safety because there were several uncontrolled factors in the operation room such

as the change of air volume in and out, operators, toxic gas volume, temperature, relative humidity, and velocity. These shall be the maintain factors for the development plan of ventilation system.

2. This activated carbon was selected to make a filter that gives the 38% of halothane adsorption. This value seems to be low because of the common use in the market and easy to find without standard qualify (standard commercial use). Therefore, it might cause the few area of gas adsorption and fasten a saturated. The value of 50 ppm for halothane concentration is slightly high. So that in the next research, the selected size and surface area of activated carbon filter; should be smaller or increase the surface area in order to increase the percentage of halothane adsorption.

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APPENDIX

APPENDIX

Table 1 Result of research for experiment at 35 times from 7 level of air change; 15, 20, 25, 30, 35, 40 and 45 air change and replicated 5 times at each level of air change.

Air change rate (air change /hr)	Concentration of halothane before adsorption (ppm)	Concentration of halothane after adsorption (ppm)	Percentage of halothane adsorption (% Adsorption)	Time duration (min)
15	46.83	37.44	20.05	10.31
15	46.27	35.54	23.18	10.31
15	47.06	36.41	22.62	10.31
15	48.52	38.02	21.64	10.31
15	46.92	35.74	23.82	10.31
20	51.78	33.81	34.71	13.75
20	49.75	33.10	33.46	13.75
20	48.26	32.84	31.95	13.75
20	47.75	31.46	34.12	13.75
20	49.15	32.01	34.86	13.75
25	49.44	32.78	33.70	17.18
25	48.42	30.32	37.38	17.18
25	48.75	30.59	37.26	17.18
25	49.32	31.68	35.75	17.18
25	48.75	30.51	37.42	17.18
30	47.59	28.98	39.10	20.62
30	48.17	29.30	39.18	20.62
30	47.95	29.74	37.98	20.62
30	48.87	30.41	37.77	20.62
30	49.26	30.88	37.32	20.62
35	48.42	29.76	38.54	24.05
35	47.57	28.99	39.05	24.05
35	48.31	29.89	38.11	24.05
35	49.46	31.26	36.79	24.05
35	49.25	30.75	37.56	24.05
40	48.15	29.88	37.95	27.49
40	49.52	31.15	37.09	27.49
40	48.33	29.43	39.12	27.49
40	47.89	29.24	38.94	27.49
40	49.55	31.41	36.61	27.49

Table 1 continue

Air change rate (air change /hr)	Concentration of halothane before adsorption (ppm)	Concentration of halothane after adsorption (ppm)	Percentage of halothane adsorption (% Adsorption)	Time duration (min)
45	48.32	29.88	38.17	30.93
45	48.65	30.21	37.90	30.93
45	47.67	28.73	39.73	30.93
45	48.81	30.33	37.86	30.93
45	49.13	31.16	36.57	30.93

Table 2 Relation between air change rate, concentration of halothane before and after adsorption, percentage of halothane adsorption and time duration.

		Air change rate (AC /hr)	Conc. of halothane before adsorption (ppm)	Conc. of halothane after adsorption (ppm)	Percentage of halothane adsorption (%)	Time duration (min)
Air change rate (AC/hr)	Pearson correlation	1	.178	-.755**	.745**	1.000**
	Sig.(2-tailed)	.	.306	.000	.000	.000
	N	35	35	35	35	35
Conc. of halothane before adsorption (ppm)	Pearson correlation	.178	1	-.156	.407*	.178
	Sig.(2-tailed)	.306	.	.371	.015	.306
	N	35	35	35	35	35
Conc. of halothane after adsorption (ppm)	Pearson correlation	-.755**	-.156	1	-.966**	-.755**
	Sig.(2-tailed)	.000	.371	.	.000	.000
	N	35	35	35	35	35
Percentage of halothane adsorption	Pearson correlation	.745**	.407*	-.966**	1	.745**
	Sig.(2-tailed)	.000	.015	.000	.	.000
	N	35	35	35	35	35

Table 2 continue

Time duration (min)	Pearson correlation Sig.(2-tailed) N	1.000** .000 35	.178 .306 35	-.755** .000 35	.745** .000 35	1 . 35

** Correlation is significant at the 0.01 level. (2-tailed)
* Correlation is significant at the 0.05 level. (2- tailed)

Table 3 Mean and Standard deviation of air change rate, concentration of halothane before adsorption, percentage of halothane adsorption and time duration.

	n	Mean	Std
Percentage of halothane adsorption (%)	35	34.9543	5.57359
Air change rate (air change / hr)	35	30.0000	10.14599
Concentration of halothane before and after adsorption (ppm)	35	48.5257	1.02594
Time duration (minute)	35	20.6186	6.97247

Table 4 Relation between percentage of halothane adsorption, air change rate, concentration of halothane before adsorption and time duration.

		Percentage of halothane adsorption (%)	Air change rate (AC/hr)	Concentration of halothane before adsorption (ppm)	Time duration (min)
Percentage of halothane adsorption (%)	Pearson correlation Sig.(1-tailed) N	1.000 . 35	.745 .000 35	.407 .008 35	.745 .000 35

Table 4 continue

		Percentage of halothane adsorption (%)	Air change rate (AC/hr)	Concentration of halothane before adsorption (ppm)	Time duration (min)
Air change rate (AC/hr)	Pearson correlation	.745	1.000	.178	1.000
	Sig.(1-tailed)	.000	.	.153	.000
	N	35	35	35	35
Conc. of halothane before adsorption (ppm)	Pearson correlation	.407	.178	1.000	.178
	Sig.(1-tailed)	.008	.153	.	.153
	N	35	35	35	35
Time duration (minute)	Pearson correlation	.745	1.000	.178	1.000
	Sig.(1-tailed)	.000	.000	.153	.
	N	35	35	35	35

Table5 Percentage of halothane adsorption has related to 2 variables; air change rate and concentration of halothane before adsorption.

Variables Entered/Removed (a)

Model	Variables entered	Variables removed	Method
1	Air change rate (Air change/ hr)	.	Stepwise (Criteria: Probability – of – F-to-enter<=.050, Probability – of- F-to –remove > =.100).
2	Concentration of halothane before adsorption (ppm)	.	Stepwise (Criteria: Probability – of – F-to-enter<=.050, Probability – of- F-to –remove > =.100).

a Dependent variable: percentage of halothane adsorption.

Model Summary

Model	R	R^2	Adjusted R^2	Std.Error of the Estimate	Change Statistics				
					R^2 Change	F Change	df 1	df 2	Sig.F Change
1	.745(a)	.555	.542	3.77353	.555	41.174	1	33	.000
2	.795(b)	.633	.610	3.48208	.078	6.755	1	32	.014

a Predictors (Constant), air change rate.

b Perdictors (Constant), air change rate, concentration of halothane before adsorption.

ANOVA(c)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression Residual Total	586.302 469.905 1056.207	1 33 34	586.302 14.240	41.174	0.000(a)
2	Regression Residual Total	668.210 387.997 1056.207	2 32 34	334.105 12.125	27.555	.000(b)

a Predictors :(Constant), air change rate.

b Predictors :(Constant), air change rate, concentration of halothane before adsorption. (ppm)

c Dependent variable: percentage of halothane adsorption.

Coefficients (a)

Model		Non-standardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	-(Constant)	22.676	2.017		11.242	.000
	-Air change rate	.409	.064	.745	6.417	.000
2	-(Constant)	-51.099	28.445		-1.796	.082
	- Air change rate	.382	.060	.695	6.380	.000
	- Conc. of halothane before adsorption (ppm)	1.537	.592	.283	2.599	.014

a Dependent variable: percentage of halothane adsorption.

Excluded Variables(c)

Model		Beta In	t	Sig.	Partial correlation	Collinearity statistics tolerance
1	- Conc. of halothane before adsorption	.283(a)	2.599	.014	.418	.968
	- Time duration	-106.250(a)	-.363	.719	-.064	1.621E-07
2	-Time duration	-170.754(b)	-.633	.531	-.113	1.607E-07

a Predictors in the model: (Constant), air change rate.
b Predictors in the model: (Constant), air change rate, concentration of halothane before adsorption.
c Dependent variable: percentage of halothane adsorption.

Table6 Categorized air change rate to be 3 groups. There are (15-20), (25-30) and (≥35) that related to percentage of halothane adsorption

One-way, Descriptive
Percentage of halothane adsorption.

Group	n	Mean	Std.	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
1	10	28.04	6.22	1.96	23.58	32.49	20.10	34.90
2	10	37.30	1.59	.50	36.16	38.43	33.70	39.20
3	15	38.00	.95	.24	37.47	38.52	36.60	39.70
Total	35	34.95	5.57	.94	33.03	36.86	20.10	39.70

ANOVA
Percentage of halothane adsorption.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	672.24	2	336.12	28.013	.000
Within Groups	383.96	32	11.99		
Total	1056.20	34			

Multiple Comparisons
Dependent variable: percentage of halothane adsorption.
LSD

(I) A1	(J) A1	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-9.26(*)	1.54912	.000	-12.4155	-6.1045
	3	-9.96(*)	1.41415	.000	-12.8405	-7.0795
2	1	9.26(*)	1.54912	.000	6.1045	12.4155
	3	-.70	1.41415	.624	-3.5805	2.1805
3	1	9.96(*)	1.41415	.000	7.0795	12.8405
	2	.70	1.41415	.624	-2.1805	3.5805

*The mean difference is significant at the .05 level.

Table 7 Relation between each of air change rate and percentage of halothane adsorption; the experiment are replicated 5 times at each of air change rate, total 35 times.

One-way, Descriptive

Percentage of halothane adsorption.

	n	Mean	Std.	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
15	5	22.26	1.45534	.65085	20.4530	24.0670	20.10	23.80
20	5	33.82	1.20499	.53889	32.3238	35.3162	31.90	34.90
25	5	36.32	1.61462	.72208	34.3152	38.3248	33.70	37.40
30	5	38.28	.83487	.37336	37.2434	39.3166	37.30	39.20
35	5	38.02	.87579	.39166	36.9326	39.1074	36.80	39.10
40	5	37.92	1.09179	.48826	36.5644	39.2756	36.60	39.10
45	5	38.06	1.10589	.49457	36.6869	39.4331	36.60	39.70
Total	35	34.95	5.57359	.94211	33.0397	36.8689	20.10	39.70

ANOVA

Percentage of halothane adsorption.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1015.983	6	169.330	117.871	.000
Within Groups	40.224	28	1.437		
Total	1056.207	34			

Multiple Comparisons

Dependent variable: percentage of halothane adsorption.

LSD

(I) Air change rate	(J) Air change rate	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
15	20	-11.5600(*)	.75804	.000	-13.1128	-10.0072
	25	-14.0600(*)	.75804	.000	-15.6128	-12.5072
	30	-16.0200(*)	.75804	.000	-17.5728	-14.4672
	35	-15.7600(*)	.75804	.000	-17.3128	-14.2072
	40	-15.6600(*)	.75804	.000	-17.2128	-14.1072
	45	-15.8000(*)	.75804	.000	-17.3528	-14.2472
20	15	11.5600(*)	.75804	.000	10.0072	13.1128
	25	-2.5000(*)	.75804	.003	-4.0528	-.9472
	30	-4.4600(*)	.75804	.000	-6.0128	-2.9072
	35	-4.2000(*)	.75804	.000	-5.7528	-2.6472
	40	-4.1000(*)	.75804	.000	-5.6528	-2.5472
	45	-4.2400(*)	.75804	.000	-5.7928	-2.6872

Multiple Comparisons

Dependent variable: percentage of halothane adsorption.

LSD continue

(I) Air change rate	(J) Air change rate	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
25	15	14.0600(*)	.75804	.000	12.5072	15.6128
	20	2.5000(*)	.75804	.003	.9472	4.0528
	30	-1.9600(*)	.75804	.015	-3.5128	-.4072
	35	-1.7000(*)	.75804	.033	-3.2528	-.1472
	40	-1.6000(*)	.75804	.044	-3.1528	-.0472
	45	-1.7400(*)	.75804	.029	-3.2928	-.1872
30	15	16.0200(*)	.75804	.000	14.4672	17.5728
	20	4.4600(*)	.75804	.000	2.9072	6.0128
	25	1.9600(*)	.75804	.015	.4072	3.5128
	35	.2600	.75804	.734	-1.2928	1.8128
	40	.3600	.75804	.639	-1.1928	1.9128
	45	.2200	.75804	.774	-1.3328	1.7728
35	15	15.7600(*)	.75804	.000	14.2072	17.3128
	20	4.2000(*)	.75804	.000	2.6472	5.7528
	25	1.7000(*)	.75804	.033	.1472	3.2528
	30	-.2600	.75804	.734	-1.8128	1.2928
	40	.1000	.75804	.896	-1.4528	1.6528
	45	-.0400	.75804	.958	-1.5928	1.5128
40	15	15.6600(*)	.75804	.000	14.1072	17.2128
	20	4.1000(*)	.75804	.000	2.5472	5.6528
	25	1.6000(*)	.75804	.044	.0472	3.1528
	30	-.3600	.75804	.639	-1.9128	1.1928
	35	-.1000	.75804	.896	-1.6528	1.4528
	45	-.1400	.75804	.855	-1.6928	1.4128
45	15	15.8000(*)	.75804	.000	14.2472	17.3528
	20	4.2400(*)	.75804	.000	2.6872	5.7928
	25	1.7400(*)	.75804	.029	.1872	3.2928
	30	-.2200	.75804	.774	-1.7728	1.3328
	35	.0400	.75804	.958	-1.5128	1.5928
	40	.1400	.75804	.855	-1.4128	1.6928

* The mean difference is significant at the .05 level.

METHOD ANALYTICAL

Instrument parameter

Injection port SPL

Temperature : 150.0 ℃

Column oven

Initial temperature : 90.0 ℃ Equibration time : 3.0 min
Column information
Column name : VB5
Serial number : 11880 Film thickness : 0.25 um
Column length: 30.0 m Inner diameter : 0.32 mm ID
Column Max Temp : 360 ℃ Installation date : 70/01/01

Detector FID

Temperature : 200.0 ℃
Range : 1
Polarity : -
Signal acquire : Yes Sampling rate : 100 msec
Stop time : 4.00 min Delay time : 0.00 min

General

Time program (2):
Total program time 1.00 min

	Time	Device	Event
1	0.01	Other	Event
2	1.00	Other	Event

Additional Heater / Flow

Peak integration parameter

Width : 3 sec Slope : 1000 uv/min
Drift : 0 uv/min T.DBL : 1000 min
Min. Area/Height : 1000 counts

Quantitative parameter

Quantitative method : External standard
Calculated by : Area Calibration level # : 4
Calibration curve : Linear Through origin : Not through
Weight regression : None Unit : ppm

Integration parameter

Window / Band : Window Window : 5 %
Default Band Time : --- Identification method : Absolute
Peck select : All pecks Grouping : None
Correction RT : Not change

Compound table

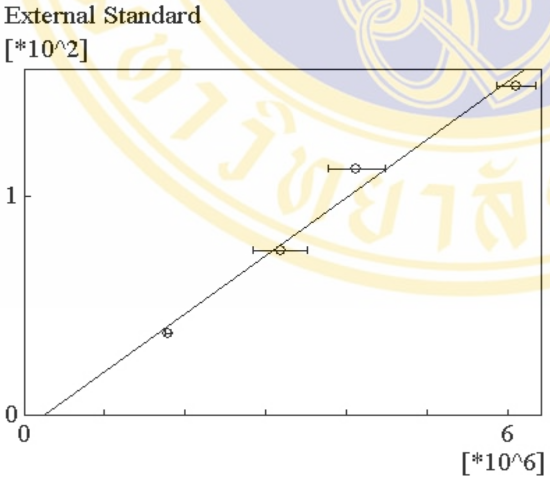
ID#	Name	Type	**Ret. Time**	Conc.1	Conc.2	Conc.3	Conc.4
1	Halothane	Target	**2.478**	37.420	74.840	112.260	149.680

Group table

Calc. method : JP Time of unretained peck : Time of 1st peak
Set time : --- Column length : 0 mm
Calculated for identified peak : OFF

Calibration curve analytical

ID# 1 Name: Halothane
F (x) = 2.124461e-005*x+7.335669
R = 0.9964455
R^2 = 0.9929036
Mean RF: 2.375978e-005
RFSD: 3.178663e-006, RFRSD: 13.37833
Curve Type: Linear
Zero Through: Not Through
Weighted Regression: None



No.	Conc.	Area
1	37.420	1780340
2	74.840	3174965
3	112.260	4119590
4	149.680	6093071

BIOGRAPHY

NAME	Lieutenant Anek Panlaem
DATE OF BIRTH	12 April 1966
PLACE OF BIRTH	Suphan Buri, Thailand
INSTITUTIONA ATTENDED	Mahidol University, 1997: Bachelor of Science (Public Health) Major of Occupational Health and Safety Mahidol University, 2006: Master of Science (Industrial Hygiene and Safety)
POSITION & OFFICE	1998-Present, Division of Preventive medicine: Department of Naval Medical. Position: Industrial Hygiene and Safety