THE PERMEATION OF SOLVENT MIXTURE THROUGH NITRILE AND BARRIER GLOVES

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Thesis
entitled

THE PERMEATION OF SOLVENT MIXTURE THROUGH NITRILE AND BARRIER GLOVES

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ABSTRACT

Breakthrough time is information provided by the manufacturer to be used for selecting CPC. It is generally the result of permeation tests with pure chemicals, while in most workplace mixtures are widely used. According to previous studies, it was found that the permeation rate of pure and mixed chemicals could be the same or different. There were several factors which affected the permeation. Additionally, there has been no exact method for selecting the gloves for the mixture yet. Therefore, this study had been conducted in order to study the permeation of the mixture through 2 kinds of gloves.

The mixture consists of n-hexane, benzene and ethylbenzene. The new and repeatedly used Nitrile gloves and Barrier gloves in cleaning printing machine process were used in the permeation tests using the ASTM F-739 standard and subsequently analysed by gas chromatography flame ionization technique. The data of other affecting factors on the permeation would be collected including the appearance of the gloves after use, weight of gloves, number of day the gloves were used, exposure duration and number of time chemical contact with the gloves as well.

For the repeatedly used gloves for 5 days, the general appearances were more colour stained and weight gain varied by number of days the gloves were used. Breakthrough time through Nitrile gloves decrease varied by number of day the gloves were used; average breakthrough time were 1454, 1427, 1427, 1340 and 1324 minutes respectively. In Comparison, of pure chemical against mixture permeation through the Nitrile gloves, it was found that Nitrile gloves can resist to the mixture better than pure chemical. Breakthrough time of n-hexane, benzene and ethylbenzene in pure chemical are 480, 16 and 43 minutes respectively, while breakthrough time of n-hexane, benzene and ethylbenzene in mixture are 1528, 1535 and >2880 minutes respectively. For Barrier gloves, there was no permeation of all three chemicals in pure chemical and mixture. In conclusion, both types of gloves can well resist the mixture chemical permeation in this study.

For further study, various types of gloves and chemicals as well as mechanism of mixture permeation should be focused on. Then, the data of chemical permeation study may be collected for guideline development of chemical protective gloves selection.

KEY WORDS: BREAKTHROUGH TIME/PERMEATION RATE/SOLVENT MIXTURE

122 pages

การแพร่ผ่านของสารทำละลายผสมผ่านถุงมือไนไตรล์และถุงมือแบร์ริเออร์
THE PERMEATION OF SOLVENT MIXTURE THROUGH NITRILE AND BARRIER GLOVES

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บทคัดย่อ

ค่าเวลาการแพร่ผ่าน (Breakthrough time) เป็นข้อมูลสำคัญสำหรับการเลือกชุดป้องกันสารเคมีที่ได้จากผู้ผลิต ซึ่งโดยทั่วไปได้จากการทดสอบการแพร่ผ่านของสารเดี่ยว ในขณะที่สถานประกอบการส่วนใหญ่ใช้สารผสม จากการทบทวนวรรณกรรมพบว่าอัตราการแพร่ผ่านของสารเดี่ยวและสารผสมอาจมีค่าเท่ากันหรือต่างกันได้ โดยอาจมีปัจจัยที่ส่งผลต่อการแพร่ผ่านหลายประการจึงยากแก่การกำหนดมาตรฐานในการเลือกถุงมือสำหรับสารผสม ดังนั้นผู้วิจัยจึงได้ทำการศึกษาการแพร่ผ่านของสารผสมผ่านถุงมือ 2 ชนิด

การศึกษานี้ทดสอบการแพร่ของสารผสมซึ่งประกอบด้วยสารเอ็นเฮกเซน เบนซีน และเอทิลเบนซีนผ่านถุงมือไนไตรล์และถุงมือแบร์ริเออร์ ทั้งถุงมือใหม่และถุงมือใช้ซ้ำในกระบวนการล้างทำความสะอาดเครื่องพิมพ์ ตามมาตรฐาน ASTM F-739 และวิเคราะห์ปริมาณสารเคมีโดยใช้เทคนิคแก๊สโครมาโทกราฟี เฟรมไอออนไนเซชัน รวมทั้งเก็บข้อมูลปัจจัยอื่นที่มีผลต่อการแพร่ผ่านได้แก่ สภาพถุงมือหลังการใช้งาน น้ำหนักของถุงมือ จำนวนวันที่ใช้งานถุงมือ ระยะเวลาในการทำงานแต่ละครั้งและจำนวนครั้งที่ใช้งานถุงมือ

ผลการศึกษาพบว่าถุงมือใช้ซ้ำ 5 วัน มีสีเปื้อนมากขึ้นและมีน้ำหนักเพิ่มขึ้นตามจำนวนวันที่ใช้งานและค่าระยะการแพร่ผ่านของถุงมือไนไตรล์ลดลงตามจำนวนวันที่ใช้งานโดยมีค่าเฉลี่ย 1454, 1427, 1367, 1340 และ 1324 นาทีตามลำดับ ส่วนผลการเปรียบเทียบการแพร่ผ่านของสารเดี่ยวและสารผสมพบว่าถุงมือไนไตรล์สามารถป้องกันการแพร่ผ่านของสารในสารผสมได้ดีกว่าสารเดี่ยว โดยมีค่าระยะเวลาการแพร่ผ่านของสารเดี่ยวเอ็นเฮก เซนเบนซีน และเอทิลเบนซีน 480, 16 และ 43 นาทีตามลำดับ ขณะที่ในสารผสมมีค่า 1528, 1535 และมากกว่า 2880 นาทีตามลำดับ ส่วนถุงมือแบร์ริเออร์ไม่พบการแพร่ผ่านของสารทั้งสามชนิดทั้งในรูปสารเดี่ยวและสารผสม สรุปได้ว่าถุงมือทั้งสองชนิดสามารถป้องกันการแพร่ผ่านของสารผสมในการศึกษานี้ได้ดี

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LIST OF ABBREVIATIONS

Abbreviation or symbol	**Term**
ACGIH	American Conference of Governmental Industrial Hygiene
ASTM	American Society for Testing and Materials Standard
BT	Breakthrough Time
CEN	European Community for Standardizations
CPC	Chemical Protective Clothing
3-DSP	Three-dimensional solubility parameter
Fig	Figure
GC-FID	Gas Chromatography – Flame Ionization Detector
ISO	International Standard Organization
NIOSH	The National Institute for Occupational Safety and Health
OSHA	The Occupational Safety & Health Administration of United state
PPE	Personal Protective Equipment
PA	Polyamide
PE	Polyethylene
PR	Permeation rate
PVA	Polyvinyl alcohol
PVC	Polyvinyl chloride
QC	Quality control
SD	Standard deviation

LIST OF ABBREVIATIONS (cont.)

Abbreviation or symbol	**Term**
TLVs	Threshold Limit Values eight-hour working day
cm^2	Square centimeters
g	Gram
l	Liter
mg	Milligram
m^3	Cubic meter
min	Minute
ml	Milliliter
µg	Microgram
µl	Micro liter
sec	Second

CHAPTER I
INTRODUCTION

1.1 Introduction

The industrial hygiene controls are the implementation of some measures in order to reduce or eliminate hazards which might impact on workers' health. The hierarchy of control should be selected based on the reliability and efficiency of the exposure reduction as following;

1) Elimination; Get rid of the hazards from workplace which is considered as the most effective way.

2) Substitution; Replace the hazardous material substance with those lesser hazardous ones.

3) Engineering control.

4) Administrative control; such as work instruction, limit working time, training as well as workplace cleaning (1, 2, 3).

5) Personal protective equipment (PPE)

As we see the PPE is considered as a last resource for control the hazard after all other means of control have been pursued. However, in some situation PPE is necessary and must be worn by the workers. For example, the use of chemical protective clothing (CPC) in conjunction with other preventive actions when working with chemicals for maintenance, and cleaning machine, and equipment. Selection of the most appropriate CPC such as glove requires the assessment of the resistance of the material to the chemicals (4, 5).

Solvent can dissolve or dilute other chemicals therefore it has been used in several process of industrial work. Generally, solvent is in liquid state which can expose to body by 2 main routes i.e. respiratory tract and skin. After entry the body and penetrate into blood circulation, chemicals could go to other part of the body. Some chemicals may affect some organs and present symptoms which could be acute and/or chronic, depending on kind and dose of chemical. Most of solvent affect mucous membrane, skin and nervous system with the symptoms of headache, dizzy, vomit and may be dead in case of high dose or highly toxic chemical. Harm to skin would occur because most solvent can dissolve lipid which is skin component, causing dry, crack, irritant or burn, prolong of skin contact can cause contact dermatitis, rash, blister and easily infect with bacteria leading to severer inflame (6, 7).

According to the Epidemiology Institute's report in the Occupational and Environmental Disease Surveillance Report shown that between B.E. 2546-2552 (8) occupational skin diseases cases were 5,973 which is in third rank of occupational disease. As mentioned previously, PPE is a method to prevent skin contact with the hazardous substance. However, not all protective clothing resists all substances, so manufacturers' specifications (e.g. duration of exposure/glove contacts time with chemical) should be followed (9). In case selected poorly and used, may actually cause or worsen hand dermatitis (by permeation and penetration). Thus, proper chemical protective clothing (CPC) selection is very important (10).

The parameters which are considered in order to select the CPC are permeation rate and breakthrough time obtained by the permeation test. ASTMF739-91 is a permeation test standard which produced by American Society for Testing and Materials (ASTM). Such method is permeation test of liquid and gas through chemical protective material in condition of continuously contact with chemical (11).

Breakthrough time is time that a chemical takes to permeate completely through the material. It is determined by applying the chemical on the glove exterior and measuring the time it takes to detect the chemical on the inside surface when a chemical is first detected. The time at which permeation rate reaches 0.1 µg/cm2/min. The breakthrough time is often the most important factor used to indicate the degree of protection which a particular glove material will provide, particularly with highly toxic chemicals. The longer the breakthrough time, the longer the protection period. Generally breakthrough time test will be proceeded only 8 hours. In case of there is no "breakthrough" within such period, it will be reported as longer than 8 hours (>8 hr) (12).

Permeation rate is the rate at which a chemical passes through the glove material once it has broken through. The permeation rate is generally expressed in terms of the amount of a chemical which passes through a given area of clothing per unit time (micrograms per square centimeter per minute) (12).

Most published breakthrough time and permeation rates are based on the tests performed with a single chemical, while many job-related activities involve the use of multiple chemicals or mixtures and repeatedly use the gloves. The permeation characteristics of the solvent mixture can be substantially different from the permeation of individual solvents, thus the selection of the appropriate protective glove is challenge. Several researchers have found that one component of a mixture may promote the permeation of other components through the protective glove at a faster rate than their pure form alone (13, 14, 15). R.L.Mickelson and et. (16) studied about permeation of three pairs of chemical mixture the results are 1) The mixture may decrease the breakthrough time of the components. 2) The component that does not permeate in it pure form but may be permeate through the CPC by another component. 3) The permeation rates for mixture may be higher than either pure component. So the researcher suggested that the permeation should be tested with using mixture and conditions of real operation.

However, working condition such as time, and number of repeated using day may contribute to chemical permeation through the gloves. Nanapat S (17) studied a single chemical permeation and found that the breakthrough time of repeatedly used glove decreased when number of using day increased, additionally, permeation rate increased when number of using day increased. Therefore, the purpose of this study was to measure the breakthrough time and permeation rate of mixture solvent including n-hexane, benzene and ethylbenzene through nitrile and barrier gloves, in order to give a guideline for appropriate selecting of gloves when working with mixture.

1.2 Objectives

1.2.1 General objectives

To compare the permeation test results of the solvent mixture used for cleaning printing machine through nitrile glove and barrier gloves.

1.2.2 The specific objectives

1.2.2.1 To evaluate and measure the physical conditions of the studied gloves, appearance and weight.

1.2.2.2 To study breakthrough time and permeation rate of the mixture on new and repeated used nitrile gloves

1.2.2.3 To study breakthrough time and permeation rate of the mixture on new and repeated used barrier gloves

1.2.2.4 To compare the permeation test results of pure and mixture solvent for nitrile gloves.

1.2.2.5 To compare the permeation test results of pure and mixture solvent for barrier gloves.

1.2.2.6 To study factors that affect the breakthrough time and permeation rate including number of used day, number of contact, and exposure duration.

1.3 Research question

1.3.1 Dose the permeation test result of the new gloves differs from reused gloves on nitrile gloves and barrier gloves?

1.3.2 Dose the permeation behavior of the mixture differs from their pure chemical on nitrile gloves and barrier gloves?

1.3.3 Does the working factor including number of used day, number of contact, exposure duration affect the permeation of the chemicals?

1.4 Research hypothesis

1.4.1 The permeation test result of the new and repeated used gloves do differ.

1.4.2 The results of the permeation test for the pure and mixture do differ.

1.4.3 The working factor i.e. number of used day, number of contact, and exposure duration affect the permeation test.

1.5 Scope of the study

1.5.1 The experimental research using ASTM F739-91 standard method to test the permeation performance of mixture, n-hexane, benzene and ethyl benzene, through 2 kinds of gloves. The GC-FID (Gas Chromatography, Flame Ionization Detector) technique is used for chemical analysis in order to calculate the amount of chemical permeated through the gloves. The permeation test results, breakthrough time and permeation rate, would be compared between two kinds of gloves for both the new and the repeated used gloves.

1.5.2 The workers would be observed while working. The factors that may affect the permeation of the chemicals such as number of used day, number of contact, and exposure duration were recorded using a form prepared by the researcher and reviewed by the expert?

1.5.3 Study gloves

1.5.3.1 Nitrile gloves this kind of gloves are currently used by the worker in the factory.

1.5.3.2 Barrier gloves researcher select this kind of gloves due to their good protection against the chemicals in the study.

1.6 Variables

1.6.1 Independent variables

1.6.1.1 The number of used days.

1.6.1.2 The number of contact.

1.6.1.3 Exposure duration.

1.6.2 Dependent variables

1.6.2.1 Permeation Rate

1.6.2.2 Breakthrough time

1.6.2.3 Visual Appearances of gloves
- Color change
- Texture
- Swollen

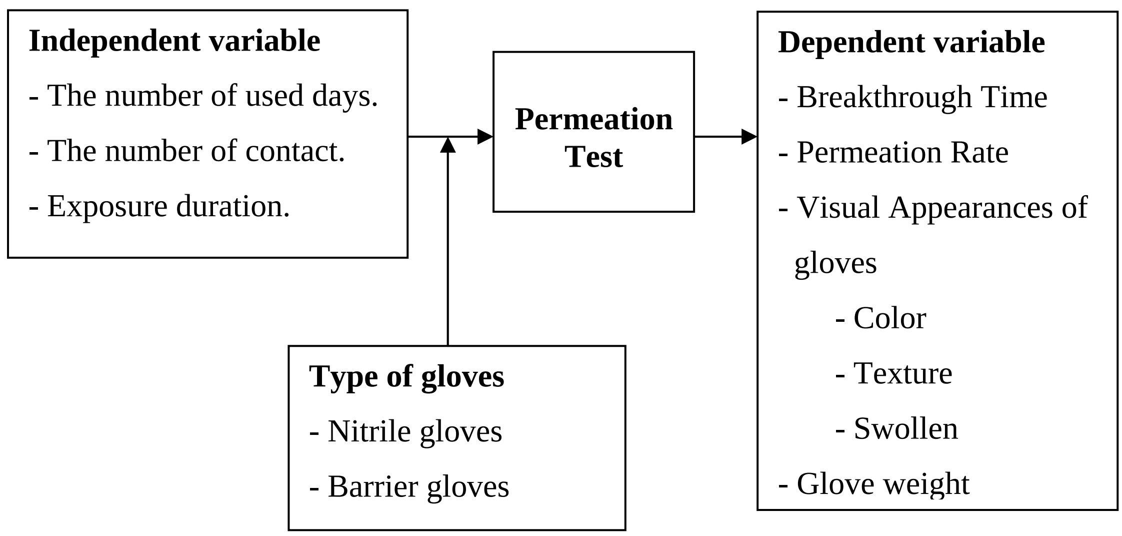
1.6.2.4 Glove weight

1.7 Expected outcomes and benefit

1) The obtained breakthrough time and permeation rate of chemical mixture could suggest the selection of CPC for mixture.

2) The observed physical conditions which have been changed after chemical exposure may suggest the appropriate duration of repeated use of the gloves.

1.8 Conceptual framework



1.9 Definitions of terms

1) ASTM: Formerly known as the American Society for Testing and Materials is a globally recognized leader in the development and delivery of international voluntary consensus standards related to ASTM F 739-91 standard test method for resistance of protective clothing materials to permeation by liquids or gases under conditions of continuous contact (11).

2) Permeation: The process by which a chemical agent migrates through the protective glove at a molecular level (12).

3) Permeation Rate: is the rate at which the chemical will move through the material. It is measured in a laboratory and is expressed in units like milligrams per square meter per second (or some other [weight of chemical] per [unit area of material] per [unit of time]) (12).

4) Breakthrough time: is time it takes a chemical to permeate completely through the material. It is determined by applying the chemical on the glove exterior and measuring the time it takes to detect the chemical on the inside surface when a chemical is first detected. The time at which permeation rate reaches 0.1 µg/cm2/min (ASTM, ISO) or1 µg/cm2/min (EU, ISO) (12).

5) Penetration: The bulk flow of a chemical agent through closures, porous materials, seams and pinholes or other imperfections in the protective glove (18).

6) Degradation: A damaging change in one or more physical properties of the protective glove as a result of exposure to a chemical agent (18).

7) Test cell: The test apparatus consist of a two-chambered cell for contacting the specimen with the test chemical on the specimen’s normally outside surface and with a collection medium on the specimen’s normally inside surface (11).

8) Personal protective equipment (PPE): is equipment worn to minimize exposure to a variety of hazards. Examples of PPE such as chemical protective gloves (19).

9) Chemical Protective Clothing (CPC): comprising gloves, boots, suits and other related components, can prevent direct skin contact and contamination (20).

10) The number of used day: Number of days that the workers have been repeatedly used the gloves.

11) Exposure duration: The period of time that the workers have been exposed to solvent while using the gloves since start to end of solvent use.

12) The number of contact: Number of times that the workers have been contacted with solvent while using the gloves.

13) Glove weight: The weight of gloves would be checked by weighing using electronic weight (gram).

CHAPTER II
LITERATURE REVIEW

2.1 Introduction

This research is compare the permeation performance of the solvent mixture, composed of n-hexane, benzene and ethylbenzene through new and reused Nitrile gloves and Barrier gloves were selected for the study which is conducted in the cleaning printing machine process. And test according to the permeation test compliant to ASTM F 739-96 standard subsequently analyze using GC-FID technique. The results include the breakthrough time and permeation rate. In addition, other factors which affect the permeation such as the number of days the gloves were used, exposure duration and the number of time the chemical contact with the gloves were also collected. The literature review of the study can be divided in to 11 parts as follows:

2.1) Introduction
2.2) Categories of chemical protective gloves
2.3) Chemical protective glove selection
2.4) Chemical resistance of protective glove
2.5) Factor influencing the permeation of gloves
2.6) Study gloves
2.7) Polymer characteristics and permeation process
2.8) Permeation performance test method
2.9) Analysis method for Solvent
2.10) Solvent in Printing Industry
2.11) Skin hazard caused by Solvent
2.12) Literature cited

2.2 Categories of chemical protective gloves

Chemical protective gloves may consist of a variety of materials, such as rubber, polyvinylchloride, polyethylene or chemically refined rubber, and therefore provide different features and capabilities. The followings are the features and capabilities of those materials (21, 22).

2.2.1 Latex (Natural Rubber - NR)

This material is comfortable to wear, which makes them a popular general-purpose glove. They feature outstanding tensile strength, elasticity and temperature resistance. In addition to resisting abrasions caused by grinding and polishing, these gloves protect workers' hands from most water solutions of acids, alkalis, salts and ketones. Latex gloves have caused allergic reactions in some individuals and may not be appropriate for all employees. Hypoallergenic gloves, glove liners and powder less gloves are possible alternatives for workers who are allergic to latex gloves (23).

2.2.2 Nitrile rubber (nitrile-butyl rubber -NBR)

This material has very good abrasion, puncture, cut and tear resistance. Protective gloves made of nitrile rubber are offered from thin and sensitive to strong variants. The coatings of the individual manufacturers are proprietary developments and thus have differing properties. Good for wide variety of solvents, oils, greases, some acids, bases and poor for oxidize, aromatic, ketones and acetate (21).

2.2.3 Polyvinyl chloride (PVC)

The material has low flexibility; therefore plasticizers are added during production. The contact of PVC material with solvents leads to elutriation of the plasticizer, and the gloves become brittle. Usually the color of these gloves will change if they have been in contact with solvents. Good for acids and bases, some organics, amines, and peroxides; poor for most organics (21, 22).

2.2.4 Polychloroprene, neoprene

Protective gloves of polychloroprene have good physical properties (abrasion, tear propagation resistance) and are more resistant to weather and ageing than gloves made of other materials. Good for acids and bases, peroxides, fuels, hydrocarbons, alcohols, phenols; Poor for halogenated, aromatic hydrocarbons and water (21, 22).

2.2.5 Butyl rubber (polyisobutylene rubber - IIR, IBR)

Butyl rubber gloves are made of a synthetic rubber and protect against a wide variety of chemical, such as peroxide, rocket fuels, highly corrosive acids (nitric acid, sulfuric acid, hydrofluoric acid and red-fuming nitric acid),strong bases, alcohols, aldehydes, ketones, esters and nitro compounds. Butyl gloves also resist oxidation, ozone corrosion and abrasion, and remain flexible at low temperatures. Butyl rubber does not perform well with aliphatic and aromatic hydrocarbons and halogenated solvents (21, 23).

2.2.6 Polyvinyl alcohol (PVA)

Protective gloves made of PVA have a limited scope of applicability, since the glove material is water soluble. For anhydrous solvents, temporally limited protection can be expected. Good for aromatic and chlorinated solvents; Poor for water-based solutions that water destroys the gloves (21, 22).

2.2.7 Fluoroelastomer (viton)

Protective gloves made of fluororubber have a broad application range. They are produced ina complex process so that they are relatively expensive. Good resistance to chlorinated and aromatic solvents and good resistance to cuts and abrasions. Poor for ketones, ester and amine (21, 22).

2.2.8 Doublematerial mixtures

Beyond the forms of chemical protective gloves listed above, there are lots of protection gloves made of material combinations. These are often used for situations of very high stress (e.g. mixtures of chemicals) but they are relatively expensive (21).

2.2.9 Multi-layer gloves (laminates)

These gloves are manufactured by welding together several layers of different materials. The welding seams may tear; mobility is often limited and wearing comfort rather low. Good for wide variety of toxic and hazardous chemicals; provides the highest level of chemical resistance. Flexible laminate glove; Poor fit- comes in small, medium, large (21).

2.3 Chemical protective glove selection

2.3.1 Hazard Assessment

An industrial hygienist or other safety professional familiar with the task can perform a hazard assessment. The hazard assessment begins with knowing what chemicals or combination of chemicals the task or job requires. The next step is to determine the chemicals' toxic properties by reviewing the Material Safety Data Sheets (MSDSs). Attention should be focused on potential local skin effects, as well as potential absorption through the skin and resultant systemic effects.

When reviewing the job requirements, the degree of dexterity required for each task must be taken into account. Tasks that require fine motor skills, such as laboratory work, may require a thinner glove material, while operations such as industrial parts cleaning may not.

Also, the length of exposure to the chemicals must be considered. Some tasks may require only splash protection or include intermittent contact, while others may involve complete immersion or continual contact with the chemicals.

Other factors to consider are chemical concentration and temperature. The higher the concentration and temperature of a chemical, the shorter the breakthrough time. The hazard assessment must also take into account other hazards of the job, such as cut or abrasion hazards.

It's important to remember that although the number of glove choices can be staggering, no one glove can possibly address all types of hand hazards. Gloves are never a substitute for safe work practices or proper engineering controls (24, 25).

2.3.2 Choosing a Glove Material

Select a glove material which has the required chemical resistance properties for the specific chemicals to be used. In terms of selection criteria, the best protective glove is one which demonstrates no significant degradation upon contact with the specific chemical(s), and has an appropriately high breakthrough time and a low permeation rate under the conditions of use (24).

2.3.3 Consider factor

Consider factors associated with actual conditions of use that might affect performance of the glove for the final selection. Additional testing under the conditions of use may need to be conducted (24).

2.4 Chemical resistance of protective glove

The selection of a glove material that provides the best protection against a particular chemical is based mainly on its chemical resistance performance upon contact with the chemical. Chemical resistance performance of a glove is generally defined in terms of its Permeation, degradation and penetration properties (26, 27).

2.4.1 Permeation

The permeation is a process by which a chemical can pass through a protective film of glove material without going through pinholes, pores, or other visible openings. Individual molecules of the chemical enter the film and "squirm" through by passing between the molecules of the glove material. In many cases the permeated material may appear unchanged to the human eye. Permeation testing of glove products is conducted in accordance with standards of ASTM F 739, EN 374-3 and ISO 6529. Permeation testing provides two important pieces of data for glove selection - breakthrough time and permeation rate (12, 26).

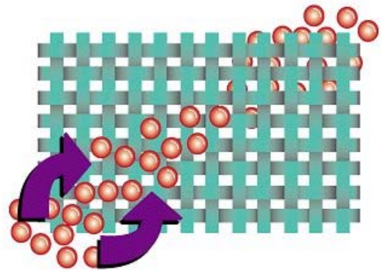


Figure 2.1 Permeation process

2.4.1.1 Breakthrough time

Breakthrough time is the time from initial chemical contact on the glove exterior to the time it is first detected on the inside surface. The breakthrough time is often the most important factor used to indicate the degree of protection a particular glove material will provide, particularly with highly toxic chemicals. The breakthrough time is usually expressed in minutes or hours. A typical test runs for up to 8 hours. If there is no measurable breakthrough after 8 hours, the result is reported as a breakthrough time of >480 minutes or >8 hours does not mean there was not permeation; it mean that permeation rate did not exceed 0.1 µg/cm2·min (ASTM), 1 µg/cm2·min (EU) and ISO. The glove material with the highest breakthrough time should be selected. This generally means selecting a glove with a breakthrough time of eight hours or greater; however, this level of resistance is not always available. Users must ensure that the expected duration for handling the particular chemical is well within the breakthrough time of the selected glove material. Otherwise, more frequent changes of the gloves are warranted (12, 26).

2.4.2 Permeation rate

Permeation rate is the rate at which a chemical passes through the glove material once it has broken through. The permeation rate is generally expressed in terms of the amount of a chemical which passes through a given area of clothing per unit time (micrograms per square centimeter per minute). Some manufacturers provide descriptive ratings from poor to excellent (12, 27).

2.4.3 Degradation

Degradation is the physical deterioration of a glove material due to contact with a chemical. This may cause the glove to soften, swell, shrink, stretch, dissolve, or to become hard and brittle. Gloves having a good to excellent rating against degradation should be selected. CPC material degradation was assumed whenever the color changed, the material wrinkled, or the material stiffened. Usually, the resistance to degradation was evaluated by noting changes in the visual appearance of the surface of a specimen after it came in contact with a chemical (18, 27).

2.4.4 Penetration

A chemical penetrates protective garment because of its design and construction imperfections, not because of the inherent material from which it is made. Stitched seams, button holes, porous fabric, and zippers can provide an avenue for the contaminant to penetrate the garment. A well designed and constructed protective suit with self-sealing zippers and lapped seams made of a nonporous degradation-resistant material prevents penetration, but as soon as the suit is ripped or punctured it loses its ability to prevent penetration. A material may also be easily penetrated once degraded (18, 27).

2.5 Factor influencing the permeation of gloves

Permeation resistance data provide a convenient means of ranking the relative effectiveness of specific gloves. Long breakthrough times and low permeation rates are desirable qualities in glove selection. The following factors, in conjunction with permeation data, should be considered when selecting a glove for a particular operation (28, 29).

2.5.1 Glove Material

Gloves are made of different polymer materials, each of which will resist permeation by some chemicals better than others. The materials that have been listed in Table 2-1 represent a wide range of available glove materials (29).

2.5.2 Frequency/Severity of Contact

The performance of glove materials can decrease significantly as chemical exposure increases, such as with the resultant shortening of the breakthrough time with increase in chemical concentration, or with direct immersion in to the chemical (29).

2.5.3 Chemical Mixtures

Permeation testing is conducted using pure chemicals. Mixtures of chemicals can significantly change the permeation rates and the physical properties of a given glove material. More aggressive towards protective clothing materials than any single chemical alone. One permeating chemical may pull another with it through the material. Very little data is available for chemical mixtures. Other situations may involve unidentified substances. In both the case of mixtures and unknowns, serious consideration must be given to deciding which protective clothing is selected. If clothing must be used without test data, garments with materials having the broadest chemical resistance should be worn, i.e. materials which demonstrate the best chemical resistance against the widest range of chemicals (24, 31).

2.5.4 Temperature

In general, permeation rates increase and breakthrough times decrease as temperatures increase. Standard permeation test data are obtained at room temperature (20^{o}C to 25^{o}C). For chemicals that are used at temperatures higher than this, there may be a significant decrease in glove performance (24).

2.5.5 Thickness

Selecting a thicker glove or double gloving may be required for adequate protection, because a thicker glove offers better chemical resistance and a significant increase in breakthrough time. As a general rule of thumb, doubling the glove thickness will quadruple the breakthrough time. When considering glove thickness, the required degree of manual dexterity and sensitivity must also be considered. Thicker gloves offer better chemical resistance, but can impair grip, manual dexterity and safety. A proper balance must be struck between the need for greater sensitivity and dexterity and an acceptable degree of chemical resistance. Disposable gloves, in particular, will offer greater dexterity but are generally intended to guard against mild chemicals and provide little or no protection against many chemicals (24, 29).

2.5.6 Reuse

The permeation of chemicals through gloves does not cease when the gloves are removed from the hands and set side. Very remitted data exist on the effect of intermittent exposure but for some compounds the break through time is the same for cumulative intermittent exposure as for continuous exposure. Continued permeation through gloves has been measured for as long as 70 hours after ending a 4 hours exposure test (30). Thus the reuse of seemingly impermeable gloves over a period of days, even with brief contact, would seem to assure that inside of the glove will eventually become contaminated.

Re-useable gloves need to washed and dried after work to avoid accidental skin contamination when next putting the gloves on. This is especially important if the work has involved immersion or handling of chemicals that can permeate the glove material. If frequently re-used the gloves should periodically be turned inside out and the inner surface washed and rinsed off. Re-useable gloves should be inspected before each use for discoloration, cracking at flexion points or damage and should be discarded if found. They must also be discarded if the inside becomes contaminated (28).

2.5.7 Manufacturers and Quality Control

The manufacturing process varies from one manufacturer to another. Consequently, a given glove material from one manufacturer may not have the same breakthrough time and/or permeation rate as one obtained from a different manufacturer when challenged with the same chemical. Tests are conducted using a single lot of a manufacturer’s gloves. The results are manufacturer/glove material specific and are valid only if the manufacturer maintains high standards of quality control (24, 29).

2.5.8 Physical Resistance

The physical properties of a particular glove material and its likelihood for puncture, tearing, abrasion or snagging under conditions of use must always be considered when selecting a glove. Penetration of chemicals through a tear or hole in a glove will lead to much higher exposures than by molecular permeation alone. It may sometimes be necessary to wear two different types of gloves; one for its chemical resistance properties, and the other for its physical resistance properties (24, 29).

2.6 Study glove

To select the chemical protective gloves, have to look for the gloves which can protect used chemical permeation. The solvent, which used in this study, consists of n-Hexane, Benzene and Ethyl benzene. There are many types of gloves can protect from those three chemicals as follows; Barrier, Silver shield, PVA and Viton gloves – Nitrile gloves is inferior. As for non-recommended gloves are Butyl Rubber, Natural Rubber, Neoprene and Polyvinyl chloride (PVC), because breakthrough time of each chemical is less than 1 hour.

According to effective comparison of the gloves as well as protecting from those three chemicals permeation - n-Hexane, Benzene, Ethyl benzene – there are several types of gloves and manufacturers (The industries in Thailand mostly use Ansell). The gloves which can protect from those three chemicals are Barrier, Silver shield, PVA and Viton gloves because breakthrough time of each chemical is more than 8 hours. Besides, Rubber, Natural Rubber, Neoprene and Polyvinyl chloride (PVC) breakthrough time of each chemical is less than 8 hours, that can see in the below table. Then about the price, it shown that prices of Barrier, Silver shield ,PVA and Viton gloves is 250 Bath, 550 Bath 1200 Bath and 4500 Bath consequently. Additionally, about the effective, the Barrier glove is easily worn, flexible, closely fit and moderately price rate. The Silver shield glove is not fit that might have been inappropriate to cleaning task. The PVA glove can protect from many chemicals and enduring, but not only quite expensive, it is also dissolve when contact water. The Viton glove can be used with several organic compounds, but it is so expensive. So, the Barrier glove was selected because it ist he most appropriate.

Table 2.1 Compare of gloves characteristic (32, 33, 34).

Polymer	**Gloves Type**	**Chemicals**	**Breakthrough Time (min)**	**Price (Bath)**	**Advantage**	**Disadvantage**
Laminated Film	Barrier® 	n-Hexane	> 480	≈ 250	-Appropriate for light tasks -Comfortable to wear -Loose fit -Flexibility -Medium cost	-Subject to physical damage -Easier to cut and puncture
		Benzene	> 480			
		Ethylbenzene	> 480			
Nitrile	Sol-Vex® 	n-Hexane	> 480	≈ 70	-Appropriate for medium to heavy tasks -Form-fitting for good tactile sensitivity and dexterity -Long service life -Low cost	-Can cause allergic contact dermatitis form residual processing chemical
		Benzene	28			
		Ethylbenzene	10-30			
Silver Shield		n-Hexane	> 480	≈550	-Excellent chemical resistance	Poor fit -Easily punctures -Poor grip -Stiff
		Benzene	> 480			
		Ethylbenzene	> 480			

Table 2.1 Compare of gloves characteristic (32, 33, 34) (cont.)

Polymer	**Gloves Type**	**Chemicals**	**Breakthrough Time (min)**	**Price (Bath)**	**Advantage**	**Disadvantage**
Supported Polyvinyl Alcohol	PVA™ 	n-Hexane	> 480	≈ 1200	-Specialty glove -Resists a very broad range of organics -Good physical properties	-Very expensive -Water sensitive -Poor for light alcohols
		Benzene	> 480			
		Ethylbenzene	> 480			
Natural Rubber	Canners and Handler 	n-Hexane	< 5	≈ 90	-Physical properties -Good dexterity -Low cost	-Poor for oils, greases, organics -Frequently imported; may be poor quality
		Benzene	< 10			
		Ethylbenzene	< 10			
Best® Butyl	878 	n-Hexane	13	≈ 2300	-Specialty glove -Polar organics -Good for ketones and esters	-Poor for gasoline, aliphatic, aromatic and halogenated compounds -Only available as re-useable -Poor touch sensitivity -Expensive
		Benzene	34			
		Ethylbenzene	-			

Table 2.1 Compare of gloves characteristic (32, 33, 34) (cont.)

Polymer	Gloves Type	Chemicals	Breakthrough Time (min)	Price (Bath)	Advantage	Disadvantage
Best Viton®	890 	n-Hexane	> 480	≈4,500	-Specialty Glove, organic solvents -Low surface tension repels most liquids -Good resistance to cuts and abrasions - Low surface	-Extremely expensive -Poor physical properties -Poor vs. some ketones, esters, amines
		Benzene	> 480			
		Ethylbenzene	> 480			
Best® Neoprene	6780 	n-Hexane	173	≈ 150	-Medium cost -Medium chemical resistance -Medium physical properties	Easier to cut and puncture
		Benzene	15			
		Ethylbenzene	31			

2.6.1 Nitrile Nitro-Flex Glove (32, 34)

The first type of gloves is Ansell Nitrile Sol-vex, which was currently used by the factory, made from Nitrile. Its qualifications are highly flexible, scratch resistance and non-swell when contact with chemical as well. It is recommended to use in petroleum industry, transportation, cleaning, greasing, and maintenance. The study results of Thinner on Nitrile gloves as follows breakthrough time of Benzene and Ethyl benzene is less than 1 hour .However, it shown that breakthrough time of n-Hexane is more than 8 hours.

Figure 2.2 Nitrile Nitro flex Glove

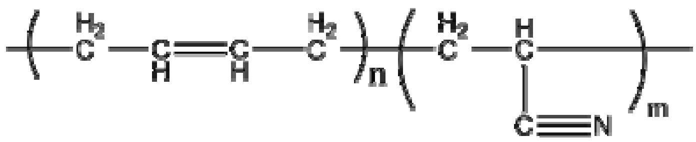


Figure 2.3 Chemical structure of Nitrile Butadiene Rubber

2.6.2 Ansell Barrier Glove (32)

The second gloves, which the researcher selected, is Barrier. It consists of 5 layers of film with highly flexible, good chemical resistance as well as seaming by high technology. This gloves is recommend to use in petroleum industry, planting, transportation, chemicals management; organic substances, acids, bases and ketones, process photographs, and photograph printing. The study results of pure chemical on this gloves shown that breakthrough time is more than 8 hours. However, it shown that breakthrough time of each chemical - n-Hexane, Benzene and Ethyl benzene– is more than 8 hours. So, the researcher selects this type of gloves to test for studying the result.

Figure 2.4 Ansell Barrier™ Glove

2.7 Polymer characteristics and permeation process

2.7.1 Permeation Process

Historically, permeation has been regarded as a three stage process (see Figure 2-5). First, the permeant dissolves into the membrane, then it diffuses across the membrane; finally it evaporates from the opposite. In effect, permeation is mainly a function of solubility and diffusivity through the polymer, while evaporation plays a small role (35).

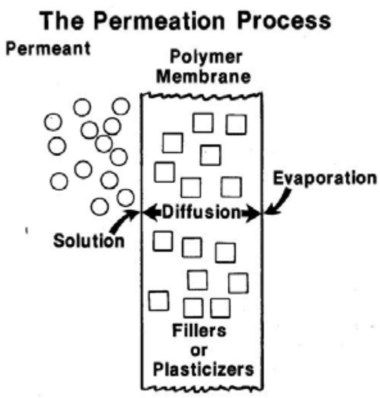


Figure 2.5 Three step of Permeation process.

Several things can occur to alter this physical process. These include the chemical reaction or molecular interactions of the permeate with the polymer or plasticizers and other non-polymer additives which may be add to the polymer to make it more elastic or economical. The solubility step is dependents upon the molecular interactions between chemical and polymer, and it may be the most important in the permeation process. Furthermore, the diffusing step can be altered from a straightforward Fickian behavior by permeant-polymer interactions (so-called non-Fickiandiffustion). Hence, these molecular interactions may be most important in the permeation process. They may also be the key to predicting breakthrough times, permeation rates or other permeation parameters.

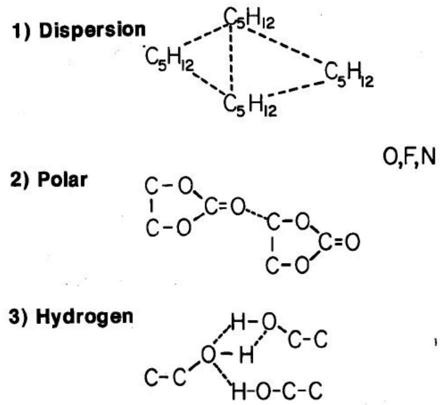


Figure 2.6 Three type of molecular interaction exemplified by Pentane (Dispersion), Ethylene Carbonate (Polar) and Ethanol (hydrogen bonding).

During the 1950s and 1960s chemists began relating these molecular interactions to the solubility concept. Their basic premise was that “like dissolves like,” so a polymer (or resin of the polymer) with molecular interactions similar to those of given permeant should ne soluble in that permeant. The nature of these molecular interactions was the key to predicting solubility’s.

In 1967, Hansen proposed that the solubility parameter for any compound (*i.e.,* the square root of the sum of forces that hold the molecules together, also known as total cohesive energy) is composed of four parameters. He considered three of these to be most important. These are shown in an approximate manner in Figure2. The first component is the dispersion force (D) caused by rapid fluctuations in the temporary dipole moments of a non-polar molecule. It occurs due to a slight polar charge around a molecule, whose location fluctuates depending on the center of the negative charge caused by the electron cloud. This is the only force contributing to the solubility parameter for a saturated, non-polar hydrocarbon such as pentane. The second force (P) is due to permanent dipoles of polar molecules such as water and often attributed to exposed oxygen, fluorine or nitrogen atoms as shown in Figure2 for ethylene carbonate. The third force (H) is due to hydrogen protons and unshared electrons of another molecule. This force also occurs in polar compounds such as water; however, the presence of dipole forces does not necessarily yield hydrogen bonding forces of a given magnitude or vice versa. Figure2-6 shows an example of hydrogen bonding for ethanol (36).

Table 2.2 Type and force of molecular interaction.

type	**Force (Kcal/mol)**
Dispersion	0.05-40
dipole – dipole force	5-25
hydrogen bond , H – bond	10-40

Hansen made thousands of observations and calculations to ascertain values of these three parameters for hundreds of solvents. Their relationship to the overall solubility parameter (S) or total cohesive force is as follows (37).

$S^2 = D^2 + P^2 + H^2$

The total cohesive force or square of the solubility parameter is the sum of squares of these three forces and quantifies (calories / cc) the energy holding the molecules together. The three-dimensional vector with coordinates (D, P, H).

2.8 Permeation performance test method

The resistance of a protective clothing fabric to permeation by a potentially hazardous chemical is determined by measuring the breakthrough time and the permeation rate of the chemical through the fabric. Permeation tests have been conducted following the ASTMF739, EN374-3 or ISO 6529

- American Society for Testing and Materials (ASTM) method has been established for permeation testing (ASTM F739-91), This test method measures the permeation of liquids and gases through protective clothing materials under the condition of continuous contact. The average elapsed time between initial contact of the chemical with the outside surface of the fabric and the time at which the chemical is detected at the inside surface of the fabric at a permeation rate of 0.1 µg/cm2·min (38).

- European Community for Standardization (CEN) Test Method EN-374-3, Protective glove against chemicals and microorganism Part 3 : Determination of Resistance to Permeation by Chemicals. Resistance to permeation is assessed by measuring the time for a chemical to breakthrough the glove material. Samples, cut from the palms of gloves, are placed in a permeation cell which enables the chemical to be placed in contact with the outer surface of the gloves. Collection air or water is passed through the cell to collect any chemical that has broken through to the inside surface of the glove sample. The average elapsed time between initial contact of the chemical with the outside surface of the fabric and the time a twhich the chemical is detected at the inside surface of the fabric at a permeation rate of 1 µg/cm2·min (39).

- International Standard Organization (ISO) Test Method ISO 6529, Protective Clothing --Protection Against Chemicals -- Determination of Resistance of Protective Clothing Material to Permeation by Liquids and Gases

Method A is applicable to the testing of liquid chemicals, either volatile or soluble in water, expected to be in continuous contact with the protective clothing material

Method B is applicable to the testing of gaseous chemicals expect to be in continuous contact with the protective clothing material

Method C is applicable to the testing of liquid chemicals, either volatile or soluble in water, expected to be in intermittent contact with the protective clothing material

The average elapsed time between initial contact of the chemical with the outside surface of the fabric and the time at which the chemical is detected at the inside surface of the fabric at a permeation rate of 1 µg/cm2·min. or0.1 µg/cm2·min (40).

Table 2.3 Difference amount permeation test method.

Test Method	**Chemicals Permitted**	**Typical Control**	**Collection Medium Flow rate (ml/min)**	**Minimum Test Sensitivity (µg/cm^2/min)**	**Test Results Reported**
ASTM F 739-91	Liquids and Gases	Continuous	50-150	0.1	- Breakthrough Time - Permeation Rate
EN 374-3	Liquids and Gases	Continuous	50-150	1.0	- Breakthrough Time have six class - Permeation Rate
ISO 6529	Liquids and Gases	Continuous or intermittent	50-150	1.0หรือ 0.1	- Breakthrough Time - Permeation Rate

The Permeation Test Cell for ASTM F-739 was developed through a voluntary consensus process by ASTM Committee F-23 on Protective Clothing. This cell is used worldwide to determine the permeation of hazardous chemicals through protective clothing (41).

This test involves placing a disc of glove material in a standardized test cell. The challenge chemical is placed in one side of the cell against the test specimen, and the downstream side is monitored on a continuous or repeating basis for the presence of the challenge chemical. The collection medium is typically nitrogen, air, or water (42).

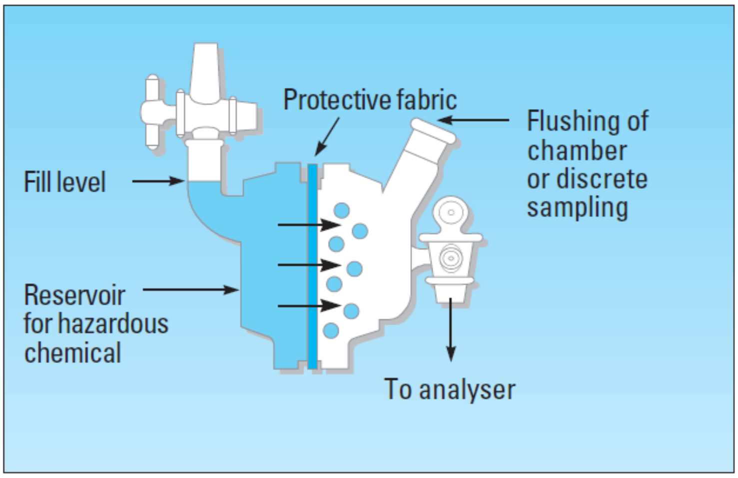


Figure 2.7 ASTM Permeation Test Cell

The time at which the challenge chemical is first detected downstream of the test specimen is called the "breakthrough time". Once the chemical has broken through the glove material, the rate at which the chemical passes through the material is determined. This number is called the permeation rate and is expressed in mass of permeated chemical per area of glove material per unit of time, usually µg/cm^2/min

Permeation tests are usually conducted for a maximum of eight hours. If no breakthrough is observed in this time period, it is reported as a breakthrough time greater than (>) 480 minutes and no permeation rate is listed does not mean there was not permeation; it mean that permeation rate did not exceed 0.1 µg/cm2·min (ASTM), 1 µg/cm2·min(EU) and ISO (43).

2.9 Analysis method for Solvent

Analysis method for solvent mixture (n-Hexane, Benzene, Ethyl benzene) is conducted by gas chromatography using flame ionization detector (GC-FID) that is fully validated and is described in NIOSH method (45).

2.9.1 Gas Chromatography (GC)

Gas chromatography is a chromatographic technique that can be used to separate organic compounds that are volatile. A gas chromatograph consists of a flowing mobile phase, an injection port, a separation column containing the stationary phase, a detector, and a data recording system. The organic compounds are separated due to differences in their partitioning behavior between the mobile gas phase and the stationary phase in the column (46, 47).

Mobile phases are generally inert gases such as helium, argon, or nitrogen. The injection port consists of a rubber septum through which a syringe needle is inserted to inject the sample. The injection port is maintained at a higher temperature than the boiling point of the least volatile component in the sample mixture. Since the partitioning behavior is dependant on temperature, the separation column is usually contained in a thermostat-controlled oven. Separating components with a wide range of boiling points is accomplished by starting at a low oven temperature and increasing the temperature over time to elute the high-boiling point components. Most columns contain a liquid stationary phase on a solid support. Separation of low-molecular weight gases is accomplished with solid adsorbents. Separate documents describe some specific GC Columns and GC Detectors.

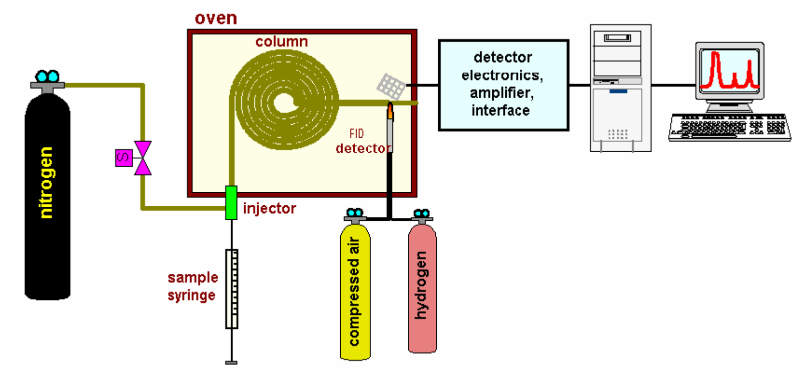


Figure 2.8 Gas chromatograph diagram.

2.9.2 Flame Ionization Detector (FID)

Flame ionization detector is the most common type of detector used in GC. In flame ionization detector Hydrogen (H2) and Oxygen (O2) are present in the gas form. This will create a flame. The components that are eluting out will burn by the flame and will turn into ions. The formation of ions will ultimately create an electrical current. Electrical current depends on the components present in the sample. The following reaction will occur in order to form the electrical current.

The detector is very sensitive towards organic molecules (10^{-12} g/s, linear range: 10^6 –10^7), but relative insensitive to a few small molecules e.g. N_2, NO_x, H_2S, CO, CO_2, H_2O. If proper amounts of hydrogen/air are mixed, the combustion does not afford any ions. If other components are introduced that contain carbon atoms cations are produced in the effluent stream. The more carbon atoms are in the molecule, the more fragments are formed and the more sensitive the detector is for this compound (--> response factor). However, due to the fact that the sample is burnt (pyrolysis), this technique is not suitable for preparative GC. In addition, several gases are usually required to operate a FID: hydrogen, oxygen (compressed air), and carrier gas (48).

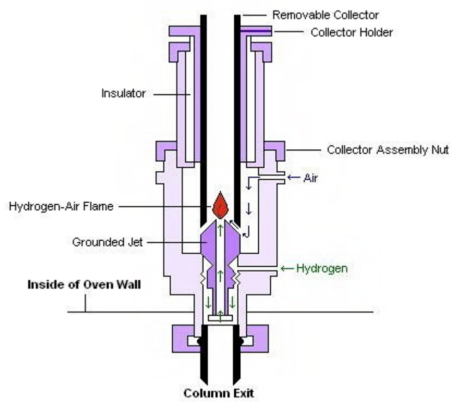


Figure 2.9 Flame Ionization Detector

2.10 Solvent in Printing Industry

Solvent, is a sort of chemicals, which can dilute the other chemicals for being severally useful that depends on what kind of tasks. The proportion of any solvent will be changed when it is used in the different task. Normally, the state of solvent is liquid, which would be harmful or not. Although most of solvents are harmful they are always extensively used in many industries because it is so useful– in the process of cleaning, dry-cleaning, wiping lipid stain in electronics industrial, being additives in polymer production such as glue or coating material. Additionally, there is a kind of solvents, which is non-harmful, in the human's body, it can dilute and conduct the nutrition molecule, which is necessary against to human living, to the other cells thorough out the body, besides, as well as diluting and conducting waste from cells out of the body, the mentioned solvent is water. Most of the solvents in many manufacturing are harmful because of its qualification such as inflammable and harmful to human's health as well.

According to how to work with any solvents, most workers might have closely contacted the solvents - washing devices, cleaning stain and spraying. When the mixture solvent contact skin, it will be absorbed in lipid layer- that is a cause of skin crack, irritation and burn- as well as reach to blood circulation. So, worker who maybe expose to any solvents, is supposed to wear the chemical protective gloves for avoiding harm which can be occurred by contacting the solvent (49).

About the publishing industries, solvent is usually used in mixing colors and cleaning color printing machine process. However, the workers would expose to the solvent from cleaning color printing machine process because the worker have to pour solvent in rag before cleaning the machine. Components of the solvent are n-Hexane, Benzene and Ethyl benzene (50).

The first production process of publishing manufacturing is taking order from the customers what kind of products they want; printing on paper, label, box, sticker or the other products. Then, designing process– what the pattern and color it is. The third is printing –put pieces of paper in printing machine and fill the color as the customer's request. After that, goes to coating, cutting or pressing process as the request. The quality controlling process – finished good was randomly checked as per the standard. Finally, packaging process is the last one. However, the process which worker mostly exposes to the solvent is cleaning printing machine. After finishing printing process, the worker would wipe the machine by using solvent, which consist of n-Hexane, Benzene, Ethyl benzene. So, cleaning printing machine process maybe a cause of harm from exposing to chemical.

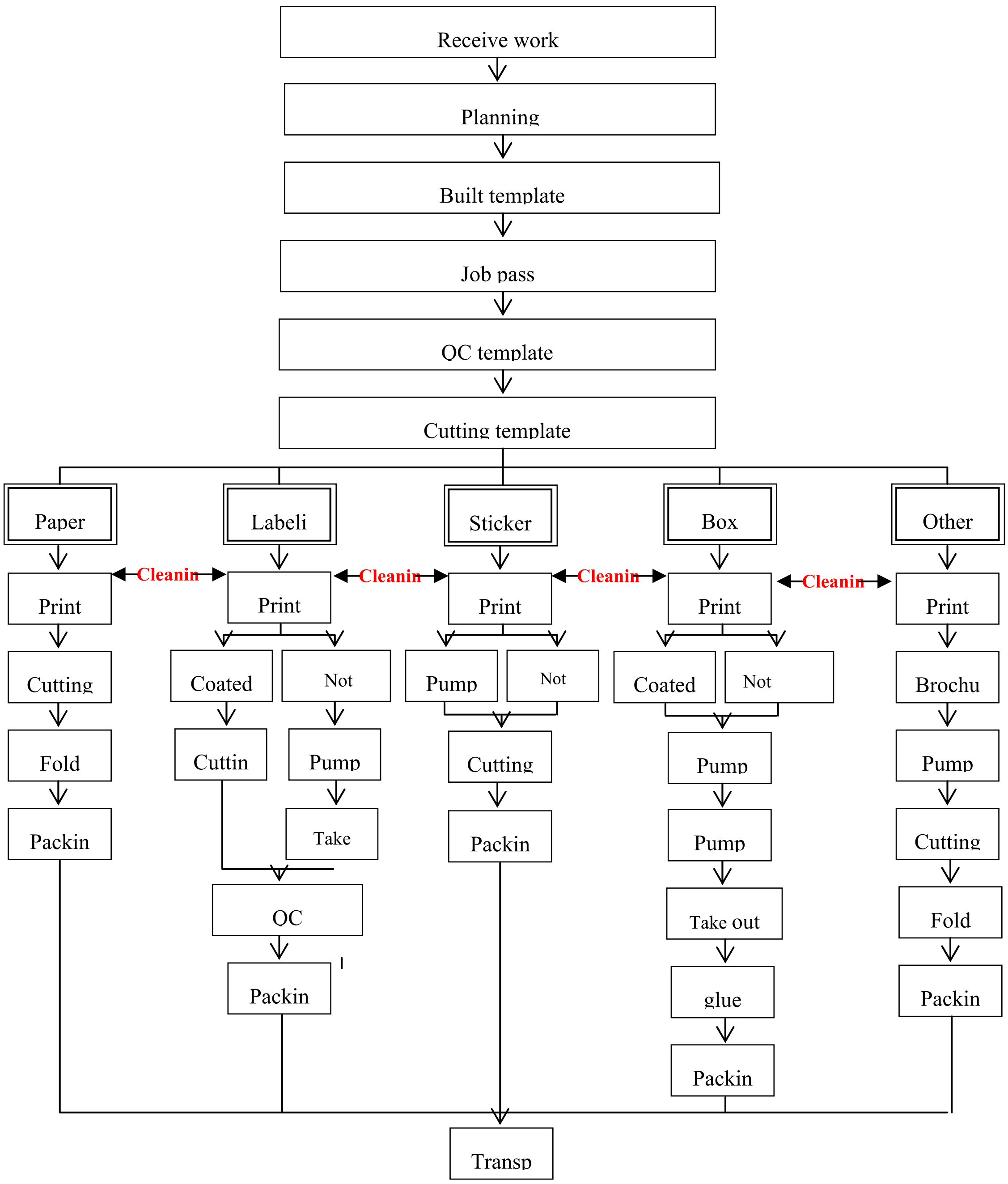


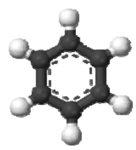
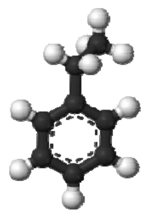
Figure 2.10 Process flow of publishing manufacturing.

2.11 Skin hazard caused by Solvent

The publishing manufacturing uses the solvent which consist of n-Hexane, Benzene, Ethyl benzene in cleaning printing machine process. These chemicals can be absorbed to the body by inhalation, ingestion, eyes and skin contacting.

In case of cleaning printing machine process, skin is mostly contact to solvent. Generally, the worker would clean the machine 5-15 minutes per time, and 4-6 times per day. So maximum amount of solvent contacting period is 2 hours per day. There are harms of the different compounds in solvent as follows; (51, 52)

Table 2.4 physical and skin hazard information for chemical.

Detail	**Chemicals**		
	n-Hexane	**Benzene**	**Ethyl benzene**
1.Molecular Formula	C_6H_{14}	C_6H_6	C_8H_{10}
2. Structure			
3.Group of Chemical	Alkane	Aromatic Hydrocarbon	Aromatic Hydrocarbon
4.LD_{50} Rabbit Skin	2,000 mg/kg	> 8260 mg/kg	15,354 mg/kg
5.Symptom of skin contacting	Acute: Irritation, Rash Chronic: Dermatitis	Acute: Burn Chronic: Rash, Skin Inflammable, Leukemia	Acute: Irritation Chronic: Skin Inflammable
6. Notation	Can be absorbed to skin.	Can be absorbed to skin.	-
7. Hazard Designation (ACGIH)	-	Confirmed human carcinogen	Confirmed animal carcinogen

2.12 Literature cited

In2002 T.D.Klingner and M.F.Boeniger were studied chemical-resistant gloves and clothing is the primary method used to prevent skin exposure to toxic chemicals in the workplace. The process for selecting gloves is usually based on manufacturers' laboratory-generated chemical permeation data. However, such data may not reflect conditions in the workplace where many variables are encountered (e.g., elevated temperature, flexing, pressure, and product variation between suppliers). Thus, the reliance on this selection process is questionable. Variables that may influence the performance of chemical-resistant gloves are identified and discussed. Passive dermal monitoring is recommended to evaluate glove performance under actual-use conditions and can bridge the gap between laboratory data and real-world performance (53).

In1997 Jimmy L. Perkins and Kim C. Rainey were studied to selection of gloves and other articles of chemical protective clothing(CPC) based on their performance against chemical permeation is the most common approach to the control of skin permeation of toxicants. However, there are several factors that can affect the efficacy of CPC which are not considered in the typical permeation test. These include temperature variations, intermittent use and reuse, thickness variations, and tool use. In this article the effects of hand flexure on permeation parameters are reported. Polyvinylchloride (PVC) or neoprene gloves were exposed to heptane or acetone and a human hand provided the flexing motion at average rates of about 30 or 50 flexes per minute for periods of up to 2 hours. A static or no flex condition was also tested as baseline. Permeation was assayed through weight loss by weighing together the test system (gloves and test cell) at periodic intervals. Results showed an effect of flex on permeation parameters for both polymers. While there was a statistically significant difference in both of the flex results (low or high) versus the no flex condition, there was no difference in the two flex levels. However, for the PVC system there was a clear trend of increasing permeation from no to low to high flex results. It is concluded that glove flexing does affect permeation behavior; however, the flexing conditions used in this experiment probably represent a near worst-cases scenario for these effects (54).

In 2010 Keh-Ping Chao et al were studied N,N-dimethyl for mamide (DMF) and methyl ethylketone (MEK) are the hazardous chemicals commonly used in the synthetic leather industries. Although chemical protective gloves provide adequate skin exposure protection to workers in these industries, there is currently no clear guideline or understanding with regard to the use duration of these gloves. In this study, the permeation of DMF/MEK mixture through neoprene gloves and the desorption of chemicals from contaminated gloves were conducted using the ASTM F739 cell. The acceptable use duration time of the gloves against DMF/MEK permeation was estimated by assuming a critical body burden of chemical exposure as a result of dermal absorption. In a re-exposure cycle of 5 days, decontamination of the gloves by aeration at 25 °C was found to be inadequate in a reduction of breakthrough time as compared to a new unexposed glove. However, decontamination of the gloves by heating at 70 or100 °C showed that the protective coefficient of the exposed gloves had similar levels of resistance to DMF/MEK as that of new gloves. Implications of this study include an understanding of the use duration of neoprene gloves and proper decontamination of chemical protective gloves for reuse (55).

In 1986, R.L. Mickelsen, M.M. Roder and S.P. Berardinelli were evaluation of glove materials against three different binary chemical mixtures selected from common industrial solvents was conducted. Changes in breakthrough time and permeation rate of the mixture components were evaluated as a function of the mixture composition. An increase in employee risk resulting from early mixture breakthrough time and enhanced mixture permeation rate over that of the pure chemicals was demonstrated. The permeation of a binary mixture through chemical protective clothing could not be predicted by the permeation results of the pure components. It is recommended that chemical protective clothing be tested for its permeation characteristics with the use of the chemical mixtures and conditions that reflect the work site exposure (56).

In 2008, Keh-Ping Chao, Ya-Ping Hsu and Su-Yi Chen were studied permeation of binary and ternary mixtures of benzene, toluene, ethyl benzene and *p*-xylene through nitrile gloves were investigated using the ASTM F739 test cell. The more slowly permeating component of a mixture was accelerated to have a shorter breakthrough time than its pure form. The larger differences in solubility parameter between a solvent mixture and glove resulted in a lower permeation rate. Solubility parameter theory provides a potential approach to interpret the changes of permeation properties for BTEX mixtures through nitrile gloves. Using a one-dimensional diffusion model based on Fick's law, the permeation concentrations of ASTM F739 experiments were appropriately simulated by the estimated diffusion coefficient and solubility. This study will be a fundamental work for the risk assessment of the potential dermal exposure of workers wearing protective gloves (57).

In 2002, Ge´rald Perron was to study the chemical resistance of commercial protective membranes to mixed solvents. All the techniques used gave comparable results, but the swelling experiment, based on the elongation of a polymeric strip over time, is probably the simplest way of estimating the resistance of various membranes to pure solvents or solvent mixtures. For most systems examined, the observed deviations from additive for the mixtures, based on the data for the pure solvents on a mol fraction scale, follow three simple rules: (1) The observed trends for *t*BT are opposite those for SSPR and SR, showing that all these properties are related to the diffusion in the membrane, (2) the sign of the deviation from additive of the thermodynamic parameters of the pure liquids in the mixture is independent of the nature of the three membranes, provided that the membranes are not degraded by one of the solvents, and (3) the sign and magnitude of the trends are largely related to the enthalpy of mixing of the liquids. The results of this study suggest that solvent–solvent interactions play a leading role in the deviations from additive in chemical mixtures (58).

CHAPTER III
MATERIALS AND METHOD

Based on research question and literature review in chapter 1 and 2, the research method is designed in order to answer the question. The study method comprises 2main parts, which are field work and lab work. The topics of both parts which will be cover under this chapter are as follow**s:**

Part I Field work

3.1 Study Design.
3.2 Studied Work.
3.3 Glove Selection.
3.4 Studied mixture chemical.
3.5 Sample size.
3.6 Field Study method.

Part II Lab work

3.7 Physical analysis of the gloves and sample preparation for lab analysis.
3.8 Lab study method.
3.9 Equipment, material and reagents.
3.10 Quality control.
3.11 Data analysis.

3.1 Study design

This is operational and experimental research, which is designed to compare the permeation performance of the chemical mixture, composed of n-hexane, benzene and ethylbenzene, through new and reused gloves. Nitrile gloves and barrier gloves were selected for the study which are conducted in a cleaning printing machine process. During the days the workers will be observed while they are working and some data which may affect the chemicals permeation are collected. Such data are the number of used day, number of contact, and exposure duration with the gloves. The gloves will be collected according to the specified time table. They will be checked to see any physical change which may be appear after expose to chemicals. Then the glove will be cut at the palm to test according to the permeation test compliant to ASTM F 739-91 standard. The air flow through the test cell will be subsequently analyzed using GC-FID technique (Gas Chromatography Flame Ionization Detector). The results of this study are comparing breakthrough time and permeation rate of nitrile with barrier gloves; both new and repeated used gloves. In addition, it would be compared the permeation test of pure chemical which was done by the manufacturer as per ASTM F 739-91 standard, with mixture which would be done as per the same standard in this study. This study was reviewed and approved by the Ethics Review Committee for Human Research of Faculty of Public Health, Mahidol University (MUPH 2012-193).

3.2 Studied work.

The studied site is a publishing manufacturing and kind of products printing on paper, label, box, sticker or the other products. The first production process is taking order and then, designing process. The third is printing –put pieces of paper in printing machine and fill the color as the customer's request. After that, goes to coating, cutting or pressing process. Finally quality controlling and packing. The samples will be collected in the printing section. There are 5 workers in the section.

Three workers work with the bigger printing machines which are used for printing the big stuff with a great number of them. Another 2 workers work with the smaller printing machines which are used for printing the small stuff with a little number of them but many times per day. However, All of them do the same work, including preparation of the printing machine and fill up the color into the machines. After finish printing, they would clean the printing machine by pouring mixture solvent onto a rag then wipe on the machine. They usually wear nitrile gloves while cleaning the machine. Each pair of gloves was used around 5 days. About 4-6 times per day and 10-15 minutes per time. Therefore the workers have exposure the chemical approximately 2 hours a day.

3.3 Glove selection

The gloves will be selected based on the permeation performance information provided by the manufacturer. Most of the manufacturers have tested the permeability of only pure chemical, but have not tested the permeability of the mixture. Nonetheless, this study interested in testing of the permeation of chemical mixture of n-hexane, benzene and ethyl benzene, therefore the gloves with the long breakthrough time for all three chemicals will be selected for study. Barrier is meet this requirement and easy to wear, flexible and fit in mid-range price. Another kind of glove that is selected is nitrile glove which is currently used in the factory. The data was conducted by the manufacturer shown that breakthrough time of benzene and ethylbenzene through nitrile gloves is less than 1 hour and breakthrough time of n-hexane is more than 8 hours. (Table 3.1)

Table 3.1 Breakthrough time of chemical mixture for nitrile and barrier gloves.

Glove Material	**Breakthrough Time (minute)**		
	n-Hexane	**Benzene**	**Ethyl benzene**
Nitrile	>480	16	43
Barrier	>480	>480	>480

3.4 Studied mixture chemical

The solvent mixture which is used in cleaning printing machines process of publishing industry will be studied. The mixture is Shellsol 60/145. The proportions of the chemicals in the mixture are shown in Table3.2.

Table 3.2 Chemical component.

Chemical Component	Concentrations (%)
n-Hexane	10-30
Benzene	≤ 0.25
Ethyl benzene	≥ 0.10 - ≤0.30

3.5 Sample size

Number of samples is calculated under considering the breakthrough time of benzene through barrier gloves obtained from Ansell occupational healthcare. Nitrile gloves which were tested with benzene, had breakthrough time of 14 minutes and standard deviation(σ_1) of 2.7 (57) and breakthrough time of benzene in solvent mixture is 34 minutes and standard deviation (σ_2) is 8.9 (57). These data are used to calculate the sample size of each group, the selected power of test is 80%, so the probability of error is only 5%. Sample size calculation based on formula for comparing tux group means.

$$n/group = \left[\frac{(Z_\alpha+Z_\beta)(\sigma_1^2+\sigma_2^2)}{\mu_1-\mu_2}\right]$$

When σ = Average standard deviation= $(\sigma_1^2+\sigma_2^2) = (2.7^2+9.2^2)$

= 86.5

$\mu_1-\mu_2$ = Difference of average breakthrough time of the two type gloves = 50

α = 0.05, Z_α = 1.96

$1-\beta$ = 0.80, Z_β = 0.84

Hence;

$$n/group = \left[\frac{(1.96+0.84)(91.93)}{50}\right]$$

$$= 4.84 \approx 5$$

With the power of test at least 80% and the probability of error in the conclusion that the compared sets of gloves are different is not more than 5%, 5 samples are required for each type and each set of gloves. Therefore nitrile gloves was collected at least 10 samples from 5 unused gloves and 5 used gloves and barrier gloves was collected at least 10 samples from 5 unused gloves and 5 used gloves, amount of samples is 20 which are the minimum amount of collecting samples. If gloves are able to prevent the permeation of a chemical for more than 4 hours, which is the duration of cleaning task, the gloves will be collected as sample after 1-day using, 2-day using till 5-day using or the gloves are reduced protection ability of chemical permeation less than 4 hours or the gloves are damaged, it will be stopped collecting. Therefore the number of samples is 60.

Table 3.3 Sample size.

Type of gloves	**Number of Samples**					
	Unused gloves	**Used gloves for 1 day**	**Used gloves for 2 days**	**Used gloves for 3 days**	**Used gloves for 4 days**	**Used gloves for 5 days**
Nitrile	5	5	5	5	5	5
Barrier	5	5	5	5	5	5
Total	10	10	10	10	10	10
Grand Total	60					

3.6 Field study method

The objectives and method of the study focusing on those related to the workers such as use and care and storage of the gloves, data collection from the workers, etc.

3.6.1 Orientation and training the workers.

In order to receive the good cooperative from the workers, the researcher will give the orientation and training to all workers before the study start. The following issues will be informed and trained the workers and the time will be spared for any questions they may have at the end of the training.

3.6.1.1 How to select the gloves size to fit each worker's hands.

3.6.1.2 How to inspect the gloves before each use. If there is any damage, the gloves should be changed a new one and bring the old one to the researcher.

3.6.1.3 How to fill in the data in the form.

- The data such as exposure duration were collected in order to analyze to see the contribution to the permeation though the gloves.
- These factors will be recorded everyday by the workers in a form developed by the researcher (Appendix C).
- The researchers will randomly check the records 1-2 days per week to ensure that the data are recorded and done correctly.

3.6.1.4 How to clean the gloves after each use at the end of the shift using the following steps:

- Turn the faucet onto flow water over the gloves' surface. Then put the detergent on gloves to clean it.
- Polish around the palms, fingers as well as the area between them.
- Place the right hand over the left hand to polish and then switch to do the other.
- Turn the faucet onto flow water through the gloves again, and then air it to be dry in a good ventilated area.

3.6.2 Appearance of gloves

The physical conditions and appearance of gloves emphasized on color, texture, and weight would be observed and recorded. Such observation would be conducted before giving them to the workers and do the same one more time when collect them from the workers using the form in the appendix D.

3.6.3 Sample storage

Each set of gloves will be collected according to Table 3-4 on the next morning as the samples. The clean and dry samples will be kept in a zip lock bag and stored in a box to avoid the sunlight during storage. They will be immediately analyzed in the laboratory in the next day or as soon as possible.

3.6.4 Sample collection

The gloves will be collected from the workers as the following detail.

3.6.4.1 The first set of gloves would be used for 1 day and the worker would clean and dry at the end of the work shift. There searcher would collect the gloves on the next day for analyze in the laboratory. If breakthrough time that all component is still greater than 480 minutes, the study will continue to the 2nd set for that kind of glove.

3.6.4.2 The second set of gloves would be given to the worker to use for 2days. The worker must daily clean and dry them everyday after use. Then the researcher would collect them to analyze in the laboratory. If breakthrough time that all component is still greater than480 minutes, the study will continue to the 3rd set for that kind of glove.

3.6.4.3 The third set of gloves would be given to the worker to use for 3 days. The worker would daily clean and dry it them everyday after use. Then the researcher collects them to analyze in the laboratory. If breakthrough time that all component is still greater than 4hours, the study will continue to the 4th set for that kind of glove. The fourth set of gloves would be given to the worker to use for 4 days. The worker would daily clean and dry it them everyday after use. Then the researcher collects them to analyze in the laboratory. If breakthrough time that all component is still greater than 480 minutes, the study will continue to the 5th set for that kind of glove until it would be found that breakthrough time of each component is less than 480 minutes, or the gloves are damaged, then the test would be stopped. These can be summarized as in the Table 3-4.

Table 3.4 Sampling nitrile and barrier gloves.

Set 1	**Set 2**	**Set 3**	**Set 4**	**Set 5**
1 used day ↓ Collected for analysis. (BT of all compounds> 4 hours).	2used days ↓ Collected for analysis. (BT of all compounds> 4 hours).	3 used days ↓ Collected for analysis. (BT of all compounds> 4 hours).	4 used days ↓ Collected for analysis. (BT of all compounds> 4 hours).	5 used days ↓ Collected for analysis.

3.7 Physical analysis of the gloves and sample preparation for lab analysis

The gloves would be brought to the lab and visually checked the general condition i.e. color, texture and swollen. Any changes on the gloves would be recorded in the form. Weight of gloves would be checked by weighing using electronic weight, Mettler Toledo brand. And then the gloves will be cut at the palm into circle shape with the diameter of 60 mm, in order to prepare the sample for permeation test.

3.8 Lab study method

The study could be divided into five part, i.e. Permeation test cell, GC-FID condition, detector range and sensitivity of GC, calibration and standardization and sampling analysis.

3.8.1 Permeation test

Permeation test cell is equipment used in the permeation test of ASTM standard F739-91the cell’s body are made of stainless steel which is resistant to corrosive chemical and do not react with the tested chemicals. The diameter of cell is 51 mm (2.0 in).The cell consist of 2 part, the first part is for fill the test chemical, its size is 22 mm (0.85in) in length. The second part is for fill the collection medium, its size is 35mm (1.4in) in length. Both compartments have sealing gasket to prevent the test chemical leakage – it is made of Teflon in addition there is O-ring rubber for seaming.

Figure 3.1 Permeation test cell

3.8.2 GC-FID condition

GC-FID (Gas Chromatography, Flame Ionization Detector) was used to analyze the amount of chemicals that permeate through the glove. The GC-FID which is used for chemical analysis (n-hexane, benzene and ethylbenzene) has nitrogen. The GC condition set for the analysis as the following.

Detector		Flame Ionization Detector.
Oven;		
	Initial temp	80 °c
	Maximum temp.	240 °c.
	Runtime	15 min.
Black inlet;		
	Injector port temp.	200 °c.
	Pressure	7.52 psi.
	Total flow	13.3 mL/min

Colum;

	Capillary Column	Agilent 19091F-115 HP-FFAP Polyethylene Glycol TPA (320 µm × 50 m)
	Max temp.	240 °c.

Front Detector;

	Temp.	250 °c. (on)
	Hydrogen flow	40 ml/min (on)
	Air Flow	450 ml/min (on)
	Mode	Constant makeup flow.
	Makeup Gas Type	Nitrogen.
	Flame	On.
	Electrometer	On.

Nitrogen gas flow	50 cm^3/min (According to the ASTM F739 Standard)
Injector volume.	1 ml.

3.8.3 Detector range and sensitivity

According to the breakthrough time (BTT) was determined for the elapsed time which GC-FID must be able to detect at 0.1 µg/cm^2/min. The concentration is converted from the permeation rate at 0.1 µg/cm^2/min to µl for into the Tedlar bag as explained in section 3.8.3.1.

3.8.3.1 Calculation for n-hexane, benzene and ethylbenzene Volume

Calculation to volume of n-hexane, benzene and ethylbenzene to be into the Tedlar bag to get concentration or mass equal to the permeation rate of 0.1 µg/cm^2/min according to ASTM F739-91 method, the permeation rate was P (µg/cm^2/min) of each solvent was calculated as follows:

$$P = \frac{C \times F}{A}$$

P = Permeation rate (μg/cm^2/min)

C = Concentration of the test chemical in collection medium, μg/l

F = Flow rate of collection medium through the cell, l/min

A = Area of the gloves sample contacted, cm^2 In this study The following values are used

P = 0.1 μg/cm^2/min

F = 0.05 l/min (50 cm^2/min)

A = 20.42 cm^2

The amount of the chemical under test in the carrying-gas which is permeation through the gloves at 0.1 μg/cm^2/min for this study is

$$0.1\ \mu g/cm^2/min = \frac{C \times 0.05\ l/min}{20.42\ cm^2}$$

$$C = 40.82\ \mu g/l$$

The test chemical permeated to the gloves at rate 0.1 μg/cm^2/min that can be detected within the carrier gas is equal to 40.82 μg/l

Preparing the mixture which consists of n-hexane, benzene and ethylbenzene for chemical quantification testing of permeation according to ASTM standard is 0.1 μg/cm2/minor 40.84 μg/ l. Then inject in Tedlar bag as 5 L, which is calculated as the formula follows;

$$D = \frac{M}{V}$$

D = Density (g/ml)

M = Mass (g)

V = Volume (ml)

n-Hexane	Benzene	Ethylbenzene
Concentration = 97%	Concentration = 99.5%	Concentration =99.5%
Density (D) = 0.660 g/ml	Density (D) = 0.879 g/ml	Density (D) = 0.876 g/ml

; n-Hexane 100 g. Has mass 97 g.

$$V = \frac{100\ g}{0.66\ g/ml}$$

$$= 151.34\ ml$$

n-Hexane 151.34 ml has mass = 97 g

n-Hexane 151.34 ml × 10^3 µl has mass = 97 × 10^6 µg

$$\text{n-Hexane 1 µl has mas} = \frac{97 \times 10^6\ \mu g}{151.34}$$

$$= 641.96\ \mu g$$

N-hexane 1 µl has mass 641.96 µg. When this is injected into Tedlar bag's size 5 liters, there will be n-hexane has mass 128.39 µg/l. To get required mass of 40.84 µg/l it need to inject 0.32 µl of n-hexane into Tedlar bag.

Benzene 1 µl has mass 874.65 µg. When this is injected into Tedlar bag's size 5 liters, there will be benzene has mass 174.93 µg/l. To get required mass of 40.84 µg/l it need to inject 0.21 µl of benzene into Tedlar bag.

Ethylbenzene 1 µl has mass 862.67 µg. When this is injected into tedlar bag's size 5 liters, there will be ethylbenzene has mass 172.53 µg/l. To get required mass of 40.84 µg/l it need to inject 0.24 µl of ethylbenzene into Tedlar bag.

3.8.3.2 Preparation of n-hexane, benzene and ethylbenzene gas mixture

3.8.3.2.1 Clean 5L Tedlar bag before using by flush the bag with nitrogen gas 3 times. Flush the bag by putting nitrogen gas into Tedlar bag at the flow rate about 2 l/min.

3.8.3.2.2 After cleaning the bag, put nitrogen gas 80% of the bag into Tedlar bag and then inject 0.3 µl of n-hexane using 1-µl micro syringe into the bag. Stored the bag at room temperature with good ventilation for at least 12 hours to achieve will mixed n-hexane in nitrogen.

3.8.3.2.3 Inject 1 ml of the gas in the Tedlar bag into GC-FID.

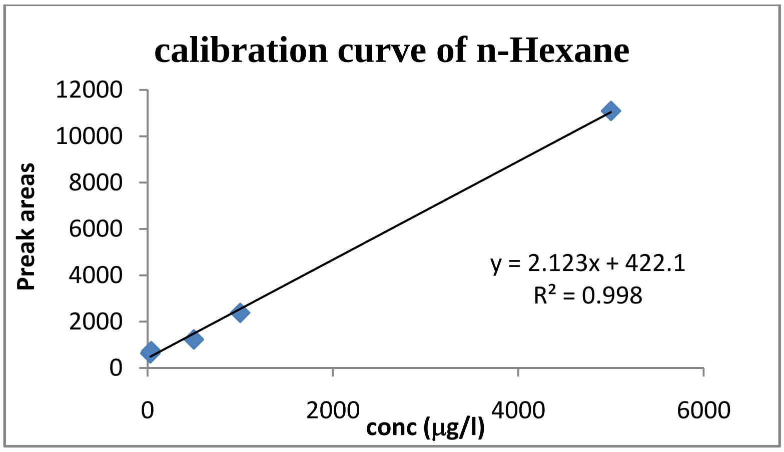
3.8.3.2.4 Do 3.8.3.2.1 to 3.8.3.2.3 steps with benzene and ethylbenzene.

3.8.3.3 Sensitivity test

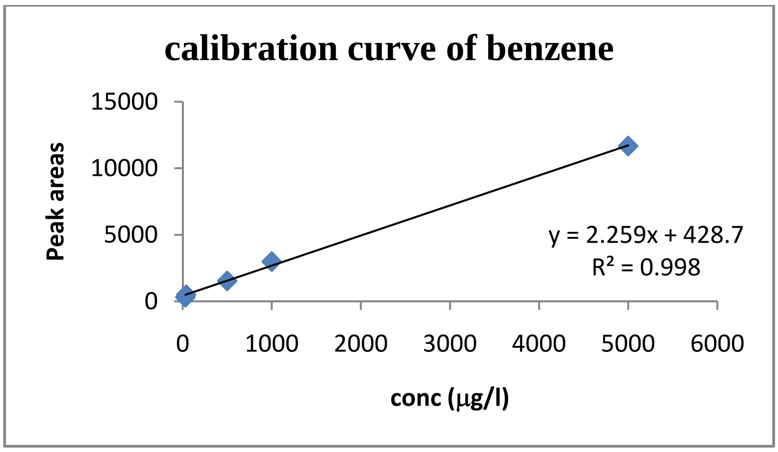
After calculate volume of the mixture (n-hexane, benzene and ethylbenzene) to be into the Tedlar bag to get concentration or mass equal to the permeation rate of 0.1 µg/cm^2/min that found n-hexane need 0.32 µl, benzene need 0.21 µl and ethylbenzene need 0.24 µl into the Tedlar bag for ensured the sensitivity of GC-FID was at least 0.1 µg/cm^2/min therefore the test was conducted by inject 0.14 µl of n-hexane, 0.15 of benzene and 0.18 0f ethylbenzene into the 5 L Tedlar bag. Then inject the air from Tedlar bag into the GC-FID column by using Gas-tight syringes of size 1 ml through the silicone septum in order to verify that the equipment can detect all components (n-hexane, benzene and ethylbenzene). It was found that the GC-FID can detected solvent mixture at the concentration which the chromatogram showed in appendix G that the peak of n-hexane, benzene and ethylbenzene eluted complete within 16 minutes. The peaks of n-hexane was eluted at a retention time of 3.177 minutes, benzene was eluted at a retention time of 5.111 minutes and ethylbenzene was eluted at a retention time of 8.489 minutes.

3.8.4 Calibration curve of n-hexane, benzene and ethylbenzene

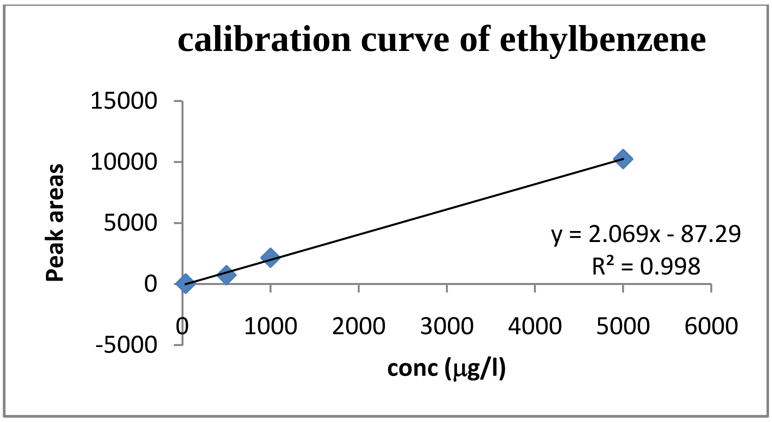
To obtain the calibration curve, the known amount of pure n-hexane, benzene and ethylbenzene was injected into the Tedlar bag (as explained in section 3.8.3.2) to get the concentration of 20-5,000 µg/ml for n-hexane, 25-5,000 µg/ml for benzene and 30-5,000 µg/ml for ethybenzene. Then injected those gas into the GC-FID 3 time for each concentration. The standard curves showed a linearity of the relative peak area against concentrations as shown in Fig 3.2.The correlation coefficient of the curve of n-hexane is 0.9988, benzene is 0.9986 and ethylbenzene is 0.9984. Each chemical concentration calculated from the calibration curve is in µg/l which can be translated into µg/cm^2/min by using the below equation.



(a) n-Hexane; Y = 2.123X + 422.1, R^2 = 0.9988



(b) Benzene; Y = 2.259X + 428.7, R^2 = 0.9986



(c) Ethylbenzene; $Y = 2.069X - 87.29$, $R^2 = 0.9984$

Figure 3.2 The calibration curve of n-hexane, benzene, ethylbenzene

3.8.5 Sampling analysis

The test cell will be prepared and the collection medium will be analyzed and quantified using GC-FID in order to determine breakthrough time and permeation rate as the following;

3.8.5.1 Perform the permeation test on the sample prepared in 3.7, then place it between the challenge chamber, which is containing the solvent and sampling chamber which is containing collection medium, and then close the chamber to be ready for the next step.

3.8.5.2 Connect nitrogen gas tank to the sampling chamber for collect medium of the Permeation Test Cell. Then connect the carrier gas tube of Permeation Test Cell to the injection outlet of the GC.

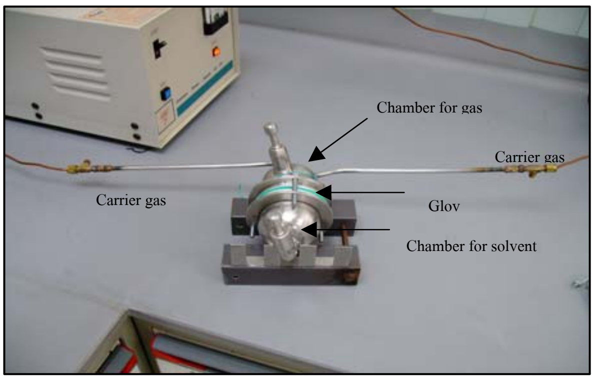


Figure 3.3 Permeation test cell connect to carrier gas and GC

3.8.5.3 Open the valve on the nitrogen gas tank to allow the carrying-gas to flow through the copper tube to permeation test cell and gas chromatography equipment sequentially. Ensure that there is no leakage on all joints by applying soap solution and check that there is no bubble. Adjust the flow rate of the carrying-gas to 0.05 l/min or 50 cm^3/min. The flow will be measured by using the electronic flow meter and the experimental system and associated equipment is shown in Fig. 3.4

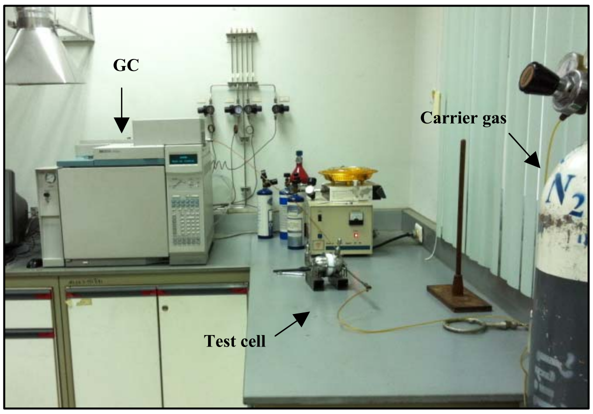


Figure 3.4 Experimental system and associated equipment.

3.8.5.4 Fill the solvent into the challenge chamber of the permeation test cell and close the cover to prevent the chemical from evaporating and then start of timer.

3.8.5.5 Press the start button on the GC to allow the carrier gas to flow through the permeation test cell to the column of the GC for 1 ml of carrier gas were injected using a automatic injector valve and sampling point at 16-minute intervals. Measure the flow rate of the carrier gas using the flow meter periodically. Record the read value from the chromatogram and the amount of chemical under test in the carrier gas according to the ASTM F739-91 standard. The duration at which the chemical under test is detected in the carrier gas at the permeation rate of 0.1 $\mu g/cm^2/min$ is the breakthrough time. It was shown in figure 3.5. Therefore, the time from the chemical under test firstly a contact the gloves till it is detected that the chemical under the test permeates through the gloves to the carrier gas at 40.84 µg/l (3.7.4.1). The test was continue till the amount of the chemical under test in the carrier gas is stable in order to determine the permeation rate. The stable state is determined by reading the same permeation rate for 5 times in consecutive. Record the result data.

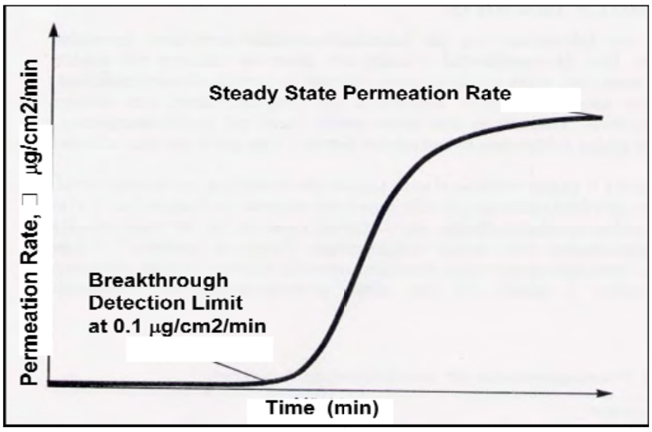


Figure 3.5 Curve of breakthrough time and permeation rate

3.8.5.6 Close the nitrogen gas tank valve. Remove the copper tube for the permeation test cell on both sides of the sampling chamber for collection medium. Remove all the remaining chemicals. Take out the gloves sample. Then, clean and dry the permeation test cell.

3.8.5.7 Repeat the step 3.8.5.1 - 3.8.5.6 for all gloves sample.

3.9 Equipment, material and reagents

3.9.1 Equipment and accessories

3.9.1.1 Permeation Test Cell complying ASTM F739-91 standard.

3.9.1.2 Gas Chromatograph with Flame Ionization Detector (FID) type, model HP 6890 series from Hewlett Packard, serial no.US00006316

3.9.1.3 Electronic weight, Mettler Toledo brand, PB602 class with granularity of 0.01gram.

3.9.1.4 Electronic Flow meter, Hewlett Packard 5182-3494, Serial No. 562939 0-1000 cm^3/min range accurate to ± 1 %

3.9.1.5 Gas regulators.

3.9.1.6 Tedlar bag 5.0 liter, SKC, cat. No. 231-05A

3.9.1.7 Beaker 50, 150 ml

3.9.1.8 Erlenmeyer flask 125 ml

3.9.1.9 Pipette

3.9.1.10 Pipette bulb

3.9.1.11 Micro Syringe 1µl, 1ml (Hamilton, Switzerland)

3.9.1.12 Gas-Tight syringes 1 ml (Hamilton, Switzerland)

3.9.1.13 Liquid leak detector, MS-snoop-8oz, Agilent technologies, Part number: 9300-0311.

3.9.1.14 Record form of exposure time and number of contact.

3.9.1.15 Other accessories such as screw, scissor, carrier gas container etc.

3.9.2 Material and reagents

3.9.2.1 Chemical protective glove

1) Nitrile Glove (Nitro-flex 730, Malaysia) Lot; 34202435

2) Barrier Glove (Ansell 02-100, USA) Lot; 0903002101

3.9.2.2 Solvent Mixture (ShellSol 60/145, Shell company of Thailand)

3.9.2.3 n-Hexane 97%, Dr. Ehrenstorfer GmbH

3.9.2.4 Benzene 99.5 %, Dr. Ehrenstorfer GmbH, CA 10535000 , Lot: 90402

3.9.2.5 Ethylbenzene 99% Dr. Ehrenstorfer GmbH, CA 1332000 , Lot: 90105

3.9.2.6 Nitrogen Gas, High purity grade (99.95%), Thai special gas Co, Ltd.

3.9.2.7 Hydrogen Gas, High purity grade (99.95%), Thai special gas Co, Ltd.

3.9.2.8 Helium Gas, High purity grade (99.95%), Thai special gas Co, Ltd.

3.9.2.9 Distilled water

3.10 Quality control

This study control all samples to be treated similarly. That is the quality control of the sample. The training was provided to the workers; glove using and cleaning (as the section 3.5.1.1), collecting the samples (as the section 3.5.3), collecting data for analysis (as the section 3.5.1.2.)

3.11 Data analysis

The statistical analysis in this research uses SPSS program version 16. The descriptive statistics i.e. mean and standard deviations were used for weight, thickness, breakthrough time and permeation rate. To find out the relationship between breakthrough times and permeation rate with work related factors, the Spearman Rank Test statistic was used.

CHAPTER IV
RESULTS

4.1 Introduction

According to the method mention in the chapter 3, the printing department was surveyed and observed. It was found that there were 5 workers work with printing machines. Three workers work with the bigger printing machines and two another workers work with the smaller printing machines. The routine works during 8-working hour of each day include receiving the job from the designing department, preparing color and printing. The smaller printing machine would be changed the color much more time than the bigger printing machine. After finishing printing, the workers would clean the printing machine. During cleaning the machine, wearing the chemical protective gloves, the workers poured the mixture which is consisted of n-hexane, benzene and ethylbenzene in the container into the machine. The cleaning process could be different according to the position of the parts, i.e. removable and fixed parts.

For the devices which can be taken out of the machine, the worker, after wear the chemical protective gloves, take the devices off and place them on the table. Then take a piece of cloth with their right hand and dip it in the mixture, then wipe the devices by the right hand while the left hand hold the device. After finished cleaning, the worker would assemble the devices to the machine, then take the chemical protective gloves off and hang for using in the next time.

In the process of cleaning the roller which cannot be taken out of the machine, the worker had worn the chemical protective gloves, and then take a piece of cloth with their right hand and dip it in the mixture, then wipe the roller from the right to the left, and the left hand grab the machine. After finished cleaning, the worker would drop that piece of cloth, and then assemble the parts in the machine, then take the chemical protective gloves off and hang for using in the next time. The cleaning would take about 5-15 minutes per time and around 1-10 times per day. The data was shown in section 4.2.1

The gloves were given to the workers and collected for appearance check and lab analysis the results are as the following.

1) Exposure data and physical condition.
2) Permeation test result of the mixture through reused nitrile gloves.
3) Permeation test result of the mixture through reused barrier gloves.
4) Comparison and analysis of test results with those of chemical from the manufacturer's data.
5) Comparison and analysis of the results in nitrile and barrier glove.
6) The relationship between permeation performance and studied factors

4.2 Exposure data and physical condition.

The results of study are separated into 2 sections; Exposure data and physical condition. Exposure data is from the study about the number of used days, exposure duration and the number of contact with the gloves. Physical condition is studied by noticed visible condition i.e. color, texture, swollen and weight of gloves would be checked by weighing using electronic weight.

4.2.1 Exposure data

The chemical protective gloves would be washed after using in each day only. There was no washing during day because the chemical protective gloves had to be dried before using for the next time, and it would take long time to have the gloves dried. Therefore, the chemical protective gloves would be washed after using once per day.

The number of used days, exposure duration and the number of contact with the gloves was recorded by each worker every time that they wore the chemical protective gloves to clean the printing machine. Before the study began, the researcher had trained all 5 printing machine workers to record the factors affecting permeation resistant performance of the gloves on the provided form (Appendix C).The result is as follow.

Nitrile gloves, which were repetitive used for 1 day, had been used for 3-14 times per day; 2-20 minutes per time, and total exposure time is 25-53 minutes per day. Besides, nitrile gloves, which were repetitive used for 5 days, had been used for 6-43 times per day; 5-50 minutes per time. , and total exposure time is 87-260 minutes per day. Therefore, it was found that the gloves which were increasingly used, the exposure time would be increasing, too as the detail in Table 4.1. And number of time the chemical contact with the gloves of the workers No. 4 and 5 are most because they work with the smaller printing machines which is used for printing a little number of stuff and the color must be often changed. Number of time the chemical contact with the gloves of the workers No. 1, 2 and 3 are lesser but exposure times are longer because they work with the bigger printing machines which is used for printing a great number of stuff per time. As the detail in Table 4.1

Barrier gloves, which were repetitive used for 1 day, had been used for 1-11 times per day; 5-20 minutes per time, and total exposure time is 20-65 minutes per day. Besides, barrier gloves, which were repetitive used for 5 days, had been used for 6-67 times per day; 5-30 minutes per time. , and total exposure time is 90-400 minutes per day. Therefore, it was found that the gloves which were increasingly used, the exposure time would be increasing, too as the detail in Table 4.2

Table 4.1 Number of contact and exposure time of nitrile gloves.

Used day	**Pair No.**	**Number of contact (times)**	**Exposure time (minute)**	
			Per each used (min-max)	**Total exposure time**
1	1	3	10-20	50
	2	2	10-15	25
	3	3	5-15	25
	4	14	2-10	53
	5	9	5-10	50

Table 4.1 Number of contact and exposure time of nitrile gloves. (cont.)

Used day	Pair No.	Number of contact (times)	Exposure time (minute)	
			Per each used (min-max)	Total exposure time
2	1	4	5-15	35
	2	5	5-25	45
	3	7	5-20	70
	4	25	5-15	155
	5	20	2-10	64
3	1	5	8-20	78
	2	13	3-35	82
	3	9	5-35	120
	4	34	2-15	194
	5	22	2-10	153
4	1	6	7-30	92
	2	15	3-20	142
	3	15	5-20	125
	4	50	5-10	245
	5	30	2-15	135
5	1	6	5-22	87
	2	16	5-45	212
	3	13	5-50	185
	4	48	5-15	260
	5	44	5-15	210

Table 4.2 Number of contact and exposure time of barrier gloves.

Used day	Pair No.	Number of contact (times)	Exposure time (minute)	
			Per each used (min-max)	Total exposure time
1	1	3	15-20	55
	2	1	20	20
	3	8	5-20	55
	4	11	5-10	65
	5	9	5-10	55
2	1	7	5-20	85
	2	4	10-25	45
	3	12	5-20	75
	4	24	5-10	135
	5	19	5-10	105
3	1	3	15-20	50
	2	7	10-25	105
	3	13	5-15	100
	4	26	5-10	155
	5	22	5-10	125
4	1	4	15-20	65
	2	11	5-25	135
	3	19	5-30	170
	4	31	5-10	200
	5	31	5-15	190
5	1	6	10-20	90
	2	9	5-25	150
	3	32	5-30	250
	4	67	5-15	400
	5	53	5-15	330

4.2.2 Physical condition of gloves

The study about physical condition of the gloves which was changed, indicate the degradation of gloves which affect the effectiveness of chemical permeation protection. The visible condition measured were color, wrinkle, swell, shrink, texture and weight of gloves.

4.2.2.1 Visible condition

The visible condition of unused nitrile gloves can be described as green color, without lining, long nearly the elbow and with lozenge pattern on the palm and finger tips to increase efficiency of grasp and hold. After being used for 1, 2 and 3 days has a little bit black stains appeared on palm and finger area, especially around the lozenge pattern area. The stains mostly appeared on the right-hand gloves because all 5 workers are right-handed. The workers wiped the printing machine by their right hand while the left hand was just holding the printing machine, so the stain appeared on the right-hand gloves more than the left-hand gloves. The gloves which had been used for4 and 5 days, there were more black stain and printing color appeared on finger, palm and back of the hand are especially around the lozenge pattern area. Additionally, the stain appeared on the right-hand gloves more than the left-hand gloves as the detail in Table 4.3.

The unused barrier gloves can be described as white color, thin, with smooth and glossy surface. After using for 1 day, a little bit black stains, printing color stains appeared on the finger and palm areas. Besides, a little bit wrinkles appeared on palm area. Additionally, all effect appeared on the right-hand gloves which use to wipe the printing machine more than the left-hand gloves. The gloves which had been used for 4 and 5 days, there were more black stains, printing color stains appeared on the finger, palm and back of hand areas. Besides, more wrinkles appeared on finger joints and palm area as well as the scratch cause from part of printing machine appeared. Additionally, the gloves which had been used for 5 days, the seam of gloves was damaged and torn around finger area. Because the barrier gloves are thin and the worker have to take some parts of machine off for cleaning, so the gloves are hooked and torn. Additionally, all effect appeared on the right-hand gloves more than the left-hand gloves as the detail in Table 4.4.

Table 4.3 Physical condition of nitrile gloves

Used day	**Visual Appearance (new glove)**	**Change in Visual Appearance**				
		Repetitive day = 1	**Repetitive day = 2**	**Repetitive day = 3**	**Repetitive day = 4**	**Repetitive day = 5**
0	Green, with lozenge pattern on the finger and palm area to increase efficiency of grasp and hold	-	-	-	-	-
1	(0)	Green, a bit black stains appear on finger and palm area	-	-	-	-
2	(0)	(1)	Green, a bit black stains appear on finger and palm area	-	-	-
3	(0)	(1)	(2)	Green, black stains appear on finger and palm area	-	-
4	(0)	(1)	(2)	(3)	Green, more black stains appear on finger, palm and back hand area; mostly on lozenge pattern	-
5	(0)	(1)	(2)	(3)	(4)	Green, more black stains appear on finger, palm and back hand area; mostly on lozenge pattern

Remark : (0) = Physical condition similar of 0 used day (1) = Physical condition similar of 1 used day

(2) = Physical condition similar of 2 used day (4) = Physical condition similar of 3 used day

Table 4.4 Physical condition of barrier gloves

Used day	**Visual Appearance (new glove)**	**Change in Visual Appearance**				
		Repetitive day = 1	**Repetitive day = 2**	**Repetitive day = 3**	**Repetitive day = 4**	**Repetitive day = 5**
0	White, without lozenge pattern	-	-	-	-	-
1	(0)	White, black stains appear on finger area, smooth texture	-	-	-	-
2	(0)	(1)	White, black stains appear on finger area and edge of gloves, wrinkles appear on finger joint part, rough texture	-	-	-
3	(0)	(1)	(2)	White, black stains appear on finger area and edge of gloves, wrinkles appear on finger joint part, rough texture	-	-
4	(0)	(1)	(2)	(3)	White, black stains appear on finger, palm area and edge of gloves, wrinkles appear on finger joint part, rough texture	-
5	(0)	(1)	(2)	(3)	(4)	White, more black stains appear on finger, palm part and edge of gloves, wrinkles and scratches appear on finger joint part, rough texture, damaged seam and torn finger area

Remark : (0) = Physical condition similar of 0 used day (1) = Physical condition similar of 1 used day

(2) = Physical condition similar of 2 used day (4) = Physical condition similar of 3 used day

4.2.2 Weight of gloves

4.2.2.1 Weight of nitrile gloves

Comparing weight of nitrile gloves before and after using has shown that weight of before-using glove is lower than after-using gloves. The weight of nitrile gloves tended to increase as the number of using day increase. The 1-day used gloves have average weight before using as 28.94 g and after using as 29.43 g. The 2-day used gloves have average weight before using as 28.73 g and after using as 29.79 g. The 3-day used gloves have average weight before using as 28.72 g and after using as 30.11 g. The 4-day used gloves have average weight before using as 28.77 g and after using as 30.53 g. The 5-day used gloves have average weight before using as 29g and after using as 31.17 g. as the detail in Table 4-5.

Table 4.5 Weight of nitrile gloves

Used day	**Weight (g)**													
	Pair No.1		**Pair No.2**		**Pair No.3**		**Pair No.4**		**Pair No.5**		**X**		**S.D**	
	Before	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
1	29.05	29.85	28.80	28.95	28.80	29.09	28.85	29.63	29.19	29.62				
	29.07	29.85	28.79	28.95	28.81	29.08	28.86	29.63	29.19	29.62				
	29.07	29.86	28.79	28.95	28.80	29.09	28.86	29.62	29.20	29.62				
X	29.06	29.85	28.79	28.95	28.80	29.09	28.86	29.63	29.19	29.62	28.94	29.43	0.1771	0.387
2	28.54	30.06	28.92	29.22	28.70	29.85	28.76	30.03	28.72	29.80				
	28.55	30.06	28.92	29.22	28.70	29.85	28.76	30.03	28.72	29.81				
	28.55	30.07	28.92	29.21	28.70	29.85	28.76	30.03	28.72	29.81				
X	28.55	30.06	28.92	29.22	28.70	29.85	28.76	30.03	28.72	29.81	28.73	29.79	0.1327	0.339
3	28.56	30.09	28.86	30.19	28.67	30.03	28.74	30.24	28.78	30.01				
	28.55	30.09	28.87	30.19	28.67	30.02	28.74	30.23	28.78	30.02				
	28.54	30.08	28.86	30.18	28.68	30.02	28.75	30.23	28.78	30.01				
X	28.55	30.09	28.86	30.19	28.67	30.02	28.74	30.23	28.78	30.01	28.72	30.11	0.1173	0.101

Table 4.5 Weight of nitrile gloves (cont.)

Used day	Weight (g)													
	Pair No.1		Pair No.2		Pair No.3		Pair No.4		Pair No.5		X		S.D	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
4	28.41	30.13	28.53	30.20	28.78	30.18	29.02	31.85	29.14	30.26				
	28.40	30.14	28.53	30.20	28.78	30.19	29.03	31.89	29.15	30.25				
	28.40	30.13	28.53	30.21	28.79	30.19	29.02	31.86	29.14	30.26				
X	28.40	30.13	28.53	30.20	28.78	30.19	29.02	31.86	29.14	30.26	28.77	30.53	0.3139	0.746
5	28.36	30.15	28.83	31.02	29.00	30.43	29.65	32.30	29.19	31.97				
	28.35	30.14	28.83	31.03	28.99	30.44	29.65	32.28	29.18	31.97				
	28.36	30.15	28.83	31.02	28.99	30.44	29.65	32.28	29.19	31.97				
X	28.36	30.15	28.83	31.02	28.99	30.44	29.65	32.29	29.19	31.97	29.00	31.17	0.4736	0.934
X											28.83	30.21	0.1291	0.674

4.2.2.2 Weight of barrier gloves

Comparing weight of barrier gloves before and after using has shown that weight of before-using glove is lower than after-using gloves. The weight of Barrier gloves tended to increase as the number of using day increase. The 1-day used gloves have average weight before using as 9.14 g and after using as 9.36 g. The 2-day used gloves have average weight before using as 9.09 g and after using as 9.38 g. The 3-day used gloves have average weight before using as 9.10 g and after using as 9.49g.The 4-day used gloves have average weight before using as 9.14 g and after using as 9.45 g. The 5-day used gloves have average weight before using as 9.13 g and after using as 9.66 g. as the detail in Table 4-6.

Table 4.6 Weight of barrier gloves

Used day	Weight (g)													
	Pair No.1		Pair No.2		Pair No.3		Pair No.4		Pair No.5		X		S.D	
	Before	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
1	9.09	9.44	9.24	9.19	9.15	9.42	9.18	10.15	9.08	9.70				
	9.09	9.45	9.24	9.19	9.15	9.42	9.18	10.15	9.08	9.70				
	9.09	9.44	9.24	9.20	9.15	9.42	9.18	10.15	9.09	9.70				
X	9.09	9.44	9.24	9.19	9.15	9.42	9.18	10.15	9.08	9.70	9.14	9.36	0.0661	0.2503
2	9.18	9.07	9.21	9.75	9.01	9.52	9.10	9.53	9.08	9.03				
	9.17	9.07	9.21	9.75	9.01	9.52	9.10	9.53	9.08	9.03				
	9.18	9.07	9.21	9.75	9.01	9.52	9.11	9.53	9.08	9.03				
X	9.18	9.07	9.21	9.75	9.01	9.52	9.11	9.53	9.08	9.03	9.09	9.38	0.0620	0.3203
3	9.15	9.52	9.09	9.45	9.05	9.24	9.12	9.55	9.11	9.32				
	9.15	9.52	9.09	9.45	9.05	9.23	9.12	9.55	9.11	9.33				
	9.16	9.52	9.08	9.45	9.05	9.24	9.12	9.56	9.12	9.33				
X	9.15	9.52	9.08	9.45	9.05	9.24	9.12	9.55	9.12	9.33	9.10	9.42	0.0391	0.1307

Table 4.6 Weight of barrier gloves (cont.)

Used day	Weight (g)													
	Pair No.1		**Pair No.2**		**Pair No.3**		**Pair No.4**		**Pair No.5**		**$\bar{X}$**		**S.D**	
	Before	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
4	9.11	9.42	9.18	9.52	9.07	9.27	9.19	9.56	9.13	9.46				
	9.11	9.42	9.18	9.52	9.07	9.27	9.19	9.56	9.13	9.46				
	9.11	9.42	9.18	9.52	9.07	9.27	9.19	9.56	9.13	9.46				
X	9.11	9.42	9.18	9.52	9.07	9.27	9.19	9.56	9.13	9.46	9.14	9.45	0.0498	0.1122
5	9.16	10.44	9.05	9.52	9.18	9.34	9.21	9.49	9.05	9.53				
	9.17	10.44	9.05	9.52	9.18	9.34	9.21	9.48	9.05	9.52				
	9.16	10.43	9.06	9.53	9.18	9.34	9.21	9.48	9.05	9.53				
X	9.16	10.43	9.05	9.52	9.18	9.34	9.21	9.48	9.05	9.53	9.13	9.66	0.0752	0.4371
X											9.12	9.46	0.0235	0.1203

4.3 Permeation test result of the mixture through nitrile gloves.

The chemical permeation test of the mixture which is consisted of n-hexane 10 – 30%, benzene ≤ 0.25% and ethylbenzene ≥ 0.10 - ≤ 0.30% through nitrile to test the breakthrough time and permeation rate values and using GC-FID to detect and analyze for the amount of the chemicals that permeates through the gloves.

N-hexane consisted in the mixture of 10-30 % which is the breakthrough time of nitrile gloves tended to decrease as the number of using day increase. While the permeation rate trended to increase as the number of using day increase. The average breakthrough time of unused gloves is 1528.2 minutes and the average of permeation rate is 0.6295 μg/cm2/min. The average breakthrough time of 1-day used gloves is 1454.6 minutes and the average of permeation rate is 1.5320 μg/cm2/min. And the average breakthrough time of 5-day used gloves is 1324.4 minutes and the average of permeation rate is 4.6986 μg/cm2/min as the detail in Table 4-7 and Table 4-10.

Benzene which is consisted in the mixture has the breakthrough time of nitrile gloves trended to decrease as the number of using day increase. While the permeation rate trended to increase as the number of using day increase. The average breakthrough time of unused gloves is 1535.2 minutes and the average of permeation rate is 0.4030 μg/cm2/min. The average breakthrough time of 1-day used gloves is 1469.6 minutes and the average of permeation rate is 1.1450 μg/cm2/min. And the average breakthrough time of 5-day used gloves is 1387.8 minutes and the average of permeation rate is 2.9612μg/cm2/min as the detail in Table 4-8 and Table 4-11.

Ethylbenzene which is consisted in the mixture, when the permeation test of 5-day used gloves was done, it was found that no ethylbenzene permeated through nitrile gloves. The permeation test had taken 2880 minutes or 48 hours or 2 days, there was no ethylbenzene permeated through nitrile gloves. Therefore, breakthrough time which was reported as > 2880 minutes and permeation rate is 0 μg/cm2/min as the detail in Table 4-8 and Table 4-11 It might be caused by a few proportion of ethylbenzene consisted in the mixture; only ≥ 0.10 - ≤ 0.30%, so there was no its permeation.

Comparing the result of permeation test of 3 chemicals; n-hexane, benzene and ethylbenzene through nitrile gloves. It was found that breakthrough time of n-hexane was lowest and benzene respectively. However, ethylbenzene was not found. Besides, Permeation rate of n-hexane is highest, benzene respectively and the permeation rate of ethylbenzene is 0 µg/cm2/min it was shown that there was no permeation of ethylbenzene, as the detail in Table 4-8 and Table 4.13.

Table 4.7 Breakthrough time of solvent mixture (n-hexane) for nitrile glove

	Breakthrough Time (min) n-hexane						
	Pair No.1	**Pair No.2**	**Pair No.3**	**Pair No.4**	**Pair No.5**	**X**	**S.D**
0	1500	1517	1545	1536	1543	1528.2	19.2536
1	1465	1453	1448	1422	1465	1454.6	10.2616
2	1467	1478	1455	1365	1374	1427.8	53.9323
3	1372	1442	1365	1327	1332	1367.6	46.0359
4	1348	1375	1347	1307	1324	1340.2	25.8979
5	1354	1368	1322	1283	1295	1324.4	36.6101

Table 4.8 Breakthrough time of solvent mixture (benzene) for nitrile gloves

Used day	**Breakthrough Time (min) benzene**						
	Pair No.1	**Pair No.2**	**Pair No.3**	**Pair No.4**	**Pair No.5**	**X**	**S.D**
0	1534	1528	1531	1538	1545	1535.2	6.6106
1	1477	1485	1465	1425	1496	1469.6	27.3825
2	1443	1414	1435	1392	1421	1421.0	19.8116
3	1426	1392	1418	1387	1398	1404.2	16.9470
4	1414	1402	1408	1375	1375	1394.8	18.5661
5	1404	1393	1397	1368	1377	1387.8	14.8560

Table 4.9 Breakthrough time of solvent mixture (ethylbenzene) for nitrile gloves

Used day	**Breakthrough Time (min) ethylbenzene**						
	Pair No.1	**Pair No.2**	**Pair No.3**	**Pair No.4**	**Pair No.5**	**X**	**S.D**
0	>2880	>2880	>2880	>2880	>2880	2880.0	0.0000
1	>2880	>2880	>2880	>2880	>2880	2880.0	0.0000
2	>2880	>2880	>2880	>2880	>2880	2880.0	0.0000
3	>2880	>2880	>2880	>2880	>2880	2880.0	0.0000
4	>2880	>2880	>2880	>2880	>2880	2880.0	0.0000
5	>288	>288	>2880	>2880	>2880	2880.0	0.0000

Table 4.10 Permeation rate of solvent mixture (n-hexane) for nitrile gloves

Used day	**Permeation rate (µg/cm²/min) n-hexane**						
	Pair No.1	**Pair No.2**	**Pair No.3**	**Pair No.4**	**Pair No.5**	**$\bar{X}$**	**S.D**
0	0.5096	0.7682	0.6320	0.5504	0.6872	0.6295	0.10393
1	1.4325	1.6230	1.5492	1.6817	1.3734	1.5320	0.12819
2	1.8450	2.0371	1.7902	2.5239	2.3204	2.1033	0.31352
3	1.9013	1.9823	2.1094	2.8043	2.7423	2.3079	0.43182
4	2.4439	2.3494	2.9350	3.4933	3.4921	2.9427	0.54906
5	3.9392	4.1290	4.8736	5.3392	5.2120	4.6986	0.63358

Table 4.11 Permeation rate of solvent mixture (benzene) for nitrile gloves

Used day	Permeation rate (µg/cm²/min) benzene						
	Pair No.1	Pair No.2	Pair No.3	Pair No.4	Pair No.5	$\bar{X}$	S.D
0	0.3992	0.4010	0.3827	0.4761	0.3561	0.4030	0.04465
1	0.9438	1.0438	1.4402	1.3485	0.9487	1.1450	0.23335
2	1.2932	1.4832	1.4983	1.9404	1.8943	1.6219	0.28205
3	1.8590	1.5942	1.9504	2.6945	2.4056	2.1007	0.44247
4	2.3045	1.9405	2.3409	3.1934	2.8324	2.5223	0.49127
5	2.2550	2.4493	2.8032	4.0593	3.2393	2.9612	0.71918

Table 4.12 Permeation rate of solvent mixture (ethylbenzene) for nitrile gloves

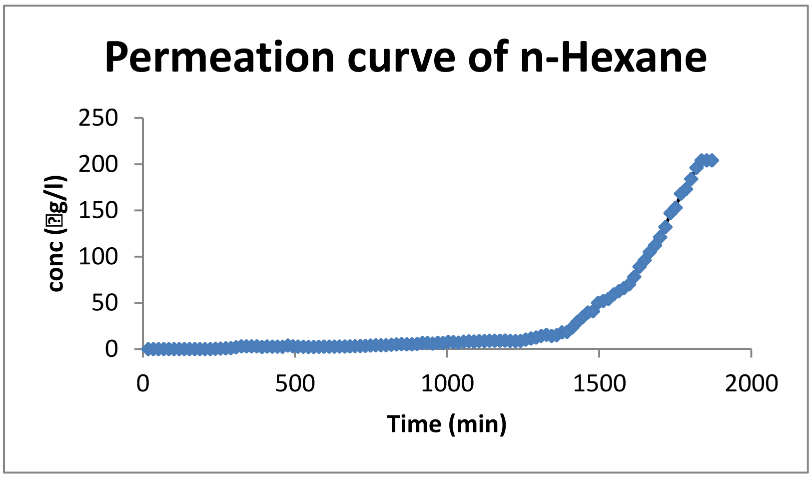
Used day	**Permeation rate (µg/cm²/min) ethylbenzene**						
	Pair No.1	**Pair No.2**	**Pair No.3**	**Pair No.4**	**Pair No.5**	**$\bar{X}$**	**S.D**
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 4.13 Summary of breakthrough time and permeation rate of solvent mixture for nitrile gloves

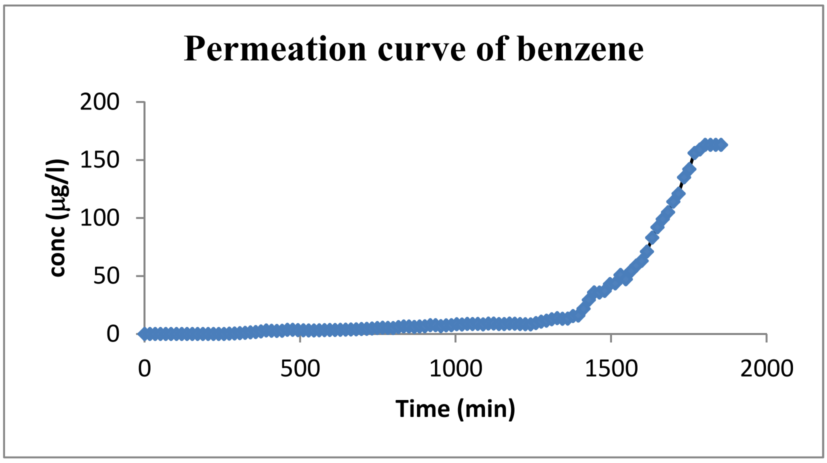
Used day	Breakthrough Time (min)			Permeation rate (μg/cm^2/min)		
	n-Hexane	Benzene	Ethylbenzene	n-Hexane	Benzene	Ethylbenzene
0	1528.2	1535.2	>2880[#1]	0.6295	0.4030	0.0000
1	1454.6	1469.6	>2880[#1]	1.5320	1.1450	0.0000
2	1427.8	1421.0	>2880[#1]	2.1033	1.6219	0.0000
3	1367.6	1404.2	>2880[#1]	2.3079	2.1007	0.0000
4	1340.2	1394.8	>2880[#1]	2.9427	2.5223	0.0000
5	1324.4	1387.8	>2880[#1]	4.6986	2.9612	0.0000

Remark ;#1 This was reported as real experiment. However, ASTM Standard states that if there is no measurable breakthrough time after 480 minutes, reporting as >480 minutes are allowed.

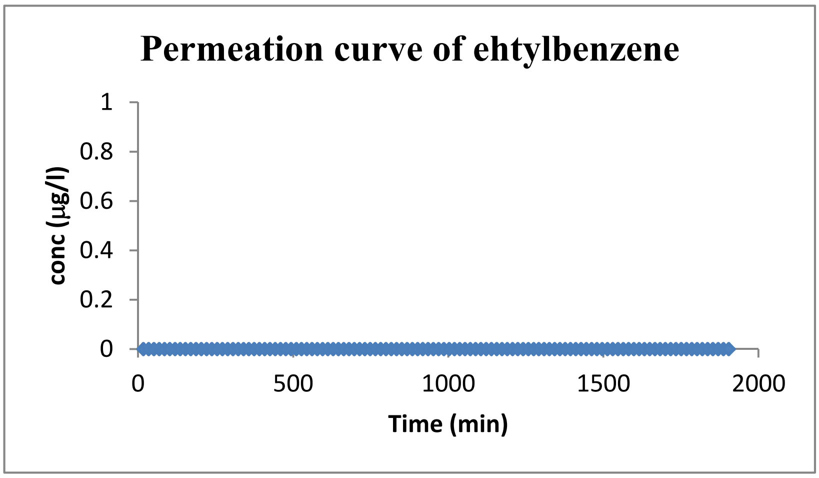
The permeation curve of n-hexane, benzene and ethylbenzene through nitrile gloves as shown in the figure 4.1. The breakthrough time of n-hexane is 1500 minutes and the permeation test was run until the permeation of the chemical was stable, the permeation rate of n-hexane is 0.6295 μg/cm^2/min. The breakthrough time of benzene is 1534 minutes and permeation rate is 0.403 μg/cm^2/min, and for ethylbenzene, there was no breakthrough so the permeation curve was as shown in the figure.



(a) Permeation curve of n-Hexane



(b) Permeation curve of benzene



(c) Permeation curve of ethylbenzene

Figure 4.1 The permeation curve of n-hexane, benzene, ethylbenzene

4.4 Permeation test result of the mixture through barrier gloves.

Breakthrough time of n-hexane, benzene and ethylbenzene through barrier gloves which used for 5 days were still >2880 minutes but their physical condition were not suitable for using; seam of gloves was damaged and lots of scratch on the gloves' surface, so stop using such gloves. The test result of breakthrough time and permeation rate of barrier gloves is elaborated below.

The permeation test of barrier gloves which were used for 5 days was not detected permeation of all 3 chemicals, after testing for 2880 minutes or 48 hours or 2 days. Therefore, breakthrough time of all 3 chemicals through barrier gloves is >2880 minutes and permeation rate is 0 µg/cm2/min as the detail in Table 4.14.

Table 4.14 Summary of breakthrough time and permeation rate of solvent mixture for barrier glove

Used day	Breakthrough Time (min)			Permeation rate (µg/cm^2/min)		
	n-Hexane	Benzene	Ethylbenzene	n-Hexane	Benzene	Ethylbenzene
0	>2880[#1]	>2880[#1]	>2880[#1]	0.0000	0.0000	0.0000
1	>2880[#1]	>2880[#1]	>2880[#1]	0.0000	0.0000	0.0000
2	>2880[#1]	>2880[#1]	>2880[#1]	0.0000	0.0000	0.0000
3	>2880[#1]	>2880[#1]	>2880[#1]	0.0000	0.0000	0.0000
4	>2880[#1]	>2880[#1]	>2880[#1]	0.0000	0.0000	0.0000
5	>2880[#1]	>2880[#1]	>2880[#1]	0.0000	0.0000	0.0000

Remark ;#1 This was reported as real experiment. However, ASTM Standard states that if there is no measurable breakthrough time after 480 minutes, reporting as >480 minutes are allowed.

4.5 Comparison and analysis of test results with those of chemical from the manufacturer's data.

The comparison of the average breakthrough time and permeation rate of n-Hexane, benzene and ethylbenzene through unused nitrile and barrier gloves specified by the manufacturer with single chemical compliant ASTM F 739 compare with studied result of mixture chemical in this study.

Nitrile gloves: The average breakthrough time from this study is 1528 minutes while the value from the manufacturer is more than 480 minutes. It was found that n-hexane cannot permeate in single chemical state but in mixture state can permeate at minutes of 1528.The average permeation rate from the researcher is 0.6295µg/cm2/min while the value from the manufacturer is 0.00 µg/cm2/min. It was found that breakthrough time of benzene is 1535 minutes while the value from the manufacturer is 16 minutes. The average permeation rate from the researcher is 0.4030 µg/cm2/min while the value from the manufacturer is 164µg/cm2/min. It was found that breakthrough time of ethylbenzene is more than 2880 minutes while the value from the manufacturer is 43 minutes. The average permeation rate from the researcher is 0.00µg/cm2/min while the value from the manufacturer is 124µg/cm2/min. Ethylbenzene in mixture state can permeate slower than in single chemical state.

Barrier gloves: The average breakthrough time of n-hexane, benzene and ethylbenzene from this study is more than 2880 minutes which is as same as the value obtained from the manufacturer. The average permeation rate obtained from the study is 0.00µg/cm2/minute which is as same as the value obtained from the manufacturer. The breakthrough time and permeation rate obtained from the study are not different; there was no permeation of all 3 chemicals.

Table 4.15 Breakthrough time and permeation rate of unused nitrile gloves comparison between value from the researcher and the manufacture

Glove type	Chemical	Permeation test	N	From Researcher (X)	From Manufacturer (X)
Nitrile	n-Hexane	Breakthrough time	5	1528.2[#1]	>480
		Permeation rate	5	0.6295	0.00
	Benzene	Breakthrough time	5	1535.2[#1]	16
		Permeation rate	5	0.4030	164
	Ethylbenzene	Breakthrough time	5	>480[#1]	43
		Permeation rate	5	0.000	124

Remark ;#1 This was reported as real experiment. However, ASTM Standard states that if there is no measurable breakthrough time after 480 minutes, reporting as >480 minutes are allowed.

Table 4.16 Breakthrough time and permeation rate of unused barrier gloves comparison between value from the researcher and the manufacture

Glove type	Chemical	Permeation test	N	From Researcher $(\bar{X})$	From Manufacturer $(\bar{X})$
Barrier	n-Hexane	Breakthrough time	5	>2880[#1]	>480
		Permeation rate	5	0.000	0.000
	Benzene	Breakthrough time	5	>2880[#1]	>480
		Permeation rate	5	0.000	0.000
	Ethylbenzene	Breakthrough time	5	>2880[#1]	>480
		Permeation rate	5	0.000	0.000

Remark ;#1 This was reported as real experiment. However, ASTM Standard states that if there is no measurable breakthrough time after 480 minutes, reporting as >480 minutes are allowed.

4.6 Comparison of permeation performance of chemical mixture through the two glove type

The comparison of permeation performance of all 3 chemicals through the nitrile gloves and barrier gloves which were reused for 5 days was done by using statistical tests on the difference of breakthrough time and the difference of permeation rate between the two types of glove. The difference of the average breakthrough time and the difference of the average permeation rate between the two types of gloves as the detail follow.

The comparison of the breakthrough time of n-hexane permeate through nitrile gloves ($\bar{X}_1$) and barrier gloves ($\bar{X}_2$) found that equal to 1382.92 and >2880 respectively. It was shown that both types of gloves can protect permeation of n-hexane well that is more than 480 minutes. The average permeation rate of nitrile ($\bar{X}_1$) and barrier ($\bar{X}_2$) gloves is 2.72 and 0.00 µg/cm2/min respectively. The difference of permeation rate (X_2 - X_1) between two types of glove is 2.72 µg/cm2/min. It was shown that n-hexane can permeate through nitrile gloves better than barrier gloves from using for 5 days.

The comparison of the breakthrough time of benzene permeate through nitrile gloves (X_1) and barrier gloves (X_2) found that the p-value equal to 1415.48 and >2880 respectively. It was shown that both types of gloves can protect permeation of benzene well that is more than 480 minutes. The average permeation rate of nitrile (X_1) and barrier (X_2) gloves is 2.07 and 0.00 µg/cm2/min respectively. The difference of permeation rate (X_2 - X_1) between two types of glove is 2.07 µg/cm2/min. It was shown that benzene can permeate through nitrile gloves better than barrier gloves from using for 5 days.

The comparison of the breakthrough time of ethylbenzene permeate through nitrile gloves (X_1) and barrier gloves (X_2) found that the p-value equal to >2880 and >2880 respectively. The average permeation rate of nitrile (X_1) and barrier (X_2) gloves is 0.00 and 0.00 µg/cm2/min respectively. It was shown that ethylbenzene cannot permeate through nitrile gloves and barrier gloves from using for 5 days.

Table 4.17 Comparison of breakthrough time and permeation rate of nitrile gloves and barrier gloves for n-hexane

Chemical	Permeation Test	Used day	Glove Type		Mean difference
			Nitrile (X_1)	Barrier (X_2)	
n-Hexane	Breakthrough Time	0	1528.2#1	>2880#1	0.00#2
		1	1454.6#1	>2880#1	0.00#2
		2	1427.8#1	>2880#1	0.00#2
		3	1367.6#1	>2880#1	0.00#2
		4	1340.2#1	>2880#1	0.00#2
		5	1324.4#1	>2880#1	0.00#2
		Total ($\bar{X}$)	1382.92#1	>2880#1	0.00#2
	Permeation Rate	0	0.6295	0.00	0.6295
		1	1.5320	0.00	1.5320
		2	2.1033	0.00	2.1033
		3	2.3079	0.00	2.3079
		4	2.9427	0.00	2.9427
		5	4.6986	0.00	4.6986
		Total ($\bar{X}$)	2.843	0.00	2.843

Remark ;#1 This was reported as real experiment. However, ASTM Standard states that if there is no measurable breakthrough time after 480 minutes, reporting as >480 minutes are allowed.

;#2 Breakthrough time of barrier gloves are higher than those of nitrile gloves with unable to specify number of mean difference.

Table 4.18 Comparison of breakthrough time and permeation rate of nitrile gloves and barrier gloves for benzene

Chemical	Permeation Test	Used day	Glove Type		Mean difference
			Nitrile ($\bar{X}_1$)	Barrier ($\bar{X}_2$)	
Benzene	Breakthrough Time	0	1535.2$^{\#1}$	>2880$^{\#1}$	0.00$^{\#2}$
		1	1469.6$^{\#1}$	>2880$^{\#1}$	0.00$^{\#2}$
		2	1421.0$^{\#1}$	>2880$^{\#1}$	0.00$^{\#2}$
		3	1404.2$^{\#1}$	>2880$^{\#1}$	0.00$^{\#2}$
		4	1394.8$^{\#1}$	>2880$^{\#1}$	0.00$^{\#2}$
		5	1387.8$^{\#1}$	>2880$^{\#1}$	0.00$^{\#2}$
		Total ($\bar{X}$)	1201.4$^{\#1}$	>2880$^{\#1}$	0.00$^{\#2}$
	Permeation Rate	0	0.4030	0.00	0.4030
		1	1.1450	0.00	1.1450
		2	1.6219	0.00	1.6219
		3	2.1007	0.00	2.1007
		4	2.5223	0.00	2.5223
		5	2.9612	0.00	2.9612
		Total ($\bar{X}$)	1.7924	0.00	1.7924

Remark ;#1 This was reported as real experiment. However, ASTM Standard states that if there is no measurable breakthrough time after 480 minutes, reporting as >480 minutes are allowed.

;#2 Breakthrough time of barrier gloves are higher than those of nitrile gloves with unable to specify number of mean difference.

Table 4.19 Comparison of breakthrough time and permeation rate of nitrile gloves and barrier gloves for ethylbenzene

Chemical	**Permeation Test**	**Used day**	**Glove Type**		**Mean difference**
			Nitrile ($\bar{X}_1$)	**Barrier** ($\bar{X}_2$)	
Ethylbenzene	Breakthrough Time	0	>2880[#1]	>2880[#1]	0.00
		1	>2880[#1]	>2880[#1]	0.00
		2	>2880[#1]	>2880[#1]	0.00
		3	>2880[#1]	>2880[#1]	0.00
		4	>2880[#1]	>2880[#1]	0.00
		5	>2880[#1]	>2880[#1]	0.00
		Total ($\bar{X}$)	>2880[#1]	>2880[#1]	0.00
	Permeation Rate	0	0.00	0.00	0.00
		1	0.00	0.00	0.00
		2	0.00	0.00	0.00
		3	0.00	0.00	0.00
		4	0.00	0.00	0.00
		5	0.00	0.00	0.00
		Total ($\bar{X}$)	0.00	0.00	0.00

Remark ;#1 This was reported as real experiment. However, ASTM Standard states that if there is no measurable breakthrough time after 480 minutes, reporting as >480 minutes are allowed.

4.7 The relationship between permeation performance and studied factors

From the chemical permeation test results, it was found that there was permeation of n-hexane and benzene through nitrile gloves while there was no permeation of chemicals through barrier after permeation test for 5 using days. However, the gloves cannot be used further because of their physical conditions was not suitable for using, so stop using such gloves.

The studying on the relationship among breakthrough time, weight, number of used days, exposure duration, number of contact. The factors studying of nitrile gloves were performed for 5 days by using Spearman rank test analysis. The result of relationship study was presented in Table 4-30.

1. The breakthrough time was correlated with weight, the number of used days, exposure duration, number of contact with correlation coefficient (r) = -0.772, -0.779, -0.783 and -0.746, respectively. This can be explained that higher number of used days, longer exposure duration and higher number of contacts will have shorter breakthrough time.

2. Weight were correlated with the number of used days, exposure duration and the number of contact in the same direction with correlation coefficient (r) = 0.891, 0.895, 0.667 respectively. This means that the gloves were more weight when number of days the gloves were used, exposure duration and the number of time the chemical contact with the gloves were higher. The breakthrough time had relationship with weight and in opposite direction with correlation coefficient (r) = -0.772. This implies that breakthrough time decreased while weight increase.

Table 4.20 Correlation between permeation performance and studies factor (N=25)

Variable		Breakthrough time	weight	Used days	Exposure duration	Contact time
Breakthrough	Correlation Coefficient	1.000	-.772*	-.779*	-.783*	-.746*
	Sig. (1-tailed)	.	(<.001)	(<.001)	(<.001)	(<.001)
weight	Correlation Coefficient	-.772**	1.000	.891*	.895*	.667*
	Sig. (1-tailed)	.000	.	(<.001)	(<.001)	(<.001)
Exposure	Correlation Coefficient	-.783*	.895*	.821*	1.000	.810*
	Sig. (1-tailed)	(<.001)	(<.001)	(<.001)	-	(<.001)
contact	Correlation Coefficient	-.746*	.667*	.530*	.801*	1.000
	Sig. (1-tailed)	(<.001)	(<.001)	(<.001)	(<.001)	.
Used	Correlation Coefficient	-.779*	.891*	1.000	.812*	.530*
	Sig. (1-tailed)	(<.001)	(<.001)	-	(<.001)	.003

CHAPTER V
DISCUSSION

5.1 Introduction

This research studies about comparing the permeation of mixture solvent,which consists of n-hexane, benzene and ethylbenzene, through new and repeatedly used gloves for two types of gloves i.e.nitrile and barrier gloves in cleaning printing machine process. The physical study has shown that the gloves are more color stained varied by the number of days the gloves were used. However, the permeation of mixture is lower varied by the number of days the gloves were used. According to the permeation test, the gloves can resist permeation of mixture better than pure chemical. The result is explained in chapter IV and discussed in this chapter as the sections as follow;

- Physical changes
- Permeation test for reused glove
- Comparison of chemical permeation between pure chemical and mixture chemicals for nitrile and barrier glove.
- The relationship between permeation performance and other factors.

5.2 Physical changes.

The purpose of physical changing study is to evaluated degradation of the gloves that affects on the effectiveness of chemical. The factors which are considered in visual test before and after repeated using i.e.color stain, wrinkle, swelling, shrinking and texture of the gloves as the results are shown in the table 4-3 and 4-4. The nitrile gloves after using present the color stain around palm and finger parts and it is increasing varied by the number of days the gloves were used. However, because of high flexibility of the gloves, there is no wrinkle or scratch appeared on the gloves (34).

After using the Barrier gloves, there is the color stain around palm and finger parts, and the stain is increasing varied by the number of days the gloves were used. Moreover, there are wrinkle and a bit scratch around finger joint and palm parts. Because of low flexibility of the gloves, wrinkle and scratch are appeared when the worker moves his handswhile working (59). The gloves of the worker No. 1 and 2 are torn around finger parts after 5 days using that may be the gloves are thin and must be used to hold and carry big parts of printing machine, so they are hooked and torn.

The physical appearance of both types of gloves presented as the pictures in the table 5.1 and 5.2. Ithas shown that there is no swelling, shrinking or texture changingafter usingboth types of gloves. However, the gloves are increasingly stained varied by the number of days the gloves were used; that may be caused of the gloves degradation by the chemical reaction (60, 61). It is clearly seen that both types of gloves are also color stained although the gloves are daily cleaned. It might be deeply color stained in skin of the gloves, so it is hard to clean and increasingly stained. Especially, the gloves of the worker No. 4 and 5, which are used with the small printing machine, are most stained because in each day they are often used (table 4-1) than the other gloves. Besides, the Barrier gloves are less stained because of their smooth texture, so they are easier cleaned (59).

Table 5.1 The appearance of new and repeatedly used nitrile gloves

Number of used day					
New	**1 day**	**2 days**	**3 days**	**4 days**	**5 days**
					

Table 5.2 The appearance of new and repeatedly used barrier gloves

Number of used day					
New	**1 day**	**2 days**	**3 days**	**4 days**	**5 days**
					

The results study about weight of both types of gloves is presented in table 4-5 and 4-6. It has shown that weight of both types of gloves after using more than new gloves and trend to increase while the number of using day is increasing. Additionally, weight gain of the gloves worker No. 4 and 5 is more than the other gloves. The increasing average weight of Barrier gloves is 0.34 grams that less than Nitrile gloves which is 1.38 grams.

The weight gain and color stain after repeated using indicates a type of degradation of gloves (22, 60, 62). It affects the chemical absorption in the material of the gloves that may cause of the gloves' weight gain (17, 63, 64). However, there is no swelling of gloves in this study. If the chemical is absorbed among molecule of polymer it is just a little bit that cannot affect to make the visual swelling. It is possible that the gloves' weight gain is come from the color stained on the gloves. The gloves of the worker No. 4 and 5which used with the smaller printing machine are more weight gain because they are more used; it is more degraded and stained. While the barrier gloves' weight gain is lesser than the nitrile gloves because they are not degraded and lesser stained.

5.3 Permeation test for reused glove.

Breakthrough time and permeation rate of each chemical through the repeatedly used nitrile and barrier gloves are presented in table 4-7– 4-14. About nitrile gloves, average breakthrough times of n-hexane after 5 day-using are 1454, 1427, 1367, 1340 and 1324 minutes respectively. Average breakthrough times of benzene after 5 day-using are 1469, 1421, 1404, 1394 and 1387 minutes respectively. It has shown that breakthrough time trend to decrease as the number of using day is increase. Ethylbenzene is not breakthrough although the gloves have been tested for 2880 minutes; it is the same result when 5 day-used gloves are tested. Generally, it will be reported that breakthrough time is >480 minutes if there is no permeation of chemical within 480 minutes.

The reduction of breakthrough time of n-hexane and benzene varied by the number of days the gloves were used presented in figure 5-1 and 5-2. It might be due to the degradation of nitrile gloves as above mentioned (63, 64). In addition, repeated used gloves and hand movement while working have the affect to polymer chains that make more space between polymers as well as the chemical permeate through the gloves faster (54). Especially, breakthrough times of chemical for the gloves No. 4 and 5 have trend to decrease more than other gloves. It is due to more often using and exposure duration than other gloves as well as the gloves movement. So such gloves are more degraded (more color stain and weight gain) that causes of more decreasing of breakthrough time.

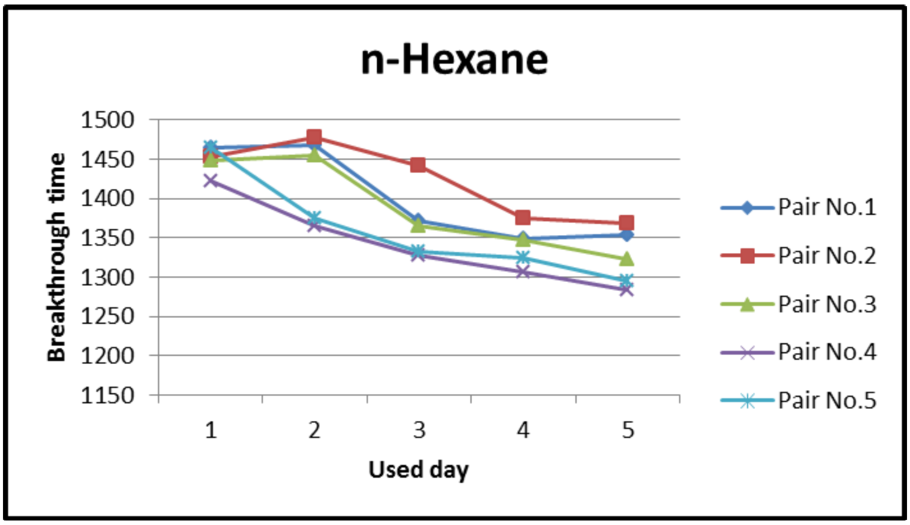


Figure 5.1 Breakthrough time trend of n-hexane for nitrile glove.

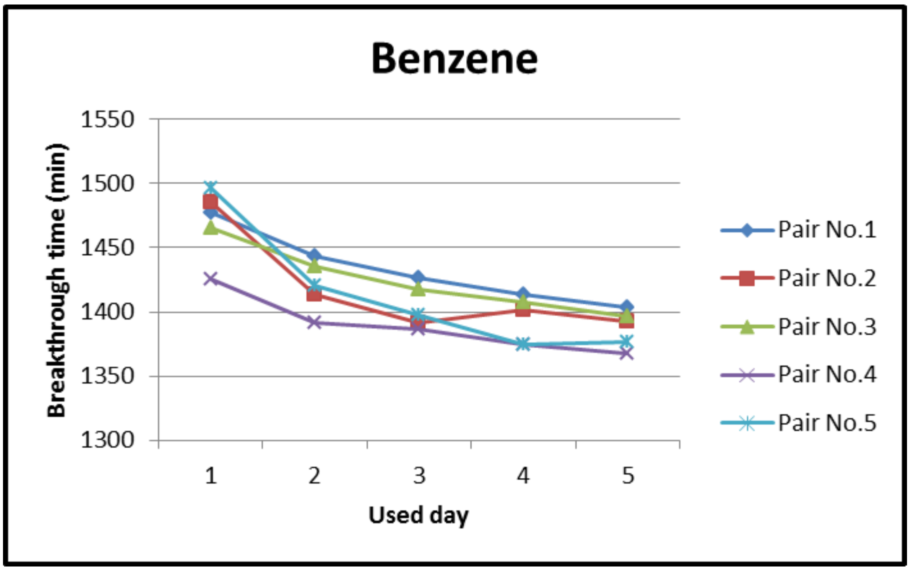


Figure 5.2 Breakthrough time trend of benzene for nitrile glove

Barrier gloves have tested with mixture for 2880 minutes, but there is no chemical breakthrough; it is the same result when 5 day-used gloves are tested. So it is reported that breakthrough time is >2880 minutes, it causes the permeation rate gets closer 0 µg/cm^2/min. Although there is movement while working likes nitrile gloves. That is probably due to other factors such as the mixture; which makes slower chemical permeation (54) and chemical resistibility of gloves' material (24). Additionally, because the chemical is less absorbed observed from a bit weight gain, there is no permeation of chemical through the gloves. (65)

5.4 Comparison of chemical permeation data between pure chemical and mixture chemical for nitrile and barrier glove.

About nitrile gloves, the manufacturer's data states that breakthrough time of n-hexane, which is in pure chemical is >480 minutes and in mixture is 1528 minutes. Breakthrough time of benzene in pure chemical is 16 minutes and permeation rate is 164 µg/cm^2/min, but in mixture is 1525 minutesand permeation rate gets closer 0.00 µg/cm^2/min. Breakthrough time of ethylbenzene in pure chemical is 43 minutes and permeation rate is 124 µg/cm^2/min, but in mixture is >2880 minutes and permeation rate gets closer 0.00 µg/cm^2/min so breakthrough time obviously increases.

Barrier gloves testing with all three chemicals regardless of pure chemical and mixture, the result is not different. Breakthrough time is >480 minutes and permeation rate gets closer 0.00 µg/cm^2/min.

Breakthrough time of n-hexane in pure chemical and mixture through nitrile glove are not clearly compared because the manufacturer have to reported breakthrough time is >480 minutes if there is no permeation of chemical within 480 minutes.(12) However, nitrile gloves can resist mixture permeation better than pure chemical; notice from breakthrough time of benzene and ethylbenzene are increasing. L. B. Georgoulis (66) stated that permeation rate of mixture dependent on proportional to the composition of the mixture that is to say the higher proportion of the "lower permeation" solvent (n-Hexane) can decreases the permeability of the "higher permeation" solvent (benzene and ethylbenzene). The studied mixture is proportionally compound of n-hexane: benzene: ethylbenzene as 10-30 % : ≤ 0.25 % : ≥ 0.10 - ≤ 0.30% . N-hexane is the most proportion and low permeation (breakthrough time is >480 minutes) so n-hexane makes other chemical permeate slower. Additionally, because of a few proportion of benzene and ethylbenzene consisted in the mixture, so there was little permeation of those chemicals as well.

The comparison of the two types of gloves: breakthrough time of n-hexane, benzene and ethylbenzene through nitrile gloves were 1528, 1525 and >2880 minutes respectively, and those of all three chemicals through barrier gloves were >2880 minutes. It was regarded as both types of gloves are able to resist the permeation of the mixture well because breakthrough times were longer than 8 hours. This may be related to the solvent-solvent interaction and polarity of each chemical. Polar would react with polar, and non-polar would react with non-polar as well (58, 66). It may relate to solvent–membrane interactions. If the chemical and polymer are the same type of polar, the chemical will permeate faster, but slower in case of the different type of polar (58). All three chemicals are non-polar (51) nitrile gloves is polar (67) and barrier is non-polar but its quality like polar (68) So all three chemicals may react with non-polar chemical and both types of gloves, it causes all three chemical permeated through the gloves slower.

5.5 The relationship between permeation performance and other factors.

According to permeation test for nitrile gloves, the first chemical permeated is n-hexane and its breakthrough time is 1528 minutes. Additionally, after repeatedly used for 5 days, breakthrough times are 1454, 1427, 1367, 1340 and 1324 minutes respectively. Obviously, breakthrough time is decreasing that varies by the number of used days. It brings about study on relation of breakthrough time, gloves weight, number of used day, exposure duration and number of contact of nitrile gloves.

The result of relation study about gloves weight (a factor for indicating the degradation), number of used day, exposure duration and number of contact with of nitrile gloves. The statistic of spearman rank testis used for analysis, it has shown that all values are in the same direction with correlation coefficient(r) = 0.891, 0.895, 0.667 respectively. The number of used day, exposure duration and number of contact with the gloves increase, that causes gloves weight increase, too (gloves' degradation) (63, 64). Some of the weight gain may be from the color stain on the gloves that is varied by number of time/day the gloves were used. According to collecting the data of the factors,the gloves which are used with the smaller printing machines and the most often used, are the most weight gain due to more color stain than other gloves.

The relation of breakthrough time and the factors i.e. number of used day, exposure duration and number of contact and gloves weight; value of all factors go the opposite direction with breakthrough time as -0.779, -0.783, -0.746, -0.772 respectively. All values are around 0.7 that is in high relation. It can be explained that increasing of all factors; number of used day, exposure duration and number of contact and gloves weight, makes breakthrough time decrease. Besides, the gloves which are used with the smaller printing machines, the most often used, have breakthrough time decreased, too. According to literature review (30), it was found that repeated using affect the chemical resistibility of gloves because the chemical continuously permeatesin spite of stop using chemical. Additionally, concentration of chemical also affects chemical permeability; if the chemical is more concentrated, permeability of the gloves will be decreased. (66) According to this study, it has shown that shorter breakthrough time, it might be due to gloves' movement and repeated using that make more space between polymer chains as well as the chemical permeated faster (54).

CHAPTER VI
CONCLUSION AND RECOMMENDATION

6.1 Conclusion

This research studies the permeation performance of the chemical mixture composed of n-hexane, benzene and ethylbenzene through nitrile and barrier gloves. The study is conducted in the cleaning printing machine process. Used gloves were daily collected for test according to ASTM F 739-91 and subsequently analyzedusing GC-FID technique (Gas Chromatography Flame Ionization Detector); the results are the breakthrough time and permeation rate. Other factors which affect the permeation are the gloves appearances after using including coloring, shrinking, wrinkle, texture and weight. In addition, the number of used days, exposure duration and the number of contact with the gloves are also observed and analyzed for developing the guideline for appropriate selecting glove when working with mixture.

6.1.1 The physical condition

The physical condition of nitrile and barrier gloves after using was found that they were stained around palm and finger parts and more color stained varied by number of days the gloves were used. However, barrier gloves were wrinkled around finger joints and palm parts. Moreover, some pairs of barrier gloves were also torn around finger parts after using for 5 days due to their low flexibility and very thin the gloves were hooked by some parts of printing machine that causes of tearing.

About weight of nitrile and barrier gloves, it was found that both types of gloves after using are weight gains more than the gloves before using. Weight of gloves is varied by number of days the gloves were used. Additionally, average barrier gloves’ weight gain is lesser than average nitrile gloves’ weight gain.

The weight gain and more color stain after repeated using are some kinds of indicator which indicate the degradation of gloves. The gloves’ weight gain may be due to chemical absorption in material of the gloves. However, both types of gloves in this study are not swell. Both types of gloves appearance which is clearly seen, they are more color stained varied by number of days the gloves were used so the most used gloves were most color stained and weight gains as well. While barrier gloves are lesser color stained and weight gain because their texture are smoother and easier clean.

6.1.2 The permeation test result

The permeation test result of mixture through nitrile and barrier gloves after repeated using for 5 days, it was found that breakthrough times of n-hexane through nitrile gloves are 1454, 1427, 1367, 1340, 1324 minutes respectively. Breakthrough times of benzene are 1469, 1421, 1404, 1394, 1387 minutes respectively. Breakthrough time tends to decrease which is varied by number of day nitrile gloves were used. It might have caused of the gloves' degradation; it was observed from weight gain and color stain after using. In addition, gloves' movement during working and repeated using affect the polymer chains to make more space between polymers, it causes chemical permeate the gloves faster. Obviously, breakthrough time of chemical through the most used gloves and longest exposure durationis lowest as well (Table 4-7).

About barrier gloves, there was no breakthrough of chemical though the gloves although it is passed 2880 minutes of testing. So in this study, it was reported that breakthrough time of all three chemicals through barrier gloves is >2880 minutes. It might have other variables those are probably more important than flexing alone such as mixture affects the permeation of chemical slower, kind of gloves' material affects the chemical resistance.

The relationship between breakthrough times of the chemicals through nitrile gloves and other factors can be explained that while all factors increase (the number of used days, exposure duration, the number of contact and gloves weight increase), breakthrough times of the chemicals decrease. It was found that repeated using might have affected the gloves' effectiveness. The chemical continuously permeated through the gloves although chemical contact was stopped. The weight gain indicated the gloves' degradation that caused breakthrough time decrease. The weight gain may be from color stained on the gloves which is varied by number of time the gloves were used. According to gloves using analysis, it was found that the gloves No. 4 and 5 which were used with the smaller printing machines, most often used, longest exposure duration and weight gain gloves, have the most decreasing breakthrough time because of repeated using.

The chemical permeation through nitrile and barrier gloves between pure chemical and mixture chemical , has shown that the permeation test of pure chemical through nitrile gloves, breakthrough time of n-hexane, benzene and ethylbenzene is 16, 43 and > 480 minutes respectively. However, the permeation test of mixture chemical through nitrile gloves, breakthrough time of n-hexane, benzene and ethylbenzene is 1528, 1535 and >2880 minutes respectively; the chemical resistance is better. For barrier gloves, their chemical resistant were very good, for both pure and mixture chemicals. That is to say there was no permeation because the breakthrough time of all three chemicals is >2880 minutes. Permeation of mixture was slower than pure chemical might be due to proportional to the composition of the mixture. This may be related tothe solvent-solvent interaction, polarity of each chemical and solvent–membrane interaction. In this study, n-hexane is the highest proportion and its permeation is low (1528 minutes). So n-hexane decreases the permeability of the other chemicals. All three chemicals are non-polar, nitrile gloves’ material is polar and barrier gloves’ material is non-polar (but it act as polar). So all three chemicals may react together with non-polar chemical and also react with nitrile and barrier gloves which are polar. It might have affected all three chemicals permeated through the gloves slower.

Their it can be concluded that both Nitrile and Barrier gloves are appropriate to use with mixture chemical which consist of n-hexane, benzene and ethylbenzene. Although nitrile gloves is a bit degraded; observed from increasing color stain and weight gain while breakthrough time decrease which is varied by number of using day. However, glove selection should be conducted under considerations of other factors such as tactile sense, comfort, and price. During the course of these experimental, all of gloves tested were also used for our personal protection to get a feeling of how easy it is to work with them. Nitrile is more elastic and fits better to the hands, while barrier gloves is too smooth and thin and tear off after using for 5 days. Furthermore another disadvantage of the barrier is its price which is approximately eight times higher than the prices of nitrile gloves.

Therefore, the result of the study can be used for recommending of gloves using with mixture chemical and repeatedly used nitrile gloves in cleaning printing machine process as follows;

1. Gloves selection for using with mixture chemical:

It has not yet a clear guideline in gloves selection for using with mixture chemical because it may have other factors which affect mixture chemical permeation such as co-solvent which can make mixture permeate faster. However, it is the result from this study, recommended as follows;

1.1 Firstly, should study about the chemical proportion and breakthrough time of each chemical. The speed of chemical permeation depends on that of the highest proportional chemical in the mixture. Therefore, the gloves which should be selected to use, could well resist permeation of the highest proportional chemical in the mixture.

1.2 Then, should study the polarity of the chemicals in mixture. The chemicals with different polar do not interact with each other, while the chemicals with the same polar do The interacting chemicals may cause slower permeation. Therefore, in case of same polar chemicals, the selected gloves should be able to resist the chemical with largest proportion. In case of different polar chemicals, the gloves should be selected based on the resistance against all chemicals in the mixture

1.3 Lastly, should study about the interaction between solvent and polymer. The polar chemical would react with polar polymer that affect the chemical permeate through the gloves faster. About the different polarity that is to say the non-polar chemical and polar polymer would cause the chemical permeate through the gloves slower. Therefore, the gloves which should be selected to use, the polarity of gloves should be different to the polarity of chemical.

2. The repeated glove used nitrile glove in cleaning printing machine process.

Nitrile gloves can resist permeation of the mixture which is consisted of n-hexane, benzene and ethylbenzene well. Its breakthrough time is around 1500 minutes, in other words, the gloves could have resisted the chemical permeation for 1500 minutes before chemical permeate through the gloves material. This will be complied under the condition as follow;

2.1 The gloves should be checked the appearance before, during and after using such as still be in normal color, without leak or torn, and damage of gloves' seam. If a kind of degradation and penetration were found, it should be changed the new one.

2.2 After using, the gloves should be cleaned every day in order to eliminate the chemicals on the surface of the gloves to slow down the chemical permeation process. The gloves cleaning should be conducted by using the soap and water, and rinse with flow water, finally place and dry the gloves in well ventilated under the shade area before using next time.

6.2 Recommendation for furthers study.

6.2.1 More various types of gloves and solvent mixture which are different structure should be studied for guideline development of glove selection to use with solvent chemical and being more choice for user.

6.2.2 Mechanism of permeation of chemical protective clothing by chemical mixture should be studied about for being guideline of glove selection to use with solvent mixture.

6.2.3 The data from more various chemical permeation studies should be collected to summarize for being guideline of glove selection to use with solvent mixture.

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APPENDICES

APPENDIX A

DOCUMENTARY PROOF ETHICAL CLEARANCE

Certificate of Approval
Ethical Review Committee for Human Research
Faculty of Public Health, Mahidol University

COA. No.	MUPH 2012-193
Protocol Title :	THE PERMEATION OF SOLVENT MIXTURE TO NITRILE AND BARRIER GLOVES
Protocol No. :	176/2555
Principal Investigator :	Miss Tussanee Srirerai
Affiliation :	Master of Science Program in Industrial Hygiene and Safety Faculty of Public Health, Mahidol University
Approval Includes :	1. Project proposal 2. Information sheet 3. Informed consent form 4. Data collection form/Program or Activity plan
Date of Approval :	17 September 2012
Date of Expiration :	16 September 2013

The aforementioned project have been reviewed and approved according to the Declaration of Helsinki by Ethical Review Committee for Human Research, Faculty of Public Health, Mahidol University.

(Assoc. Prof. Sutham Nanthamongkolchai)
Chairman of Ethical Review Committee for Human Research

(Assoc. Prof. Phitaya Charupoonphol)
Dean of Faculty of Public Health

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APPENDIX B
INFORMATION SHEET

เอกสารชี้แจงผู้เข้าร่วมการวิจัย

1. ชื่อโครงการวิจัย

การแพร่ของสารทำละลายผสมผ่านถุงมือไนไตรล์และถุงมือแบร์ริเออร์

(THE PERMEATION OF SOLVENT MIXTURE TO NITRILE AND BARRIER GLOVES)

2. สถานที่ที่ทำการวิจัย

- สถานที่เก็บตัวอย่าง ได้แก่ แผนกจัดพิมพ์ โรงงานอุตสาหกรรมผลิตสิ่งพิมพ์แห่งหนึ่ง
- สถานที่วิเคราะห์ตัวอย่าง ได้แก่ ห้องปฏิบัติการสำนักโรคจากการประกอบอาชีพและสิ่งแวดล้อม กระทรวงสาธารณสุข

3. นักศึกษา และอาจารย์ที่ปรึกษาหลัก และที่อยู่ที่ติดต่อได้

นักศึกษา

นางสาวทัศนีย์ ศรีเรไร นักศึกษาหลักสูตรวิทยาศาสตร์มหาบัณฑิต สาขาสุขศาสตร์อุตสาหกรรม และความปลอดภัย ภาควิชาอาชีวอนามัยและความปลอดภัย คณะสาธารณสุขศาสตร์

ที่อยู่ที่สามารถติดต่อได้ 43 ธนาเพลส ซอยจรัญสนิทวงศ์ 34 ถ.จรัญสนิทวงศ์ แขวงอรุณอัมรินทร์ เขตบางกอกน้อย จ.กรุงเทพมหานคร 10700

อาจารย์ที่ปรึกษาหลัก

รศ.ดร. วันทนี พันธุ์ประสิทธิ์ อาจารย์ประจำภาควิชาอาชีวอนามัยและความปลอดภัย คณะสาธารณสุขศาสตร์

ที่อยู่ที่สามารถติดต่อได้ 420/1 ถนนราชวิถี แขวงทุ่งพญาไท เขตราชเทวี กรุงเทพฯ 10400

4. บทนำและเหตุผลในการศึกษาวิจัยของโครงการวิจัยนี้ *(อธิบายอย่างย่อโดยใช้ภาษาที่เข้าใจง่ายสำหรับผู้เข้าร่วมการวิจัย)*

การควบคุมและป้องกันอันตรายในทางสุขศาสตร์อุตสาหกรรม เป็นการดำเนินมาตรการป้องกัน หรือแก้ไขปัญหาสิ่งแวดล้อมในการทำงาน เพื่อลดอันตรายที่อาจเกิดขึ้นต่อสุขภาพอนามัยของผู้ปฏิบัติงาน มาตรการควบคุมอันตรายควรพิจารณาตามลำดับขั้นความเชื่อถือ ประสิทธิผล และแนวโน้มการลดการสัมผัส ได้แก่มาตรการการขจัดออกไป การทดแทนด้วยสาร/สิ่งที่มีพิษหรืออันตรายน้อยกว่า การควบคุมทางวิศวกรรม การบริหารจัดการ และการควบคุมโดยใช้อุปกรณ์ป้องกันอันตรายส่วนบุคคล โดยทั่วไปควรใช้อุปกรณ์ป้องกันอันตรายส่วนบุคคลก็ต่อเมื่อมาตรการการควบคุมอันตรายที่กล่าวข้างต้นไม่สามารถกำจัดอันตรายออกไปในระดับที่ยอมรับความเสี่ยงได้

อย่างไรก็ตามการทำงานสัมผัสกับสารเคมีในงานบางประเภท เช่น การเช็ด การล้างชิ้นงานด้วยสารเคมี หรือการทำความสะอาดวัสดุสิ่งของด้วยสารเคมี เป็นต้น ไม่สามารถใช้มาตรการขจัดอันตราย

อื่นๆได้ จึงต้องมีการเลือกใช้ชุดป้องกันสารเคมีได้แก่ ถุงมือ รองเท้า เสื้อ กางเกง และอุปกรณ์อื่นๆของชุด โดยวัสดุที่ใช้ในการผลิตมีมากมายหลายชนิด และวัสดุแต่ละชนิดก็มีการความสามารถในป้องกันสารเคมีแต่ละชนิดไม่เท่ากัน ดังนั้นในการเลือกใช้วัสดุป้องกันสารเคมีที่มีความเหมาะสมกับงานและสารเคมีจึงมีความสำคัญอย่างมาก

ในการเลือกใช้วัสดุป้องกันสารเคมีจะดูค่าที่มาจากการ "ทดสอบการแพร่ผ่าน" โดยการทดสอบการแพร่ผ่านจะให้มีข้อมูลที่สำคัญสองตัวคือ "เวลาการแพร่ผ่าน" และ "อัตราการแพร่ผ่าน" เวลาการแพร่ผ่าน คือเวลาที่มีแพร่ผ่านของสารจากด้านนอกของถุงมือซึมผ่านไปด้านในของถุงมือหลังจากที่ได้สัมผัสสารเป็นครั้งแรก โดยทั่วไปผู้ผลิตจะใช้ เวลาการแพร่ผ่าน แสดงประสิทธิภาพของวัสดุว่าทนทานต่อการแพร่ผ่านของสารเคมีได้นานเท่าใด ถ้า เวลาการแพร่ผ่าน มีค่ามากแสดงว่าถุงมือนั้นสามารถป้องกันการแพร่ผ่านของสารเคมีได้ดีกว่าถุงมือที่มีค่าเวลาการแพร่ผ่านน้อย ค่า อัตราการแพร่ผ่านคืออัตราการแพร่ผ่านของสารเคมีผ่านไปยังสิ่งขวางกั้น โดยอยู่ในหน่วยมวลต่อพื้นที่ต่อเวลาถ้า อัตราการแพร่ผ่านสูงแสดงว่ามีการแพร่ของสารมาก

บริษัทผู้ผลิตวัสดุป้องกันสารเคมีได้ทำการทดสอบการแพร่ผ่านถุงมือกับสารเคมีมาแล้ว โดยทำการทดสอบการแพร่ผ่านสารเดี่ยวผ่านถุงมือใหม่ แต่ในการทำงานในโรงงานส่วนใหญ่ผู้ปฏิบัติงานจะทำงานกับสารผสม และยังมีปัจจัยต่างๆเช่น ระยะเวลาในการสัมผัสสารเคมี จำนวนครั้งในการสัมผัสสาร จำนวนวันที่ใช้งานซ้ำ ลักษณะการสัมผัสสารเคมี และพฤติกรรมการใช้งานถุงมือ ไม่ว่าจะเป็นการยืดหรือดึงถุงมือ การหยิบจับวัสดุ รวมไปถึงการล้างทำความสะอาด ล้วนแล้วแต่มีผลต่อประสิทธิภาพในการต้านทานการแพร่ผ่านสารเคมีของถุงมือได้ทั้งสิ้น

จากรายงานผลการเฝ้าระวังโรคจากการประกอบอาชีพและสิ่งแวดล้อม สำนักงานระบาดวิทยาระหว่าง พ.ศ. 2546-2552 พบว่า กลุ่มโรคผิวหนัง มีผู้ป่วยทั้งสิ้น 5,973 รายอยู่ในลำดับที่สามของการจัดอันดับการเฝ้าระวังโรคจากการประกอบอาชีพ ซึ่งถือว่าโรคผิวหนังมีความเสี่ยงจากการเกิดโรคจากการทำงานสูงมาก ดังนั้นในการทำการวิจัยครั้งนี้ เพื่อเปรียบเทียบลักษณะการแพร่ผ่านของสารทำละลายที่เป็นสารผสม ผ่านถุงมือใหม่ และ ถุงมือที่มีการใช้งานจริงในกระบวนการล้างทำความสะอาดเครื่องพิมพ์ ทำการทดสอบการแพร่ผ่าน เพื่อศึกษาหาค่า เวลาการแพร่ผ่าน อัตราการแพร่ผ่านและศึกษาถึงปัจจัยต่างๆ ที่ส่งผลถึงค่าการแพร่ผ่าน เช่น จำนวนวันที่ใช้งานถุงมือ, ระยะเวลาการสัมผัสกับสารเคมีและจำนวนครั้งในการสัมผัสสารเคมี เพื่อใช้เป็นแนวทางในการเลือกถุงมือที่มีความเหมาะสมกับการใช้งานของผู้ปฏิบัติงานกับสารผสม

5. วัตถุประสงค์หลัก

เพื่อศึกษาเปรียบเทียบลักษณะการแพร่ผ่านของสารทำละลายผสมผ่านถุงมือ Nitrile และถุงมือ Ansell Barrier ในกระบวนการล้างเครื่องพิมพ์โรงงานผลิตสิ่งพิมพ์

6. เหตุผลที่เชิญชวนให้ท่านเข้าร่วมโครงการวิจัยนี้

ท่านเป็นผู้หนึ่งที่มีความเหมาะสมในการให้ข้อมูลในการศึกษาครั้งนี้ จึงใคร่ขอเชิญชวนท่านให้เข้าร่วมโครงการวิจัย เพราะท่านเป็นผู้ปฏิบัติงานสัมผัสสารทำละลายผสมและสวมใส่ถุงมือป้องกันสารเคมีตลอดระยะเวลาการทำงาน ซึ่งผลจากการศึกษาในครั้งนี้ จะสามารถใช้เป็นข้อมูลประกอบการพิจารณาเลือกใช้งานถุงมือที่เหมาะสมและมีประสิทธิภาพในการต้านทานการแพร่ผ่านสารเคมีผสม สำหรับสถานประกอบการของท่านต่อไป

7. กิจกรรมการวิจัยที่จะเกี่ยวข้องกับท่าน เมื่อท่านสมัครใจเข้าร่วมโครงการวิจัย จะมีดังต่อไปนี้

หากท่านตัดสินใจเข้าร่วมการวิจัยครั้งนี้ จะมีขั้นตอนการวิจัย ดังนี้

1. ผู้วิจัยทำการชี้แจงรายละเอียดโครงการวิจัย ให้ท่านได้ทราบอย่างละเอียด และตอบข้อซักถามของท่านจนเป็นที่เข้าใจ ทั้งนี้ผู้วิจัยจะเน้นการอธิบายความสำคัญของประสิทธิภาพถุงมือในการปกป้องผิวหนัง จากการสัมผัสสารเคมี โดยเปรียบเทียบให้เห็นระยะเวลาในการต้านทานการแพร่ผ่านสารเคมี (Breakthrough time) ของถุงมือสองชนิด ได้แก่ Ansell Barrier™ (ผู้วิจัยนำมาทดสอบ) และถุงมือ Nitrite (โรงงานใช้อยู่เดิม) โดยชนิดที่ผู้วิจัยนำมาทดสอบนั้น มีความสามารถในการต้านทานการแพร่ผ่านสารเคมีได้ดีกว่าถุงมือที่สถานที่วิจัยใช้อยู่ ก่อนอธิบายถึงรายละเอียดของโรคผิวหนังจากการทำงาน และลักษณะอาการที่เกิดกับผิวหนังในกรณีที่สารเคมีแพร่ผ่านถุงมือสัมผัสกับผิวหนัง
2. ผู้วิจัยทำการอธิบายและทำความเข้าใจเกี่ยวกับคำถามในแบบสอบถาม วิธีการตอบแบบสอบถาม และแบบสัมภาษณ์ที่ผู้วิจัยจะสอบถามจากท่าน
3. มีการอบรมและอธิบายให้ท่านทราบเกี่ยวกับการวิธีการล้างทำความสะอาดถุงมือและวิธีการตากถุงมือ Nitrile และถุงมือ Ansell Barrier™
4. ให้ท่านตอบแบบสัมภาษณ์ที่ผู้วิจัยจะเป็นคนถาม
5. ให้ท่านสวมถุงมือ Nitrile ซึ่งเป็นชนิดที่โรงงานใช้งานอยู่ และถุงมือ Ansell Barrier เป็นถุงมือที่ผู้วิจัยเสนอแนะ โดยให้ท่านทำงานตามปกติ ผู้วิจัยจะเฝ้าสังเกตการณ์การทำงานโดยไม่รบกวนการทำงานของท่าน การเก็บตัวอย่างถุงมือจะเก็บภายหลังจากท่านเลิกงานและล้างทำความสะอาดถุงมือแล้ว โดยจะเก็บตัวอย่างถุงมือที่ใช้แล้ว 1 วัน, 2 วัน, 3 วัน, 4 วัน, 5 วัน สลับไปกับการทดสอบประสิทธิภาพถุงมือในห้องปฏิบัติการ ไปจนกว่าจะตรวจพบระยะเวลาที่สารเคมีแพร่ผ่านถุงมือของสารประกอบทุกตัวน้อยกว่า 4 ชั่วโมง หรือถุงมือมีความชำรุดเสียหาย จะให้ท่านหยุดใช้งานถุงมือและเลิกเก็บตัวอย่าง
6. ให้ท่านบันทึกข้อมูลเกี่ยวกับปัจจัยการทำงานลงในแบบบันทึกข้อมูล

8. ระยะเวลาที่ท่านจะเข้ามาเกี่ยวข้องกับกิจกรรมของโครงการวิจัยนี้ *(ทดลอง/รวบรวมข้อมูล)*

- เวลาที่ผู้วิจัยสัมภาษณ์ท่านประมาณ 10 นาที

- ถุงมือที่ใช้งาน จะทำการเก็บตัวอย่างถุงมือหลังจากที่ท่านใช้งานแล้วในแต่ละวันโดยหลังจากใช้งานแล้วจะให้ท่านทำความสะอาดถุงมือ และ ตากให้แห้งก่อนนำมาทดสอบการแพร่ผ่าน (Permeation Test) จะใช้ระยะเวลาในการเก็บข้อมูลประมาณ 2 เดือน (รายละเอียดดังตาราง)

- แบบสอบถาม จะทำการเก็บข้อมูลหลังจากที่ท่านทำความสะอาดเครื่องพิมพ์เสร็จในแต่ละครั้งให้บันทึกข้อมูลลงในแบบสอบถาม ใช้เวลาประมาณ 3 นาที

ตาราง- แผนการเก็บและวิเคราะห์ตัวอย่างถุงมือ

ถุงมือ Nitrile และ Ansell Barrier	วันที่		หมายเหตุ
	เก็บตัวอย่าง	วิเคราะห์ [#1]	
ใช้งาน 1 วัน	1	2,3,4,5,6	BT > 4 ชม.[#2]
ใช้งาน 2 วัน	7,8	9,10,11,12,13	BT > 4 ชม.[#2]
ใช้งาน 3 วัน	14,15,16	17,18,19,20,21	BT > 4 ชม.[#2]
ใช้งาน 4 วัน	22,23,24,25	26,27,28,29,30	BT > 4 ชม.[#2]
ใช้งาน 5 วัน	1,2,3,4,5	6,7,8,9,10	
หยุดใช้งานถุงมือ/เลิกเก็บตัวอย่าง			

<u>หมายเหตุ</u>[#1] คาดการณ์ว่าใช้เวลาวิเคราะห์ตัวอย่างถุงมือ 5 วันต่อ 1 เซต ตามจำนวนวันใช้งาน

[#2] หยุดใช้งาน/เลิกเก็บตัวอย่างเมื่อทดสอบพบ BT < 4 ชั่วโมง หรือ ถุงมือเกิดความชำรุดเสียหาย

9. ประโยชน์ที่คาดว่าจะเกิดขึ้นทั้งต่อท่าน และต่อผู้อื่น

ประโยชน์ที่คาดว่าจะเกิดขึ้นต่อกลุ่มผู้ยินยอมตน

1. ผลของการวิจัย เพื่อเป็นแนวทางในการเลือกใช้ถุงมือป้องกันสารเคมีในงานล้างเครื่องพิมพ์ และเป็นแนวทางในการเลือกถุงมือป้องกันสารเคมีที่มีความเหมาะสมกับสารผสม

ประโยชน์ที่คาดว่าจะเกิดขึ้นต่อผู้อื่น

1. อุตสาหกรรมที่มีการใช้ถุงมือป้องกันสารเคมีกับสารผสมที่มีลักษณะคล้ายคลึงกันกับกลุ่มตัวอย่าง สามารถนำผลการศึกษานี้สร้างความตระหนักเกี่ยวกับอันตรายต่อสุขภาพของผู้ปฏิบัติงานหากเลือกใช้ถุงมือที่ไม่เหมาะสม และเพื่อใช้เป็นแนวทางในการเลือกถุงมือที่มีความเหมาะสมกับการใช้งานของผู้ปฏิบัติงานกับสารผสมได้

10. ความเสี่ยง หรือ ความไม่สบายใดๆที่คาดว่าจะเกิดขึ้นกับท่าน และ มาตรการหรือวิธีการในการป้องกันหรือลดความเสี่ยงหรือความไม่สบายใดๆ ที่อาจเกิดขึ้นในระหว่างการเข้าร่วมโครงการ

- โครงการวิจัยนี้ เนื่องจากการเก็บข้อมูลไม่ได้มีการใช้อุปกรณ์หรือเครื่องมือใดที่มีความเสี่ยงที่จะเกิดอันตรายต่อผู้ร่วมวิจัย มีเพียงการเปลี่ยนชนิดการสวมใสถุงมือเป็นชนิดที่ผู้วิจัยแนะนะ โดยให้ผู้เข้าร่วมวิจัยปฏิบัติตามขั้นตอนการทำงานปกติเท่านั้น ซึ่งหากผู้เข้าร่วมวิจัยมีอาการผิดปกติจากการสวมใสถุงมือดังกล่าวเพียงเล็กน้อย เช่น คัน ระคายเคือง ฯลฯ ผู้วิจัยจะหยุดศึกษาวิจัยในผู้เข้าร่วมวิจัยดังกล่าวทันทีและทำการปฐมพยาบาลหรือรักษาพยาบาลตามความเหมาะสม

หากเกิดกรณีไม่พึงประสงค์ต่อผู้เข้าร่วมวิจัย

- กรณีเกิดเหตุการณ์ไม่พึงประสงค์จากการวิจัยกับผู้เข้าร่วมการวิจัย สามารถติดต่อกับนางสาวทัศนีย์ ศรีเรไร ซึ่งเป็นหัวหน้าโครงการวิจัย โทรศัพท์ 081-055-7236 หรือติดต่อกับอาจารย์ที่ปรึกษา รศ. ดร.วันทนี พันธุ์ประสิทธิ์ อาจารย์ประจำภาควิชาอาชีวอนามัยและความปลอดภัย โทรศัพท์ 081-822-4939ได้ตลอดเวลา สำหรับการรักษาพยาบาล ในเบื้องต้นจะนำผู้เข้าร่วมวิจัยไปรับตรวจรักษาที่ห้องพยาบาลของสถานที่วิจัย แต่หากมีอาการรุนแรงจะส่งไป รักษาพยาบาลต่อที่โรงพยาบาลบางประกอก 3 ซึ่งอยู่ห่างจากสถานที่วิจัยประมาณ 2 กิโลเมตร เป็นโรงพยาบาลขนาด 200 เตียง เปิดให้บริการผู้ป่วยตลอด 24 ชั่วโมง และมีแพทย์เฉพาะทางทุกสาขา

11. การดูแลรักษาความลับของข้อมูลต่างๆ ของท่าน *(ได้แก่ การเก็บรักษาข้อมูลจะทำอย่างไร เก็บไว้ที่ไหน ใครสามารถเข้าถึงข้อมูลได้บ้าง และมีวิธีการทำลายข้อมูลอย่างไร และเมื่อไร)*

ข้อมูลของท่านจะถูกเก็บไว้ความลับ โดยจะไม่มีการเปิดเผยชื่อของผู้ยินยอมตน หลังจากที่ผู้ยินยอมตนลงนามในใบยินยอมตนแล้ว ผู้วิจัยจะแยกใบยินยอมตนออกจาก เพื่อป้องกันการเชื่อมโยงกันของแบบสอบถามกับใบยินยอมตน โดยผู้วิจัยเป็นผู้เดียวที่สามารถเข้าถึงข้อมูลของท่าน มีการผนึกซองข้อมูลของท่านเก็บไว้ในที่ปลอดภัย และจะเปิดเผยได้เฉพาะในรูปที่เป็นสรุปผลการวิจัย การเปิดเผยข้อมูลเกี่ยวกับท่านต่อหน่วยงานต่างๆ ที่เกี่ยวข้อง กระทำได้เฉพาะกรณีจำเป็นด้วยเหตุผลทางวิชาการเท่านั้น และเมื่อโครงการวิจัยนี้เสร็จสิ้นผู้วิจัยจะทำลายเอกสารแบบสอบถามด้วยการนำไปเผา

12. สิทธิการถอนตัวออกจากโครงการวิจัย

ท่านสามารถถอนตัวออกจากโครงการวิจัยได้ทุกเมื่อโดยไม่ต้องให้เหตุผล โดยที่ไม่มีผลเสียหรือผลกระทบใดๆต่อหน้าที่การทำงานของท่านเมื่อท่านถอนตัว

13. กรณีที่มีเหตุจำเป็น หรือฉุกเฉิน ที่เกี่ยวข้องกับโครงการวิจัยสามารถติดต่อผู้รับผิดชอบโครงการได้โดยสะดวกที่

นางสาวทัศนีย์ ศรีเรไร นักศึกษาหลักสูตรวิทยาศาสตร์มหาบัณฑิต สาขาสุขศาสตร์อุตสาหกรรมและความปลอดภัย ภาควิชาอาชีวอนามัยและความปลอดภัย คณะสาธารณสุขศาสตร์

ที่อยู่ (ในเวลาราชการ)

420/1 ถนนราชวิถี แขวงทุ่งพญาไท เขตราชเทวี กรุงเทพฯ 10400

โทรศัพท์ 0-2644-4069

ที่อยู่ (นอกเวลาราชการ)

43 ธนาเพลส ซอยจรัญสนิทวงศ์ 34 ถ.จรัญสนิทวงศ์ แขวงอรุณอัมรินทร์ เขตบางกอกน้อย จ. กรุงเทพมหานคร 10700

โทรศัพท์ 081-055-7236

โครงการวิจัยนี้ได้ผ่านการรับรองจากคณะกรรมการพิจารณาจริยธรรมการวิจัยในมนุษย์ ของคณะสาธารณสุขศาสตร์ มหาวิทยาลัยมหิดล ซึ่งมีสำนักงานอยู่ที่ อาคารสาธารณสุขวิศิษฎ์ ชั้น 4 420/1 ถนนราชวิถี เขตราชเทวี กรุงเทพฯ 10400 โทรศัพท์ 0-2354-8543-9 ต่อ 1127, 7404 โทรสาร 0-2640-9854

เอกสาร จธ 4

หนังสือยินยอมตนให้ทำการวิจัย

โครงการวิจัยเรื่อง การแพร่ของสารทำละลายผสมผ่านถุงมือไนไตรล์และถุงมือแบร์ริเออร์

วันที่ให้คำยินยอม วันที่ .... เดือน .... พ.ศ. ....

ข้าพเจ้า (นาย/นาง/นางสาว) ....ขอทำหนังสือนี้ไว้ต่อหัวหน้าโครงการเพื่อเป็นหลักฐานแสดงว่า

ข้อ 1. ก่อนลงนามในใบยินยอมตนให้ทำการวิจัยนี้ ข้าพเจ้าได้รับการอธิบายจากผู้วิจัยให้ทราบถึงวัตถุประสงค์ของการวิจัย กิจกรรมการวิจัย ความเสี่ยง รวมทั้งประโยชน์ที่อาจเกิดขึ้นจากการวิจัย อย่างละเอียด และมีความเข้าใจดีแล้ว

ข้อ 2. ผู้วิจัยรับรองว่าจะตอบคำถามต่างๆ ที่ข้าพเจ้าสงสัยด้วยความเต็มใจ ไม่ปิดบัง ซ่อนเร้น จนข้าพเจ้าพอใจ

ข้อ 3. ข้าพเจ้าเข้าร่วมโครงการวิจัยนี้โดยสมัครใจ และข้าพเจ้ามีสิทธิที่จะบอกเลิกการเข้าร่วมในโครงการวิจัยนี้เมื่อใดก็ได้ และการบอกเลิกการเข้าร่วมวิจัยนี้จะไม่มีผลกระทบต่อข้าพเจ้า/หน้าที่การงานของข้าพเจ้า

ข้อ 4. ผู้วิจัยรับรองว่า จะเก็บข้อมูลเฉพาะเกี่ยวกับตัวข้าพเจ้าเป็นความลับ และจะเปิดเผยได้เฉพาะในรูปที่เป็นสรุปผลการวิจัย การเปิดเผยข้อมูลเกี่ยวกับตัวข้าพเจ้าต่อหน่วยงานต่างๆ ที่เกี่ยวข้อง กระทำได้เฉพาะกรณีจำเป็นด้วยเหตุผลทางวิชาการเท่านั้น

ข้อ 5. ผู้วิจัยรับรองว่า หากมีข้อมูลเพิ่มเติมที่ส่งผลกระทบต่อการวิจัย ข้าพเจ้าจะได้รับการแจ้งให้ทราบทันทีโดยไม่ปิดบัง ซ่อนเร้น

ข้าพเจ้าได้อ่านข้อความข้างต้นแล้วมีความเข้าใจดีทุกประการ และได้ลงนามในใบยินยอมนี้ด้วยความเต็มใจ

ลงชื่อ ....ผู้ยินยอม

(..)

ลงชื่อ .... ผู้วิจัย

(นางสาวทัศนีย์ ศรีเรไร)

Informed consent form version 1 August 2011

10 July 2012

APPENDIX C
EXPOSURE TIME AND NUMBER OF CONTACT RECORD FORM

แบบบันทึกการใช้งานถุงมือ

รหัสพนักงาน……….............**แผนก**……………………… **วันที่**...............................

ลำดับ	วันที่	สารเคมีที่สัมผัส	ครั้งที่ล้างเครื่องพิมพ์	เวลาการล้างเครื่องพิมพ์		หมายเหตุ
				เริ่มงาน	เลิกงาน	

ลักษณะถุงมือหลังการใช้งาน ☐สีเปลี่ยน

☐มีลอยถลอก

☐ขาด

APPENDIX D

PHYSICAL CONDITION RECORD FORM

Used day	Physical condition before use	Physical condition at the end of last day use						
		Repetitive day = 1	Repetitive day = 2	Repetitive day = 3	Repetitive day = 4	Repetitive day = 5	Repetitive day = 6	Repetitive day = 7
0								
1								
2								
3								
4								
5								

APPENDIX E
PERMEATION TEST CELL AND GC-FID FIGURE

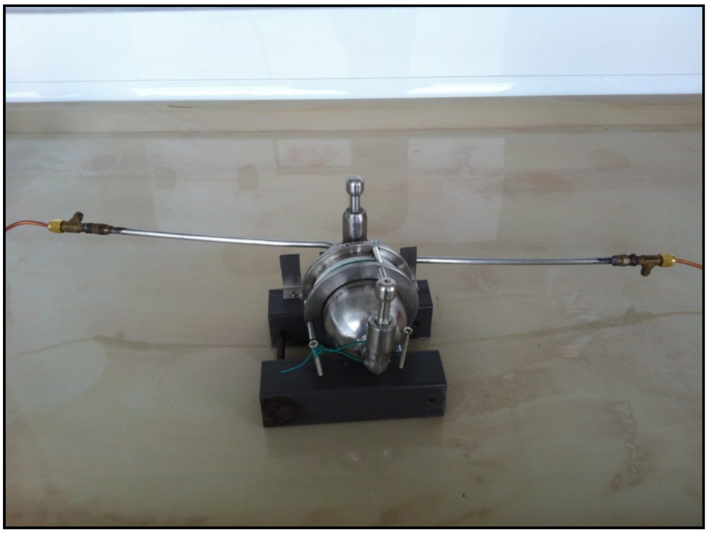

Figure E.1 Permeation test cell

Figure E.2 GC-FID connect to permeation test cell

APPENDIX F
CALIBRATION CURVE PREPARATION

Figure F.1 Injecting known concentration of chemical (n-hexane, benzene and ethylbenzene) into tedlar bag

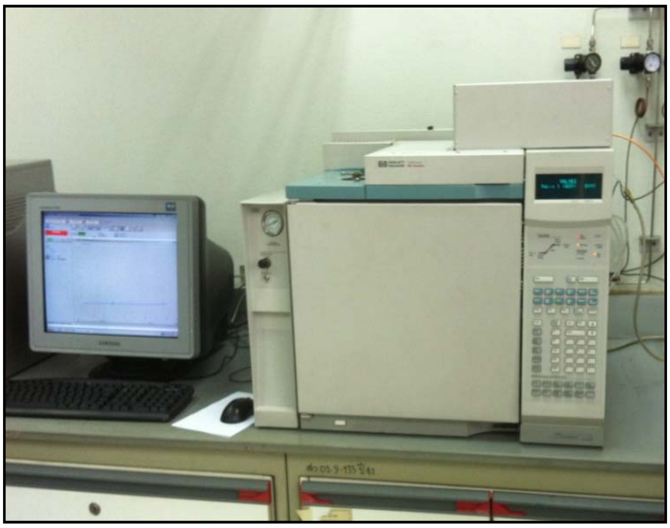

Figure F.2 Injecting known concentration of chemical (n-hexane, benzene and ethylbenzene) into GC

APPENDIX G
CHROMATOGRAMS OF MIXTURE

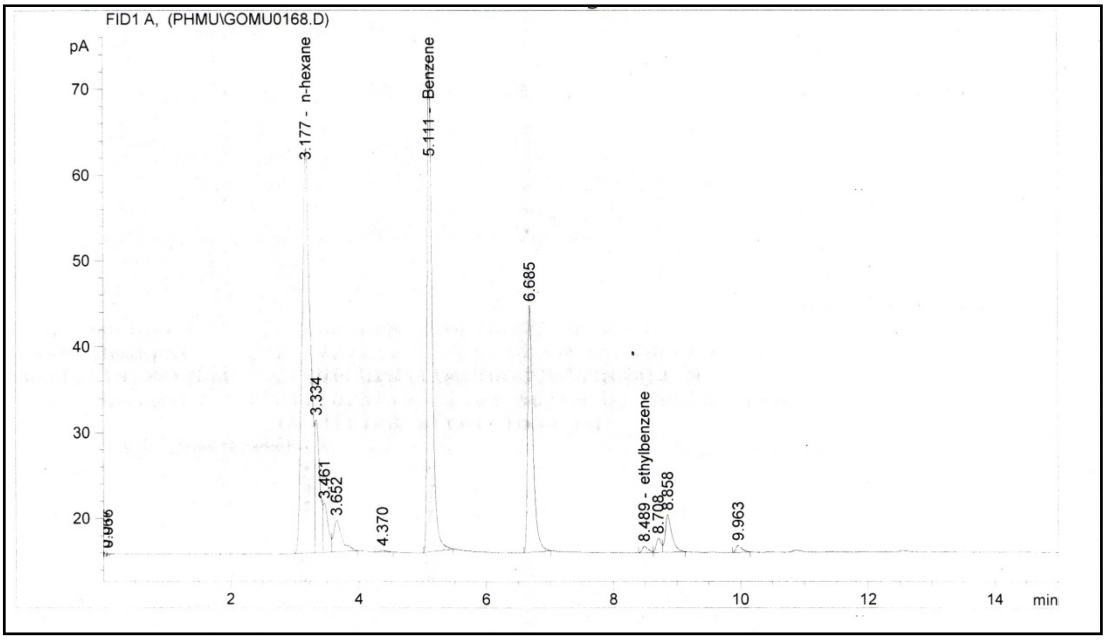

Figure G.1 Chromatograms of n-Hexane, Benzene, Ethylbenzene

APPENDIX H

WORK IN PRINTING DEPARTMENT

Figure H.1 Cleaning the roller of printing machine

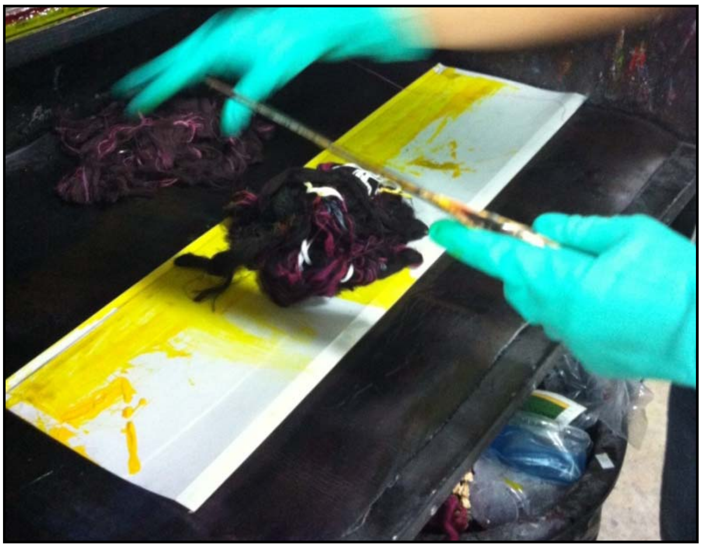

Figure H.2 Cleaning the device of printing machine

APPENDIX I
GLOVE CLEANING

Figure I.1 Cleaning protective glove

Figure I.2 Cleaning protective glove with detergent

APPENDIX J
PHYSICAL CONDITION OF GLOVES

Figure J.1 Unused Nitrile glove

Figure J.2 5-days Nitrile glove

Figure J.3 Unused Barrier glove

Figure J.4 5-days Barrier glove

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