ABSTRACT

The aim of the present study is to examine the effects of sensory pollution from treated wood panels, commonly used in the United Arab Emirates (UAE), on perceived air quality (PAQ) and human comfort. Human subjects between 20 and 30 years of age, recruited from the university community evaluated the air upstream of four different wood panels placed in a 'small' chamber of $0.216m^3$. The evaluated wood panels included: 'wood panel with water-based paint', 'wood panel with oil-based paint', 'wood panel with melamine urea formaldehyde' (MUF), 'normal MDF sample' (Medium Density Fiberboard) without any additives'. Additionally, assessment was done when the chamber was 'empty'. These conditions were assessed in random order. Furthermore, each of the conditions was assessed when a fan, placed in the chamber below the samples, was turned 'on' or 'off'. Hence, a total of 10 conditions were evaluated. Assessments were done by 20 subjects. The subjects, blinded to the 10 conditions, evaluated their level of air acceptability and freshness of air coming out of the chamber. Odour intensity and noise irritation arising from assessed air were also evaluated. Air acceptability values were used to calculate percentage of subjects' dissatisfactions for each condition. The air upstream of 'wood panel painted with oil based paint' was judged to significantly deteriorate PAQ and caused most discomfort to the subjects. Unpredictably, the UF sample assessment was equal to water based-paint sample in both chamber conditions, this indicated that subjects are accustomed to this odour in their lifestyle and experience expectations.

Female results in gender comparison showed higher levels of sensory pollution to all samples. Use of fan generally improved PAQ. Understanding from this study is relevant to creating healthy indoor environment for building occupants.

Keywords *Treated wood based products; perceived air quality; sensory pollution; human comfort*

ملخّص

هدف هذه الدراسة معاينة آثار التلوّث الحسّي الناتج عن الألواح الخشبية المعالجة، المستخدمة عادةً في الإمارات العربية المتحدة، على نوعية الهواء المحسوس وراحة الإنسان. وقيّم أشخاص، تتراوح أعمارهم بين العشرين والثلاثين عاماً اختيروا من الجامعة، الهواء الصاعد من فوق أربعة ألواح خشبيّة مختلفة وُضعت في غرفة "صغيرة" مساحتها 0.261 م^3. الألواح الخشبيّة نوع MDF (Medium Density Fiberboard) التي خضعت للاختبار: "لوح خشبي من دون طلاء، و"لوح خشبي مدهون بطلاء زيتي"، و"لوح خشبي مدهون بطلاء مائي"، و"لوح خشبي مع سطح غراء الفورمالديهايد". وجرى أيضاً اختبار عندما كانت الغرفة "خالية". وتمّ تقييم هذه الظروف بترتيب عشوائي للالواح المصنوعة. بالإضافة إلى ذلك، تمّ تقييم كل من هذه الظروف عند تشغيل او غلق مروحة موضوعة في الغرفة تحت العيّنات. وهكذا يكون مجموع ظروف الاختبار 10 ظروف، قيّمها 20 شخصاً. وفي تلك الظروف العشرة، كان نظر المشاركين محجوباً عندما أعطوا تقييمهم لمستوى صحّة الهواء الصادر من الغرفة ومستوى انتعاشه. وقيّموا أيضاً حدّة الرائحة والانزعاج منها. واستُخدمت قيم صحة الهواء لاحتساب مستوى عدم رضا الأشخاص مواضع الاختبار في كل ظرف من الظروف. وتبيّن أنّ الهواء الصاعد فوق "اللوح الخشبي المدهون بطلاء زيتي" يضرّ بشكل ملحوظ بنوعية الهواء المحسوس وسبّب أعلى مستوى من الانزعاج للأشخاص مواضع الاختبار. بشكل غير متوقع نتائج اللوح الخشبي مع سطح الفورمالديهيد مساوية لـ نـ تائـ ج اللوح الخشبي المدهون بطلاء مائي في كلتا ظروف غرفة الفحص (No Fan or Fan On) وهذا مؤشر ان الاشخاص الخاضعين للتقييم معتادون على هذه الرائحة في اسلوب حياتهم واماكن عيشهم . نتائج الاناث في التقييم (مقارنة بين الجنسين) اظهرت مستوى اعلى من التلوث الحسي لجميع العينات . وتحسّنت نوعية الهواء المحسوس بشكل عام عند استخدام المروحة لجميع الالواح المختبرة. ويساعد فهم نتائج هذه الدراسة على تأسيس بيئة داخلية صحية لسكان المباني.

أهمّ المصطلحات: المنتجات المصنوعة من الخشب المعالج، نوعية الهواء المحسوسة، التلوّث الحسي، راحة الإنسان

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CHAPTER 1: INTRODUCTION

Chapter 1: Introduction

Having unpolluted air is a fundamental necessity of life. The essence of air in entire interior spaces where users allocate a large fragment of their lifetime is of absolute necessity for maintaining hearty and active life amenities. The common term ‘indoors’ is not only referred to in the context of homes, but also includes different spaces occupied by people such as offices, retails workplaces, schools. Vehicles are also considered part of these environments. The three major elements that are integrated with the indoor environment are categorized to be the outdoor air, the building components and various human practices.

Mazzeo (2011) claims that reduced ventilation rates to achieve higher energy efficiency, apart from the excessive usage of building materials, contributes to more health dissatisfaction from space users, while vast indoor contaminants appears to be recognized as either carcinogens, allergens, neurotoxins and irritants, and can therefore possibly contribute to a phenomenon known as the sick building syndrome (SBS). Significant risk may result from various types of contaminants emitted from interior building materials, indoor equipment, or other human-induced activities such as cooling, heating, cooking, and smoking, and can lead to an expansive panorama of health issues that may gradually be fateful. The use of building materials in different indoor spaces plays a major role in indoor air pollution and quality. The lack of knowledge in many developing countries on the impact of air pollution from different building materials in indoor environment captured considerable attention from researchers, professionals and the World Health Organization (WHO). Guidelines produced by WHO in 2010 outlined selected pollutants that cause high risk of health problems in indoor spaces mainly in developing counties

(WHO Guidelines 2010). However, determining these materials in early stages prior to installation without conducting the proper study to examine their impacts on human health and wellbeing is a major concern due to exposure to emissions from these products. Recently, grave concern has been directed towards the risk of volatile organic compound (VOCs) emissions from building products.

Studies and research in this area have demonstrated the health impact and the various levels of concentrations in these materials. One of the most common types of pollutants is formaldehyde, where the use of this compound in different house products found in furniture and furnishing is extensively high. Missia *et* al (2010) state that, formaldehyde is classified to be at the top of carcinogenic indoor materials among other studied pollutants and have a direct effect on occupants' health, especially with high-level of exposure. However, it is essential not to underestimate the risk of being exposed to such compounds and increased awareness is needed in order to achieve optimum healthy indoor environment.

The level of pollutants caused by indoor materials is significant in terms of impact on occupants' health than the outdoor environment (Yrieix *et* al, 2010). Many countries in Europe, such Denmark and Germany, are trying to control the material emissions in indoor environment, while many policies and regulations are developed to reduce indoor product emissions. The volatile organic compounds and formaldehydes are applied in more manageable levels. For example, transmission of pollutants from flooring products are assessed based on the stated AgBB method that has been produced in Germany (AgBB, 2008) and the applied regulation in France (Maupetit and Mandin, 2009) that control the formaldehyde and VOC emissions of building and finishing materials in the local market

(Yrieix *et* al 2010). Recently in the United Arab Emirates (UAE), urban development and the active construction projects have substantially expanded due to the quick time-span of project development and the need to boost the tourism sector, with special concentration on the city of Dubai. Plenty of projects have been completed with very aesthetic shapes and concepts to increase investment in the country (Pacione 2005).

Conversely, and due to time constraints, several aspects have not been taken into account during the rapid expansion of the city with high demand for construction and building materials. However, given the UAE's considerable construction industry and enormous market demand, control of emissions from building materials and potential impacts on building users has not received the attention it deserves. Uhde & Salthamer (2007) state that neglecting 'sustainability' from building materials selection may vastly impact the indoor air quality system that is a major cause of occupants' health issues.

Different chemical reactions indoors are appearing regularly due to the excessive usage of building materials along with the variable room temperature and humidity levels. Thus, various health problems may appear as a result of long-term exposure. The chemical reactions of building materials may appear in indoor air, either from the material itself or as a result of reaction with other inserted material/product simultaneously. Uhde and Salthammer (2007) mention that the container of reactions with the frequent chemicals ingoing and outgoing is "*the interior environment*", while countless consequential materials are more likely to be polluting and irritating than the precedent ones. Additionally, they classified the emission sources to be primary and secondary basis. The primary emission is the result of production of new manufactured material, where the secondary release is the mixture of chemical reactions issued from the usage of materials in different indoor environment conditions. The possibility of advanced VOC emissions may raise in this case, whereas different materials are conjointly installed such wood-based products for furniture and floor covering with adhesives. Therefore, the value of indoor air quality may diminish remarkably. In the UAE, there is a lack of study in providing sufficient statements about building products' level of impact on user's health. Moreover, the use of wood-based products as part of building materials in the UAE buildings, schools, homes and fit-outs work are commonly extensive. One of the available and frequent local wood-based materials are divided between wood with water-based paint, wood with oil-based paint and wood with adhesive formaldehyde.

Yu and Kim (2011) stated that the level of emissions from wood-based products used in homes and buildings has been the chief concern to professionals in industry and special attention has been given to develop lower rates of formaldehyde emissions and other VOCs from these products to enhance indoor air quality and achieve comfortable interior spaces in terms of health and well-being. The common interior wood building materials and furniture fit outs used in the UAE are High Density Fiberboard (HDF), Medium Density Fiberboard (MDF), wood-based particleboard, chipboard and plywood applied with different grades of treatment and paint coats to assure durability and resistance.

The moisture resistant wood (MR) is bonded with melamine urea formaldehyde synthetic resin. Another grade is the boiling water resistant (BWR) bonded with phenol formaldehyde synthetic resin, in addition to the final finishes which may vary between oil and water-based paints (BA 2007). There are studies that have examined the effects of short-term exposure to emission of chemicals from treated wood-based products on sensory irritation, odour intensity, and air acceptability. A study conducted by Yu and Kim

(2011) shows a short period exposure to different wood-based products of MDF, particleboard and plywood bonded with urea formaldehyde and melamine formaldehyde resins, the symptoms that appeared after the short exposure were irritation to eyes, nose, and throat. However, little or no studies have been done in the UAE to examine this concern. The purpose of this study aims to examine this concern. Thus, objectives of this study are: (i) to examine the correlation between variation in air change rate (Fan On/No Fan) on studied treated wood-products and their impacts on human subjects' perceived odour intensity, sensory irritation, and air acceptability. (ii) to examine the significant difference in perceived air quality between gender assessments of pollutant emitted by four commonly available treated woods based products in the UAE.

1.1 Volatile Organic Compounds (VOCs)

Volatile organic compounds are the common organic chemicals found ubiquitously in outdoor air and generated as gases in various interior spaces at certain temperatures and conditions, either in solid or liquid form (EPA 2012). In interior spaces, the use of different building materials will form the emission of VOCs with associated conditions inside the room that enhance the materials to generate these gases such as ventilation rates, room temperature and humidity levels. However, in some cases, the increased level of relative humidity in indoor spaces may cause higher concentration of emissions from VOCs, while may not in others (Mazzeo 2011). According to EPA (2012), VOCs are comprised of different types of chemicals (e.g. formaldehyde, benzene and perchloroethylene), and parts of it may present short and long-term impacts. Furthermore, countless of VOC gases are frequently higher in concentration than outdoors. A study conducted by EPA (2012) in six areas in different parts of the United States, illustrated that outdoor places with high levels of air pollution supplies (e.g. petrochemical plants 42) are ten times less likely to be pollutant than indoor spaces. One of the major components of VOCs is formaldehyde, mainly utilized in wood-based products reproduction such as plywood and particleboard (Mazzeo 2011).

1.2 Formaldehyde Sources

Formaldehyde sources are neutral gases with a distinctive strong odour largely emitted in indoor environment and the chief sources of this pollutant are found in building products, furniture, various insulation materials, and different user products. In wood-based products, urea-formaldehyde (UF) resin is considered the major element of producing the frequent adhesive utilized in plywood, chipboard and particleboard and accommodates a combination of urea, formaldehyde, and water. In plywood sheets, UF resin is used as glue to compress sheets simultaneously, whereas in particleboard and chipboard, the UF resin is applied to saturate the wood fragments and flakes in order to structure the final product mixture (Turiel 1985). Mazzeo (2011) pointed out that 6-8% of the particleboard weight include UF resins, while it comprises 8-10% of the Medium Density Fiberboard weight. The emissions generated from these wood products are caused by non-reacted formaldehyde that lasts in the material after produce, and due to the effect of indoor conditions such moisture and heat; it reacts with the resin and can consequently cause crack-up (Turiel 1985).

1.3 Common Health Issues Related to the Formaldehyde Levels of Use

Formaldehyde effects can be distinguished earlier by several occupants' responses at levels that are less than 1 ppm (part per million). However, diagnosing specific health effects caused by formaldehyde level of concentration is relatively difficult when people's reactions differ extensively (Turiel 1985). During the 1970s and 1980s, the anxiety of cancer in humans caused by formaldehyde appeared widely, where it was explored that exposing laboratory rats to extensive levels of formaldehyde concentrations (6-15 ppm) have resulted in nasal cancer. The levels below 2 ppm however, did not show cancer in the laboratory animals.

Consequently, scientists pointed out that the probability of cancer occurrence on humans is neglected, where the human levels of exposure to formaldehyde has no risk of cancer (FETEG 2002). Additionally, and according to FETEG (2002), another report established by CIIT Center for Health Research associated with reports and studies from the U.S. Environmental Protection Agency, and Health Canada illustrated that the characteristics of the perceived levels of formaldehyde by human is non-carcinogenic. Conversely, the possibility of cancer risk may appear by the elevated and constant exposure to high levels of formaldehyde. In terms of health issues, such irritation to eyes, nose and throat, the formaldehyde impact starts to appear at 0.3 ppm, specifically eye irritation. However, it's quite complicated to evaluate levels of acceptability and odour intensity at which irritation take place as long as the subjective personality and indoor parameter conditions vary from one place to another.

1.4 Wood with Oil and Water-Based Paints

After the formaldehyde adhesive the other two common types of wood treatments used for furniture and furnishing in the UAE are the wood with oil-based paint and the wood with water-based paint. However, as the effect and the level of VOCs may vary between these two paints and the smoothness of surfaces will show better finishing with oil-based paint, but the health concerns remain a major issue. Aesthetically and functionally, space users and interior designers prefer the use of wood with oil or water-based paints regardless of the impact on health and this could be linked to lack of awareness and information. LGCL (2008) states that, the utilization of wood preservatives such water or oil-based paint can be a major source of sensory irritations to skin, eyes and nose, while the level of impact in water-based paint is less than oil-based paint as a result of the lower levels of VOCs used in water-based paint.

1.5 Significance of the Study

The importance of this study is mainly concentrated on testing the sensory pollution from treated wood-based products on perceived air quality and human comfort, while the use of these treatments is applicable to different material surfaces indoors. Different types of interior partitions and walls can be treated using oil-based paint, water-based paint, as well furniture, wood paneling and doors. Therefore, the study would be very beneficial for practitioners and interior designers in this country to support their decisions in their design stage regarding the material selection and application and air change rates while taking into account the perceived air quality and human comfort. Additionally, this study can help in adjusting some regulations by governmental authorities related to indoor air quality by focusing more on the need to enhance the perceived indoor air quality, since people spend the majority of their time indoors in this region. The practice of selecting proper indoor building materials can reduce the levels of concentration and emissions indoors linked to better human comfort.

1.6 Research Outline

This study consists of six chapters in reference to the classification of the research. Chapter 1 covers the introduction of the study, the common treated wood-based materials used in the UAE industry, the chemical emissions of these treatments and their impact on health, significance of the study and research outline. Chapter 2 includes an inclusive study of literature review in order to gather outlines of previously conducted studies are relevant to this research topic. Describing the knowledge gap and the research question is also covered in this chapter. Additionally, the research hypothesis and its justification is stated after discussing the aim of the research that has been converted into research question and outlined the desired objectives to support the study's aim. Chapter 3 identifies the methodology used in this research, the details of the conducted experimental method, subjects, and the relevant requirements needed to apply chamber test, in addition to the system used for analyzing the data. Chapter 4 discusses the outcomes and results derived from the conducted experiment by presenting all the subjects assessment of all samples in graphs, while Chapter 5 includes a deep discussion on the experiment's results and linking it to previous studies. Chapter 6 presents the study conclusion and answers the research question. Moreover, this chapter highlights the significance of the study, how this study is linked to the supported literature and its feasibility to interior designers and professionals in the UAE market.

CHAPTER 2: LITERATURE REVIEW

Chapter 2: Literature Review

2.1 The impact of wood based-products emission on indoor air quality

Occupant's health and employee's performance in any interior space is directly related to a major feature, and that is comfort level. Thus, the indoor air quality conditions affects these factors, inhaling this indoor air daily by occupants can determine the quality of the perceived air and evaluate its impact on indoor environment respectively. This is why the perceived air quality is a very sensitive feature in identifying many related aspects such as sick building syndrome (SBS), people performance and health. According to Melikov and Kaczmarczyk (2012), the major two characteristic aspects that establish good indoor air conditions are related to the structure of the chemical materials selected in building materials and the level of concentrations, and the relationship of the emitted pollutants with the human perception of air acceptability, odour intensity, and sensory irritation. Therefore, the emitted pollutants are essential in terms of determining the perceived air quality.

A study conducted by Molhave *et* al (1993) compared people reactions between 0 – 10mg/m³ concentration levels of 22 VOCs at three variables of temperature (18, 22, 26°C). The study illustrated that by reducing temperature value between (18 - 22°C), the nasal cavity of subjects will reduce even by increasing the VOC exposure to a higher level (10mg/m³). However, reactions were reported for odour intensity, skin temperature and dryness in face part, irritation to eye.

The authors stated that, the level of sensory irritation and perceived air quality should rely on air temperature in interior space. Consequently, the result of this study showed that people's reactions to pollutants such as VOCs will increase significantly at certain concentration levels by increasing temperature. The concern about the various indoor environment aspects in terms of air acceptability and perception, impact of contaminants, air temperature and relative humidity levels is considerably complex; however, not all aspects are well examined. Melikov and Kaczmarczyk (2012) studied the impact of air circulation on perceived air quality indoors and SBS. The study included 124 subjects for experimental method conducted in chamber to perform this study. The chamber conditions were at various air temperatures (20, 23, 26, 28°C), relative humidity (30, 40, and 70%) and the level of contamination varied between low and high. The study focused the significance use of air flow, with the focus on the impact of cool and dry outdoor air supply. The duration of exposure lasted between 60 – 235 min. Results have shown that the perceived air quality assessment improved the freshness level when air supply was applied.

Thus, by increasing the air temperature (26 - 28°) and relative humidity (40 – 70%) the discomfort level increased, but by supplying more air circulation, the negative impact on subjects minimized significantly and the sensory pollution of the perceived air quality enhanced. However, by reducing the relative humidity to low levels (30%) the air temperature will increase between 20 - 26°C and this will cause negative impact. This is why the increased air supply balances the perceived air quality to a better level and reduces discomfort. The same scenario was applied to relative humidity (30 – 60%) and the increase air supply balanced the perceived air quality but when exceeding 70% relative humidity the fact of elevating the air velocity performed less with no better assessment scored in terms of air freshness.

The air velocity value is preferable to be set at 0.82m/s in case of elevated air temperature above 26°C indoors, and this value can cause positive impact on perceived air quality, although individuals are able to adjust air movement through key control. The fact of measuring and improving indoor air quality conditions is very complex and related to many parameters that should be considered in any interior space. The direct chemical reactions caused by wood-based products and their reactions with other sources and building materials are taking place vastly in indoor environment. For that reason, occupants' responses can dramatically form a major parameter to investigate the pros and cons of indoor air conditions, either from instant exposure or after a certain exposure period. These parameters are also correlated to previously consistent studies to conclude proper conditions for space users. It is through this process that relying on people's feedback and complaints to pollutant sources are significantly hard, while more sophisticated readings and studies, such as controlled lab experiment that take into account specific pollutants source, ventilation rates, air temperature, relative humidity and subject responses need to be conducted. Melikov and Kaczmarczyk (2012) argue that the phenomenon of indoor air quality should be applied carefully and assert that creating manageable levels of control between rooms' air velocity, room temperature and outdoor air supply is a very critical strategy since the various pollution levels can cause negative impacts on occupants' health.

This fact maintains the trend of examining a full study of each pollutants source individually whilst considering the different parameters related to any indoor space. Therefore, the sensory perception of wood-based product emissions can be influenced by many indoor aspects and the level of sensory irritation, odour intensity and air acceptability can be influenced not only by the different wood treatments, but even by the poor and good indoor air conditions variables. The indoor humidity contributes to several negatives and discomfort to occupants, while studies have shown that many health issues may accumulate from poor indoor humidity levels. Zhang and Yoshino (2010) argue the importance of controlling indoor environment humidity, while relative humidity (RH) with levels less than 30% can cause poor indoor air quality and is relevant to many health syndrome such as sensory irritation of eye and skin, aridity in throat, skin and nasal, thus it is deemed better to control the RH on levels between 10% and 30% to prevent poor indoor air quality that impact on health. Correspondingly, the presence of other aspects in interior space such as the sorption from different interior materials (wood products, furniture and flooring), poor ventilation and building infiltration, can influence the indoor humidity. Providing manageable levels of indoor humidity will enhance the quality of indoor air and reduce the risk of exposure to contaminants from different building materials.

Building occupants are seeking to perceive healthy indoor environment, while an extensive range of building materials are used in indoor spaces.

Indoor air is strongly influenced by applying different building products; parallel to that the various levels of relative humidity, since less control on RH results in discomfort in indoor air. Thus, it’s highly demanded to develop different methods and techniques to enhance the perceived indoor air, by measuring both material concentration and relative humidity levels. Fanger *et* al (1988) was the first to measure the perception of indoor air by introducing it as perceived indoor air quality. His measurement focused the possible discomfort level in indoor space relying on air quality, while the health impacts were not considered directly. Currently, odour perception, air acceptability can be measured by human subjects. However, this method cannot be frequently reliable to control and manage indoor air quality, in addition to the time and cost demand and subsequently requires a more technical method. Bitter *et* al (2010) conducted a study to measure the whole VOCs and their impact on odour intensity and air acceptability by using multi-gases sensor techniques that trace the human ability of smell as a comprehensive method rather than analytical system. The authors also argue that by using the analytical technique of chemicals, it is possible to distinguish the composites and the emission levels in the air, but not the transition to the sensory perception of human, since it remains difficult to achieve better results. Furthermore, the emissions rates accumulated indoors are regularly found less than the revealing outset of such measurement tools. The experiment set up relied on merging two types of odour intensity auditing; the sensory subjects who formed 20 people and the sensory technique (Multi-gas sensor system "KAMINA"). Seven different building materials were measured and some of these products were flooring adhesive and wood glaze. Two chambers were assigned; one for the odour intensity measurement and the other for inhaling fresh air. The set point air temperature was 21°C ±1 and RH 50% ±10% and the measurement scale of samples ranged between weak to strong in terms of odour intensity, and the data analysis were presented using Regression Analysis and Linear Discriminant Analysis (LDA).

The result showed that this sensory system was functional to plan a full diagram about the odour intensity caused by tested materials emission better than subjects' perception, but the obstacle remains in the RH. While RH demands to be measured on different variables, the need to evaluate the RH independently by integrating a mathematical method to the sensory model such as "Algorithm", gives better results in terms of data analysis process. This shows the importance of measuring and controlling RH in indoor air, while it's crucial to apply manageable level of RH in order to achieve acceptable air quality in the presence of different building materials and surface finishes. All previous factors are contributors to indoor air quality. The strength of emission in wood-based products identifies the implication on the perceived indoor air. According to Schripp *et* al (2012), scientific awareness has recently increased and has gone further in terms of effect on human health by addressing the development of secondary organic aerosols (SOA), where the gas converts to ultrafine particles (UFPs) in indoor air. The indoor particle formation ozone is highly reactive with terpenes compound and this reaction increases the terpenes presence extremely. Terpenes can be found in various wood products, while it forms original components of this material (Sundman *et* al 1998). Brown (1999) states that wood materials such as pine and spruce emit terpenes in different strengths into the indoor air. Additionally, the use of other artificial compounds such as oil coats intensifies the concentration levels of terpenes and result in more pollution in the indoor air (Singer *et* al 2006).

A study conducted by Schripp *et* al (2012) addressed the impact of applying green lacquers technique to wood products on indoor air quality and also aimed to address the development of ultrafine particles (UFPs) by the conversion of gas to particles, with the existence of indoor ozone or any other reactive types by studying samples of oriented strand board (OSB) painted beech panels and rigid wood tested in $1m^3$ chamber. The range of emission of VOCs with the pattern of UFPs was among 7-300nm. The outcome of the measurement shows the sample of green lacquer with the highest source of VOC (60 mg m^{-3}), the OSB with intermediate level and the lowest concentration in the rigid wood. On the other hand, the highest (UFPs) development was found to be in one of the solid/rigid wood samples which demonstrated clear and high reaction on surface in the presence of ozone and produced a significant number of particles <40nm. This experiment shows the importance of testing samples to predict the (UFP) indoor contaminants that result from the terpenes or the ozone chemistry, where it is not necessary to focus only on artificial components that are mixed with wood products. Some materials, like the previous solid wood, can increase formation of VOC due to ozone chemical reaction. Understating the implication of wood-based products treatments concentration and various building materials on human comfort and indoor air encounters many requirements, while different studies with various methods have been proposed. Numerous studies have shown the importance of performing investigation in indoor environment to examine and accommodate the VOCs emission and indoor contaminants that influence the sensory perception and the perceived indoor air quality and which conditions can enhance the comfort levels. Additionally, air acceptability dissatisfaction is not stated by majority of exposed people, where ultimate pollutants at harmful emission rates are not determined despite the many parameters available to measure and mitigate the impact on health comfort and reduce complaints in indoor environments. Many standards and regulations have been stated in terms of sensory irritation, odour intensity and air acceptability, but not all responses are similar under those conditions because satisfaction is usually measured under different circumstances. Some people are more influenced by other aspects such as thermal, visual, and acoustical aspects of the indoor environment and require comprehensive studies to address their implication on occupants' comfort. The indoor environment remains complex and related to many factors that have direct or indirect impact on people's health and comfort levels. It is suggested that these highly important factors need to be addressed in interior spaces in the early stages to achieve a desirable indoor environment with more productivity and less complaints.

2.2 The effect of air exchange rate on wood-based product emissions

Improving indoor air quality in interior spaces has been gaining a lot of attention from professionals recently. The proper and responsible practice is an important aspect to enhancing air acceptability levels and reducing odour intensity by focusing on manageable levels of air exchange rates. This practice varies among providing natural ventilation via building envelopes or applying adequate heating, ventilation and air condition (HVAC) system, in order to improve the principal of the perceived air by humans. Thus, assessing the impact of air exchange rate levels on indoor building material emissions in early stages of design can cause less emission from building materials and finishes that enhance the level of indoor air quality.

On the other hands, it is essential to evaluate the perceived air and study the relation with many chemicals emitted from wood-based products used in interior spaces for furniture, furnishing, floor and wall treatments. However, the comprehensive use of HVAC system in indoor environment to manage air circulation in old and new buildings in UAE, conclude that speculation may rise on whether a proper ventilation practice or air exchange rates is applied to these building to reduce the emissions caused by building materials, and to what extent it can form a solution to enhance the indoor air quality with the unlimited utilization of different building materials mixed simultaneously. People generally spend a large amount of time in indoor environments, but many indoor materials can cause pollution to the perceived air inhaled daily by space users. A study conducted by Wargocki *et* al (2000) in interior office space ($108m^3$) fully furnished and equipped looked at the outdoor air flow supply with three different values (3, 10, 30 l/s) per person, parallel to three various values of air exchange rate (0.6, 2, 1 h^{-1}). The office temperature was set at 22°C and relative humidity 40% remained the same with no changes. Subjects were six female of five groups (30 subjects) and each group was exposed to the three ventilation rate values. The experiment of each group lasted for 4-6 h in the afternoon, and all subjects were uninstructed of the ventilation and air exchange rate variations, since the noise status remained at a constant level in the office. Subjects were asked to complete some regular office tasks during each exposure in order to evaluate the perceived air quality, indoor environment climate and evaluate the level of intensity of their SBS problems. Results indicated that by increasing the level of ventilation and air exchange rate accordingly, the percentage of satisfaction was increasing respectively. The air quality, odour intensity of material and furniture, and the perceived air quality showed significant differences statistically ($P<0.05$) by increasing the ventilation rates, while percentage of dissatisfactory reduced significantly between subjects. Furthermore, dryness of mouth and throat showed considerable decreases ($P<0.006$) and increased a general pleasant feeling.

This study showed the importance of increasing the current levels to higher levels in some crowded indoor spaces, such as schools and offices that contain high density of people, as this yielded positive benefits that resulted in better health and performance, and less emission loads of furniture and wood materials. These studies indicate the direct relation between the air exchange rate and its impact on wood-based products emissions. Thus, providing proper ventilation rates with proper material selection will reduce the pollution load in indoor environment. Wolkoff (1998) investigated the impact of three factors in indoor environment: air supply, air temperature and relative humidity on VOCs emission from building products. The tested building materials are frequently used in many buildings; waterborne paint on beech wood floor, PVC floor, tufted carpet, waterborne paint on walls and the sealant joint of aluminum frame profile. Products have been measured in field and laboratory emission cell (FLEC) with $0.0019m^2$ for sealant material and $0.0017m^2$ for the remaining building materials. The air velocity ranged between ca. 1cm s^{-1} to ca. 9cm s^{-1}, while the air change rate values were set at 300, 600, 1400 and 2800 ml min^{-1}, with air temperature ranging between 23 - 60°C ±1.5 and relative humidity 0 – 50% ±5%. The clean air supply was replaced by pure nitrogen. The results of air velocity and air exchange rate shows that the primary emission of waterborne paint was not affected to a significant extend the few days after experiment. The reason of that is the fast dryness component the waterborne paint has. Conversely, in the PVC floor and sealant joint, the primary and secondary emission appeared to be slightly higher when increasing the air velocity from 5 to 9cm s^{-1}. This is caused by the deterioration of the dispersants added to these building material edges, while at higher air velocity, the bound coat appeared to be smaller which could result in better contact with the material surfaces.

Generally, this study indicates that with the increased air supply rates, the primary emission levels of waterborne paint was not highly affected, and in some other building products, the secondary chemical emission may increase to higher levels such as PVC and aluminum. According to Reed et *al* (2012), the air change rates can lower the level of concentration of many emitted indoor sources; people have a general habit to open windows to ensure a healthier flow of air rates in indoor environments. But in climate conditions like that of the UAE, it is often nearly impossible to rely on natural air for ventilation and will require a focus on HVAC characteristics to better predict air rates and minimize people's exposure to the emitted compounds from different wood-based material. Gilbert *et* al (2008) studied 96 houses equipped with heating system that were fully furnished and treated with wood-based materials in Canada. The study indicated the significant association between air change rates and formaldehyde concentrations generated by different indoor pollutions such as wood-based products used in furniture, wall paneling and flooring with their added paints and coats. Gilbert *et* al (2008) argue that by increasing the ventilation rates system from $0.23h^{-1}$ within $50\mu gm^3$ of formaldehyde concentration to meet the ASHRAE recommendations by $0.35h^{-1}$, most of these houses, especially older structures, will see a dramatic reduction of formaldehyde emission levels. The result indicated that the increased ventilation rates were adequate in 5 new homes that included new furniture and materials, and the emission of formaldehyde was significantly high especially for the first three years, but gradually decreased after this period. The proper air exchange rate is essential in any new or old house, but so is the proper selection of materials and finishes of wood-based products with the other interior materials that can enhance the ventilation efficiency and rates.

A recent study by Meyer & Hermanns (2012) illustrated the impact of air change rate on formaldehyde concentration levels of different wood-based products manufactured in different years and installed in traditional and mobile houses in the USA. Figure 2 shows the concentration levels of formaldehyde emitted from plywood wall paneling and particleboard flooring bonded with urea formaldehyde resin and the occupants' exposure to these pollutants in both structures. The level of concentration of particleboard in the year 1979 is 1.5ppm and plywood is 0.8ppm, while in 1981, the concentration level was reduced to 0.5, 0.35ppm, and subsequently reached the level 0.2, 0.12ppm in 1983. The baseline of Figure 2 presents the air change rate with different values ($0 - 2h^{-1}$). By increasing the value of air change rate per hour the level of formaldehyde concentration on each sample shows significant decrease, especially in Figure 2b in traditional houses. However, controlling the level of formaldehyde concentration of wood-based products from (0.8 – 0.12 ppm) can enhance the perceived air quality but applying higher air change rates can significantly reduce the impact of wood emission. The indoor air quality was also focused by another study conducted by Wargocki *et* al (2002) in an interior office space. The existing outdoor air rate was $1h^{-1}$ with no HVAC system used. However, in order to study the perceived air quality, the outdoor air was changed from 1 to $3h^{-1}$ which is equivalent to 0.83 to 2.5 l/s per m^2. The experiment was done with the present and absent sources of pollution in that office (sealant and wooden shelves) that cause high levels of pollution and reduce the quality of the perceived air. The air temperature was set at 23°C with relative humidity at 50% which remained constant in the office with no changes. The TVOC concentration levels were measured and the 30 subjects of female employees evaluated the level of air freshness and stuffiness in the present and absence of the polluted materials. The final result showed that by changing the scenario from present source of pollution to absent while increasing the outdoor air ventilation rate, the emission loads of VOCs emitted by furniture, furnishing and other office materials were reduced significantly and the perceived indoor air was improved.

This study indicated that reducing the pollution sources emitted by wood products or any other material can improve the air quality to high levels, similar to improving the air quality by increasing the air supply rates of the space. However, in regular air exchange rate in any interior space, formaldehyde accumulates dramatically and this is why formaldehyde concentration is necessary to measuring corresponding air exchange rates. However, if the source of emissions varied from mixed material usage in indoor space, the air concentration will rely on the source of emission and the type of surface adhesive (load factor) utilized.

Studies have shown that mixing adhesive and finishes to wood surfaces will cause poor indoor air quality and in order to identify the source of pollution the measurement should start from the most significant emitters to the lowest one (Meyer & Hermanns 2012).

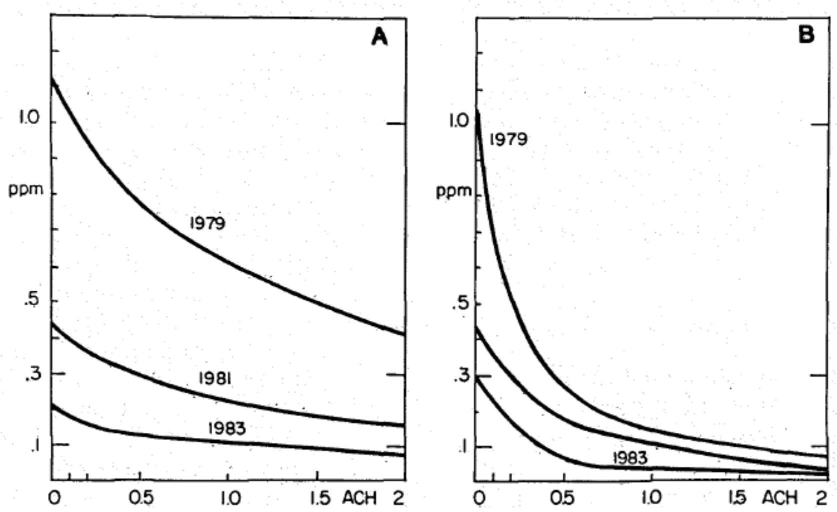


Figure 2.1 Concentration levels of formaldehyde resin in different year's corresponding different air change rate. (A) Mobile house (B) Traditional house (Meyer & Hermanns 2012)

2.3 Emission of wood (Chemical Reactions)

The use of wood-based products is common in every office, home, hotel and public building. These materials are presented as flooring, wall paneling, furniture and furnishing. In several interior spaces in the UAE, the need for these materials to be as durable, feasible, aesthetic and reasonable in price is significantly high and considered for primary use. Furthermore, the availability of wood-based products in different treatments and finishes in the local market with the huge construction sprawl accelerate production line for the industrial sector in order to cover the consumer needs. Many places in the UAE, such as hotels and schools, implement wood in interior design spaces to present luxury and embody a welcoming feature. However, the different finishes and treatments applied to these products have not yet been considered in different spaces in order to address the emission levels and chemical reactions.

As previously mentioned, the common used wood types in the UAE varies between wood with oil-based paint, wood with water-based paint, and wood with formaldehyde. The selection criterion of these products to many professionals generally does not require reading the labels of chemical emissions and its impact on human health. Wood-based products may release several VOCs into the interior space air and consist of significant bonding agent (urea-formaldehyde) that gives the panels stable bonding substances and sold at reasonable prices. However, these materials are highly toxic and can lead to many health issues (Kim *et* al 2010). Awareness on this issue can influence the community to select products with less chemical emissions and pollution that impact the indoor air quality. A study conducted by Kim *et* al (2006) using two types of wood-based products, Medium Density Fiberboard (MDF) and Particleboard (PB) – common materials in manufacturing furniture and flooring, yielded interesting results. The aim of this study was to measure the level of formaldehyde emission caused by these panels with different bonded and non-bonded edges. Japanese Industrial Desiccators Standard (JIS A 1460) was used to measure the released formaldehyde from wood panel surfaces. In each piece, the sealed edge varied between polyethylene wax, parafilm or aluminum foil. Different thickness levels were considered for the tested samples in order to identify the significant level of emission (9, 12, 15, 18 and 20mm thick) of PB and MDF in the specific temperature of 20°c. The result showed less formaldehyde emission between the sealed edges samples, while it was remarkably large in the unsealed case. The formaldehyde release was reduced between 50-80% in the PB and MDF flooring samples and 30% reduction in furniture products and both were sealed edges. Moreover, this study showed that by increasing the wood panel thickness, the formaldehyde emission was drastically reduced, and that is from the result of the different structure and porosity of each wood material.

The study also found that using sealant with polyethylene wax tends to have the highest rate of formaldehyde reduction among the other sealants although, it consumes more time in sealing but has better outcomes than aluminum and parafilm. This study showed the importance of considering the type of sealant edge in any wood product and how helpful it is to reach manageable level of emission during desiccators tests. These materials emit several types of VOCs and varied level of formaldehyde, and controlling this aspect earlier can help in reducing the negative chemical emission of these wood product surfaces prior to its installation in any building space. It is essential to install wood products – whether for flooring or furniture or any other fittings – with sealed edges to minimize the formaldehyde emission and VOCs gases in any interior space. However, the coated surfaces of any wood-based composite are a cause for concern in terms of contaminants and indoor air pollutions. Guo *et* al (2002) determined the main VOCs gases generated from PB are composed of formaldehyde, hexanol, butanone, benzene and benzaldehyde. Moreover, the plywood and particle cupboards emit other types of harmful gases, such as formaldehyde, aromatic, hydrocarbons and terpenes. The main source of these pollutants in indoor air involve various types of resins and wood fibers applied to bond fibers simultaneously, in addition to the use of different coatings and finishes to the wood surfaces.

According to Kim *et* al (2010) the most common VOCs found in indoor air varies between toluene, ethylbenzene, xylene and styrene. These compounds form the reactions of different coats used for MDF and PB surfaces. Furthermore, the emission is classified into two types: primary and secondary releases. Kim (2010) stated that most of the primary VOC emissions are caused by the utilization of wood products, the indoor environment, and releases from other building materials. Secondary emissions result from the impact of ozone in indoor space, humidity and UV light. The decomposition reactions in the coated wood floor that consist of PVC, adhesive and bonded agent can generate different VOCs gases such as butanol and ammonia, 2-ethylhexanol. The impact of emissions and reactions in indoor environment is clearly hard to control. Uhde and Salthammer (2007) classified the primary and secondary emissions into three cases: (i) undesirable reactions that take place while producing material and the consequences of reactions emitted in occupancy stage, (ii) undesirable reactions that occur on product surfaces due to mixing different materials in interior space, and (iii) undesirable reactions between two primary compositions of used materials in site (the reactions of primary gas emission from two different materials). In the UAE, most of the wood materials are imported from different countries that produce wood as building materials for interior and exterior use. In case (i), wood may have been potentially exposed to undesirable conditions during production. Generally, wood producers can recognize the impact of emissions and apply adequate procedures to avoid unwanted reaction throughout the production period. Case (ii) and (iii) present more complexities in the matter; it is essential to exclude primary emission from the secondary and study each one separately in order to determine the possibility of VOC emission with the users' complaints and health effect, especially with the increased number of chemicals that result from using different type of materials mixed with wood products. Wood products have to be treated carefully before producing them into furniture, flooring or any other fittings, in order to serve the required function with less chemical emissions. Therefore, selecting the appropriate coating to the surface can control the release of many harmful VOCs.

A study conducted by He *et* al (2012) highlighted the emission of formaldehyde and VOCs from wood-based panels in different production stages, such as the resin, wood flakes, wood fiber after adding the resin to MDF and integrating the phenol formaldehyde resin. The study presented the patterns and contents of wood materials in order to conclude and analyze the impact of raw material and the process of production. Wood panels were subject to baking and hot pressing techniques in temperatures that ranged between 120-200°c. A stainless steel chamber was used with direct air supply from top to ensure air flow and mix into the box. The temperature was controlled at 23°c via connected water bath to the chamber. The result showed four different facts: (i) 34 varied VOCs were determined such as 2-methylbutane, Acetone, Toluene, p-xylene, Pentane, although none were found repeated in all wood contents, and this illustrated the significant changes in VOCs during the production and manufacturing stages; (ii) the urea formaldehyde resin forms the major source of formaldehyde in wood based products; (iii) the release of VOCs in wood panels, especially MDF, are the result of the use of wood flakes/chips; (iv) the technique of hot pressing and baking of wood-based products were very helpful in minimizing VOCs and formaldehyde generations. Uhde and Salthammer (2007) argue that it is very critical to reduce VOC emission caused by wood materials and their reactions, and a proper test is required for each product prior to installation to minimize the pollution sources and reduce health complaints. Several types of paint are widely used in wood treatment and finishing, and many toxic compounds are included in the main compositions of these paints. The application of paint in many wood-based products varies between oil and water-based paint because the composition and the emitted chemical reactions of each differ widely from the other. Large areas of wood surfaces are coated, and the potential of contaminants emission in indoor air will occur decisively.

Li *et* al (2006) carried on a study to imitate VOC chemical emissions from water-based paint that is used for wood products indoors. FLEC chamber was designed mainly for measuring VOC emission from painted and coated materials. The emission from paint is usually categorized under three different stages: first, when covering any surface while the paint is not yet dry; second, when the material changes its form from dryness by transferring from emission evaporation to internal directed dispersion; and third, when the material transfers to dry stage is comparatively by internal dispersion. The study outcome showed that the major VOC emission from water-based paint were: 1-ethyl – 3-methylbenzene, and then the following chemical occurred: 1,2,4-trimethyl benzene, n-hexane, propylbenzene, 1,3,5-trimethylbenzene, toluene and o-xylene. The result indicated that there was a total of 23 VOCs found. The first seven major VOCs chemicals formed 85% of TVOC added the water paint composite. Ho *et* al (2011) conducted an experiment to examine the particular VOC characteristics released from various types of wood furniture used in residential spaces. The furniture were made of High Density Fiberboard (HDF), Medium Density Fiberboard (MDF), Rubber wood and Particleboard (PB). Their surfaces were covered with Polyvinyl Chloride (PVC), Polypropylene, Polyurethane Leather (PU) and Low Pressure Melamine (LPM). The experiment was conducted in large chamber ($5m^3$) at temperature set at 25°C and relative humidity (50%). The results showed that the predominant organic compounds were: α-pinene and toluene. The remaining VOCs are found widely among different chemicals: aromatic (AR), terpenes (TER), carbonyl (CBN), parattin (PR), olefin (HOL), halogenated paraffin (HRP). The results also indicated that there was no significant difference between the coated and uncoated wood products in terms of VOC emission levels. Moreover, the study also mentioned that the characteristics of VOC release are highly identified based on the main predominant chemicals between the tested wood samples.

A study conducted by Kim *et* al (2011) aimed to develop the 20L chamber method to measure formaldehyde and VOC emission according to Korean standards. The value of wood emissions from water-based paint, oil-based paint and emulsion paint were measured in 56, 121, 153 and $300g/m^3$ coat weight and 24 to 48 h treatment. The emission determinant of both formaldehyde and VOCs took place after 7 days within 34 to 48 h of treatment. The result showed the emission factors fluctuated under certain conditions while different coating weights among the four scenarios can result in different emission factor in relation to the curing time and air exchange rates in chamber. In oil-based paint sample at 121 g/m^2 weight coat, the emitted organic compound was benzaldehyde, while at higher weight surface than 121 g/m^2 to 300 g/m^2, the generated organic compounds were formaldehyde, acetaldehyde, acetone, propionaldehyde and benzaldehyde. In water-based paint, the following organic compounds were emitted between the weight surface coats (56 - 300 g/m²): formaldehyde, acetaldehyde, acetone, propionaldehyde and benzaldehyde. The emulsion paint weight coat was between 153 - 300 g/m², while at 153 g/m² acrolein was released and at higher levels up to 300 g/m² formaldehyde, acetaldehyde, acrolein, acetone, propionaldehyde and benzaldehyde were generated. However, the Korean guidelines require for paint to be measured 3 days after performing the test, while the emission components of TVOCs and formaldehyde start to settle 7 days after installation. The relation between the coat weights, installation time and emission factor is very critical in measuring the level of concentration and emission from wood-based paints. Therefore, the weight of paint coating surfaces can impact the organic compounds release of wood materials and increase the level of chemical emission indoors.

On the other hand, in an effort to mitigate the emission of formaldehyde (FA) and VOCs from wood materials, Kim (2009) studied the physical and mechanical elements and the potential of minimizing the FA and VOC release from MDF that is used in manufacturing furniture, by adding Volcanic Pozzolan (a type of siliceous material added to Portland cement widely) to the sample contents. The Korean Standard Method (desiccators and 20L chamber) was used to illustrate the FA and VOC emission before and after adding Pozzolan. As a result, the experiment showed that by adding Pozzolan to MDF contents, no remarkable changes were observed in the physical or mechanical properties of the MDF, but the emission of FA and VOCs was significantly minimized. This result indicated that Pozzolan is a good scavenger for MDF, and showed positive results in terms of emission control and/or reduction without causing any negative impact on the major properties of the wood sample. Nevertheless, according to Kim *et* al (2011), the emission factors in small chamber in terms of standards widely differs from the one used in any interior space. All the listed studies have shown the essential need to consider the coating and treatment of wood-based products in indoor environments. Meanwhile, many factors are related to various chemical reactions and emissions that harm people's health. Thus, the fact of discomfort in interior space and complaints can be reduced extensively and the optimum consequences can be derived early without any health concern or poor indoor air quality. Measuring the chemical reactions and emissions of wood-based product can be very helpful to achieving efficient ventilation and reducing energy consumption, while the ventilation and air exchange rates will be reduced significantly by specifying indoor materials with less and controlled chemical emissions.

2.4 The impact of wood based-products emission on human health

Wood is considered to be among the most commonly used materials across several civilizations throughout history and still remains a staple product for many structural and decorative elements in outdoor and indoor buildings. This material encapsulates durability, quality and good standard in terms of construction. Over the course of time, many concerns have risen up about wood treatments and finishes from the first phase of factory processing to on-site installation. The chemical emissions and reactions found in formaldehyde and VOC gases are forming a major concern in many countries globally. Moreover, the health and comfort issue is another major concern given that these types of emissions are significantly harmful to human health. Humans are exposed daily to large amount of formaldehydes that form a main composite in many materials used in indoor environment. According to the National Industrial Chemicals Notification and Assessment Schemers (NICNAS, 2006), susceptibility access of formaldehyde is easily absorbed by occupants. In case of breathe in, formaldehyde reacts immediately at the place of exposure and is rapidly metabolized in the respiratory membrane. Exposure to over 0.5ppm of formaldehyde in indoor air can cause sensory pollution to respiratory tissue, eyes and nose when inhaling this gas, thus affirming that formaldehyde is a major irritant and stimulant to human skin irritations. In principal, some of the sensory irritation that can result in spontaneous reactions upon exposure include burning eyes that shed tears, rhinorrhea, coughing, sneezing and strong alteration in the process of respiration that cause less defense to the exposed person during inhalation. It is well known that formaldehyde has a very stinging and acute odour, while it is commonly perceived by people at <1ppm concentration levels. Lang *et* al (2008) conducted a study that inspected the exposure of subjects to formaldehyde levels that correspond to the level found in their office and highlighted the potential appearance of sensory irritation and symptoms on subjects. The assessment of this experiment contained exposures to formaldehyde at the highest and lowest levels, the assessment with and without masking agent (12- 16ppm ethyl acetate (EA), and the impact of personality factors on assessment. The test was conducted on 21 healthy subjects (11 males, 10 females) and the study lasted for 10 weeks. Each volunteer conducted the test for 4 of the 10 hours of exposure settings over 10 sequential working days of the week.

The study outcomes showed the most sensitive factor is the eye irritation assessment. The occurrence of minimum objective sensory irritation was observed at the level 0.5ppm and the highest level at 1ppm. The volunteers' feedback scored complaints of irritation in eye and nasal at levels less than 0.5ppm and was highly affected by the personality factors and odour. Additionally, this study indicates that the levels of short period exposure to formaldehyde (between 0.3 – 0.6ppm) can cause irritation to the eyes, however long-term exposure at level 0.5ppm showed no sensory irritation to eye or nasal. According to Bohm *et* al (2012), the adhesives used to manufacture wood-based products such as formaldehyde is categorized separately than other pollutant sources, while it is perceived at levels below 0.03ppm, and the concentration levels above 0.1ppm can result in severe health issues. Additionally, Bohm *et* al (2012) found that this emitted gas is perceivable by smell at levels between 0.1-0.5ppm with slight possibility of sensory irritation to the eyes, nose and throat. The exceeded concentration levels among 0.5-1.0ppm in this chemical composite starts to generate sensory irritation of eye, skin and respiratory tissue in most of the exposed individual, whereas at levels that exceed 1ppm, formaldehyde can cause intensive feeling of discomfort.

A study divided into two experiments by Weber-Tschopp *et* al (1977) was conducted to measure the sensory pollution impact of different levels of formaldehyde concentration on exposed subjects. The first study contained 33 volunteers who were exposed for 35min constantly to formaldehyde emissions levels between 0 - 3.2ppm. Every 5min, eye-wink movement was measured and health questionnaires were filled concurrently. The second experiment included 48 subjects who were exposed in 1.5min to each formaldehyde value from 0 – 4ppm with flowing clean air of 8min during experiment for each subject. Subjects were only asked to fill questionnaires after 1min of inhalation across the different levels. According to the findings, the authors mentioned that at 1.2ppm, exposure to the eye and nose irritation was stated, while at 2.1ppm, there was more desire to step away from the room with larynx irritation. The eye-wink movement was observed increased at 1.7ppm level. Overall, the outset level of irritation was located between 1-2ppm. Another experimental by Anderson and Molhave (1993) was conducted on 16 volunteers and measured the sensory pollution levels from different formaldehyde concentrations. The subjects were exposed to different formaldehyde values for 5hrs (0.24, 0.42, 0.83 and 1.67ppm), including 2h of inhaling clean air prior to exposure to formaldehyde. The scale of discomfort on each level was measured, and general complaints were stated about eye irritation and feeling of dryness in nose and throat. At the minimum value (0.24ppm), 3 out of 16 (19%) complaints generated about sensory irritation in eye, and dehydration in the nose and throat, and this scale illustrates that the assigned level was irritating but not annoying. However, by increasing the level of concentration the complaints increased, while on 0.42ppm, the discomfort reached 31%, and on the level of 0.83ppm and 1.67ppm it has been reported that 94% expressed discomfort and high levels of annoyance including eye irritation and severe dehydration in nose and throat.

In the same field, an experiment conducted by Day *et* al (1984) to measure the level of formaldehyde impact on pulmonary path asked 18 volunteers to note any negative indication every 15min while exposed to 1.0ppm formaldehyde emission throughout 90min duration of exposure. The final report showed no intensive syndrome, where 83% reported eye annoyance, 39% nasal blockage, 33% burning eye, 28% larynx irritation, 17% running nose, 11% cough and 6% chest straits. Moreover, this experiment stated that there was no any clinically or high reaction either instantly or after 8h of running the experiment, illustrating that the level 1ppm of concentration had no severe impact on the pulmonary path function. Consequently, this study showed that exposure to formaldehyde emission in 1ppm level has no immediate high severe impact on people sensory irritation, while increasing the duration of exposure at that level (1ppm) can potentially increase impact on the pulmonary function and can impact the enforced expiratory volume. Kulle *et* al (1987) carried on a study on 19 volunteers (10 male, 9 female), where the formaldehyde levels were at 0, 1, and 2ppm with no activity and another 2ppm concentration with activity. Subjects were casually exposed for 3h duration. Furthermore, 10 subjects encountered the level 0.5ppm and other 9 subjects were encountered to 3ppm concentration. Rhinal flow resistance was measured directly pre and after test, and it became substantially uncomfortable at 3ppm, but not at 2ppm. The pulmonary role showed no significant changes pre-exposure, during and after 24h. To cover any warning sign, syndrome questionnaires were filled by subjects pre-experiment, after experiment and subsequently after 24h. However, 20% of subjects reported sensory irritation in eye at 0ppm. The feedback on average showed smell sensation and eye irritation at 1.44ppm. For nose and throat measure the relation were nearly significant at the 1.44ppm. However, there was a direct impact on sensory perception in terms of nose/eye irritation and odour intensity, but a significant syndrome was not reported within subjects at 3ppm neither without activity nor with activity.

In a follow-up study by Kulle (1993), additional statistical approach was used on the same indicative reaction of subjects, but by estimating new outsets of sensory reactions, where odour sense was at 0.5ppm, eye irritation ranged between 0.5-1ppm and nasal/larynx irritation at 1ppm. The result showed no considerable variations among male and female symptom feedback, and was almost similar to the average conducted in the former experiment. As a conclusion from the previous studies, the perceived sensory pollution caused by formaldehyde emissions in individuals principally includes eye sensitivity, throat and nose irritation. Most of the studies were conducted in formaldehyde levels that range between 0-3ppm to determine the impact on health. It was reported that eye and nose sensory perception occurred at levels <1ppm. Moreover, it is important to state that in 0 levels and with the absence of formaldehyde, a feedback of 20% by subjects reported eye irritation, and this percentage can confound the estimating outset of concentration. The low level responses, especially the one below 1ppm that ranges between normal and slight, illustrates the presence of pollution with no annoyance and all syndromes vanished rapidly showing that no significant effect at low levels, thus no serious reaction was stated. According to Arts *et* al (2006), in the case of low levels concentration of formaldehyde, the impact on human health can be considered to be sensory perception more than being sensory irritation or reaction. While for most subjects, eye irritation does not appear at less than 1ppm, and for most subjects, medium to strong nasal, eye and larynx irritation does not show unless the concentration level ranges between 2-3ppm or exceeds this level. Generally, duration of exposure is directly related to the levels of concentration hence, acute sensory irritation can be developed especially for those most vulnerable.

Wolkoff and Nielsen (2010) assumed that human sensitivity to irritants and pollutants may gradually increase throughout constant exposure to low emissions in indoor environment, while odours of formaldehyde is easily observable by majority of people at level below 0.08ppm since it can be measured. Spending a good portion of time indoors and inhaling various airborne contaminants from different building material and treatment such as wood-based products from furniture and furnishing can cause many acute and chronic diseases during short or long-term exposure.

Carrer *et* al (2001) emphasize that constant exposure to indoor pollutants can cause a serious problem to the upper respiratory area. Additionally, the risk of “asthma” in the lower respiratory area is greater especially for kids who are exposed to poor indoor air conditions with high airborne pollutants. Wolkoff and Nielsen (2010) explain that the level of exposure to formaldehyde has been provided by a regulations stated by the World Health Organization (WHO), where 1h exposure should not exceed the average of

0.123mg/m^3 (0.2ppm), and 8h exposure should not exceed the average of 0.05mg/m^3 (0.02ppm) in order to avoid the risk of asthma or any allergic impact on children. In terms of sensory irritation, the National Industrial Chemicals Notification and Assessment Scheme (NICNAS 2006) proposed to minimize the exposure level of concentration in formaldehyde to 0.3ppm over an 8h time weighted average (TWA). In the case of short-term exposure threshold/limit (STEL) 0.6ppm, while minimizing the exposure level to this limit can add sufficient and comfort indoor air with less sensory irritation, and reduce the risk of possible cancer on long term exposure. Therefore, it is essential to mention an outset level of formaldehyde concentration in the indoor environment with the appearance of various emissions and chemical reactions of building materials and treatment. Wolkoff and Nielsen (2010) also addressed the ability to provide indoor environment with less than 0.1ppm formaldehyde concentrations across 24hrs daily, the sensory irritation to the human exposure should be prevented substantially. However, studying the correlation in gas phase pollutants concentration emitted by the commonly treated wood products in the UAE and their impact on human subjects is very critical in terms of sensory irritation, odour intensity and air acceptability, while this product is forming a part of a larger and other building materials and products utilized in indoor environment that emit high levels of formaldehyde. Additionally, the high level of formaldehyde concentration emitted by wood-based products can have remarkable impact on health.

2.5 Knowledge Gap

Different studies have been conducted to investigate the impact of using different wood-based product finishes and coats indoors. These studies have considered all the environmental and personal factors related to indoor air quality and their impact on sensory pollution perception of space users. However, little or no studies have been considered the UAE or hot region countries in terms of sensory pollution impact indoors. The use of wood-based products with different finishes and coats is applied widely given the high demand of furniture, furnishing, flooring and wall paneling in many interior offices, hospital, schools and generally high-traffic areas. Therefore, there is an obvious lack of study and significant need of knowledge in the UAE about the perceived indoor air quality by people. Moreover, gender assessment to the perceived air quality indoors can vary between male and female and consideration of air change rates in different interior space can change people sensory perception of indoor air. According to Essed *et* al (2009) considerable differences have been elaborated between men and women patterns of health and illness either from biological, sociological, and cultural factors. Women life time average is higher than men; so far they even have a tendency to complaint more about suffering from sickness and anxiety. Moreover, the type of diseases varied widely between the two genders. For instance men are more possibly to die too early from heart attack sickness, while women suffer more from auto-immune sickness and from early depression and anxiety in the same community. On the other hand, male and female life style of health and illness are also identified by gender control and influence. Obviously, the regular lives of both genders in the same society vary frequently and affect their exposure to health risk significantly. Therefore, both biological and social factors are marked as important factors in gender comparison and assessment alongside with the cultural diversity and have a direct impact on rates of susceptibility, symptoms and reaction between genders. Thus, gender comparison has been considered in this study. All these factors can support other studies in different indoor environments in the UAE that are geared towards improving the quality of perceived air and increase the level of comfort indoors.

2.6 Research Questions

1. How would the variation in air change rate (Fan off/ Fan on) influence the emission of treated wood based products correlate with their impacts on human subjects' perceived odour intensity, sensory irritation, and air acceptability?
2. Would there be a significant difference in perceived air quality between gender assessments of pollutant emitted by four commonly available treated wood based products in the UAE?

2.7 Aim

The aim of this research is to study the impact of wood-based products treated with three different finishes used in the UAE industry on perceived sensory pollution of people.

2.8 Research Hypothesis

Hypothesis 1:

“The level of pollutants can appear higher in oil-based paint and urea formaldehyde wood samples due to the high quantities of VOCs used as solvents in these products and can result in high odours, polluted indoor air and sensory irritation**’’**.

Justification of Hypothesis 1

The perception of poor indoor air quality is generally predicted by people’s discomfort and complaints. The common indoor air complaints are linked with odour concentration, sensory irritation and air acceptability levels. According to a study by Peng *et* al (2009) that examined smell problem in an IT office (Information Technology office), the study analyzed perceptions by employees in a medical center due to frequent complaints. The study investigated VOCs and chemical pollutants concentrations emitted by installed building materials with different coats and finishes. The detected material synthetic included high concentrations of some chemical pollutants such formaldehyde, acetone and acetaldehyde that appears majorly in the composition of material finishes and treatments.

Hypothesis 2:

“The level of dissatisfaction may increase significantly in oil-based paint wood products and melamine urea formaldehyde based product based on previous studies that have been conducted with various effect between genders (Subjective measurement)**”**

Justification of Hypothesis 1

In the same study of Peng *et* al (2009), the odour intensity was assessed by subjects (non-smokers from both genders) who reported odour annoyance revealed in their offices. Consequently, and after measuring the chemical pollutants concentration and VOCs emission and comparing it to the subject's odour perception and irritation, the result showed very high correlation among VOC concentration levels and the constant odour occurrences. Thus, it is essential to measure and identify the chemical concentrations and origins of odours, and to study the correlation between indoor chemical emissions that generate various odours and cause discomfort indoor air by considering subjective measurement.

2.9 Objectives

1. To examine the correlation between variation in air change rate (Fan off/ Fan on) on studied treated wood products and their impacts on human subjects' perceived odour intensity, sensory irritation, and air acceptability.
2. To examine the significant difference in perceived air quality between gender assessments of pollutant emitted by four commonly available treated woods based products in the UAE.

CHAPTER 3: RESEARCH METHODOLOGY

Chapter 3: Research Methodology

3.1 Ethical Consent and Experimental Protocol

Faculty Research Ethics Associate Committee in the British University in Dubai confirmed the use of human subjects for the present experiment. The subject volunteers who participated in this experiment were between 20 and 30 years of age. For the experiment test scenarios, 10 subjects were present as "Group 1" for the 1st round 27th Jan and 10 subjects were present as "Group 2" in the 2nd round 28th Jan. The subjects evaluated the level of acceptability of air flow in the chamber based on constant acceptability measure scale which varied from (-1) obviously unacceptable to (+1) obviously acceptable. Secondly, the odour intensity level that was evaluated based on constant intensity scale that varied from "no odour" (zero) to excessive "overpowering odour". Moreover, additional points marked on the measurement scale were: "slight odour" (20), "moderate odour" (40), "strong odour" (60) and "very strong odour" (80). Nose and eye irritation levels followed continuous evaluation scale that varied from "no irritation" (0) reaching to "overpowering irritation" (100). Complementary points marked on the measure are: "Slight irritation" (20), "Moderate irritation" (40), "strong irritation" (60) and "very strong irritation" (80). The last scale measured by subjects was the perceived air freshness and stuffiness, by utilizing 100mm long observable peer scales with margined endpoints (right endpoint = (0) stuffy, left endpoint = (100) fresh) (Wargocki 2004).

Subjects answered questions on issues related to: smoking habit, use of lenses, their health (Gminski et al 2010) by filling a consent form, where the study and experiment was clearly detailed in this form prior to experiment in order to consider the relevant ethical aspects in conducting low risk research. Four different wood-based products that are commonly used in the UAE market were used in test by adding three different finishes to their surfaces and testing one more raw wood material without any additives. The studied samples were: (i) wood panel with water-based paint, (ii) wood panel with oil-based paint, (iii) wood panel with melamine urea formaldehyde (MUF), (iv) normal MDF sample (Medium Density Fiberboard) without any additives (Figure 3.2). Additionally, assessment was done when the chamber was 'empty'. The selection of these samples was based on their common use in the UAE market and industry, and the use of these materials in many interior design projects especially the commercial projects such as offices, where the use of wood is frequently found in furniture, wall paneling, flooring and doors. Each sample was tested in two chamber conditions: No Fan and Fan On in order to assess the perceived air quality in both states. The two subject groups are listed in Table 3.1 according to the sample sequences for each day.

In 1st round 27th Jan, the experiment started with TYP 1 (MUF) and ended with TYP 5 (Normal MDF) with no additives. Each sample was kept for 10 minutes before subject exposure under the two conditions (Fan On/No Fan) as previously mentioned. Moreover, between each sample, 15 minutes were assigned for venting the chamber to flush out the odours and emissions concentration of each sample. In the 2nd round, the same scenario was repeated but by reversing the sample sequence from TYP 5 to TYP 1. Before entering the field laboratory housing the test chamber, each subject had inhaled air coming from fan placed outside the field laboratory. The inhaled air from the fan served as a reference of what fresh air should be. Subjects were then required to hold on to the inhaled air and exhale the air just before smelling air coming out of the chamber and immediately filled the questionnaires after this process. Volunteers were only allowed to drink water during the assessment time.

Table 3.1 Subject groups and the scenario followed for wood samples on each round of experiment

Date: 27.1.2013		**Date: 28.1.2013**	
No.	**Group 1 – 10 Subjects (3M/7F)**	**No.**	**Group 2 - 10 Subjects (5M/5F)**
1.	TYP 1 (Melamine Urea Formaldehyde)	1.	TYP 5 (Normal/No Adhesives)
2.	TYP 2 (Empty)	2.	TYP 4 (Water)
3.	TYP 3 (Oil)	3.	TYP 3 (Oil)
4.	TYP 4 (Water)	4.	TYP 2 (Empty)
5.	TYP 5 (Normal/No Adhesives)	5.	TYP 1 (Melamine Urea Formaldehyde)

3.2 Chamber test

The experiment was conducted at the British University in Dubai in two of the University's classrooms; one was used to place the chamber and the second classroom was assigned for subjects to spend their time during the experiment. The subjects' classroom temperature was set at 21°c and RH 45%. The experiment duration was carried over two days. The small chamber was 60cm (L) x 60cm (W) x 60cm (H) = 0.216m^3 made from 6mm clear glass and supported by aluminum profile (4.5cm) from edges hermetically and a central fan was fixed at the bottom of the unit to provide positive pressure (controlled air flow) to the sample which is placed on a lattice plate of steel to allow air flow from the bottom of the sample (Figure 3.1). No silicon or adhesive were used to assemble the glass panels in order to reduce any outer impact emission on the sample and the measurement tools. The chamber condition was set to be ±1.7 24°c temperature, relative humidity ±10% 60% and the samples loading factor was 1.4m²/m³. The samples were tested subjectively under two air velocity conditions respectively. Subjects were inhaling the samples' smell through a PVC pipe with two scenarios; No Fan air velocity 0m/s and Fan On air velocity ±0.2 0.3m/s. The chamber was hidden by a cloth cover and the only visible part was the PVC pipe to prevent any bias and rely on subjects' sensory perception (Figure 3.3). To answer research questions and objectives, 1 and 2 survey methods were used to obtain subjects responses with regards to sensory irritation, odour intensity, and air acceptability resulting from exposures to air coming out from the test chamber.

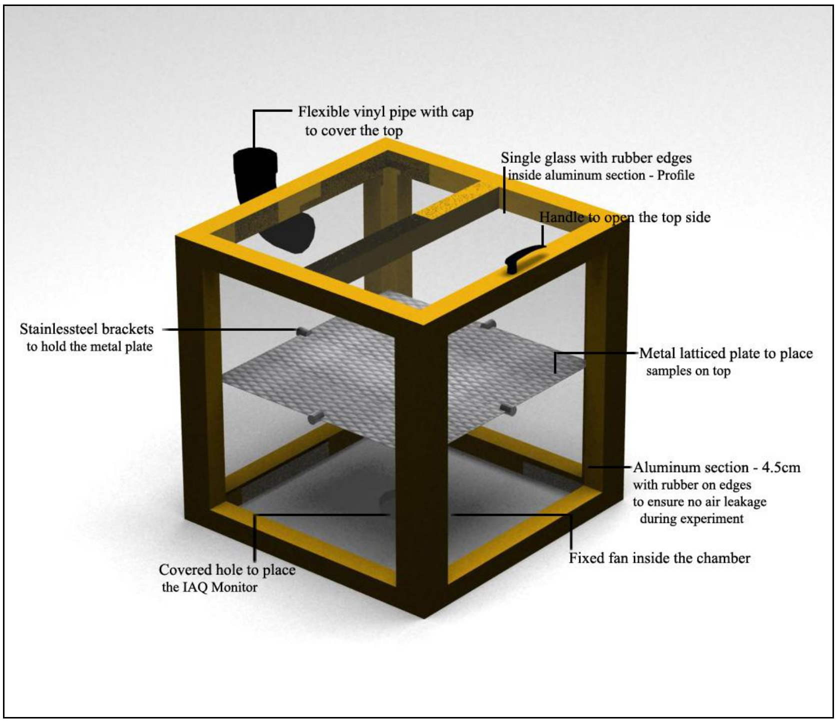


Figure 3.1 the designed chamber used to conduct the wood sample test (Author 2013)

Figure 3.2 MDF tested Samples (Author 2013)

Figure 3.3 the chamber hidden by cloth cover during assessment rounds (Author 2013)

3.3 Wood Samples Technical Information

The technical information of the wood samples was provided by EVI VERNICI CO. – DUBAI/UAE, and the wood samples were manufactured by Dubai Wood Factory – SHARJAH/UAE. All samples were made of MDF with the previous mentioned treatment. The sample size was 21cm x 29.7cm and thickness is 6mm except for Melamine Urea Formaldehyde 18mm due to the implement of double layers of transparent resin. Samples have been sealed by plastic bubbles wrap after manufacturing to contain the material compositions that may emit during delivery time and present it as new material on real site. The major composition and application field on site of water-based paint is that it is a waterborne clear basecoat suitable for the varnishing of indoor, such as doors and furniture. It is used as a base coat on pieces previously sanded with sanding paper 100. It shows a top performance in terms of covering, drying and hardness, when compared to traditional polyurethane finish. It has low solvent content and excellent flow leveling and has a low VOC of less than 3%, making it an environmentally friendly product. For oil-based paint Polyurethane sealer (PU), this transparent polyurethane basecoat is easy to sand and is indicated to varnish furniture, doors window sash frames, frames and casing. It's also endowed with good plasticity, good transparency and very good build, in addition to a good over spraying resistance conditions. The Melamine Urea Formaldehyde (Acid Curing Sealer) is a Clear Acid Curing sealer made up of two components, endowed with high solid contents and is easy to sand. It is indicated to varnish furniture, doors, window sash frames, frames and casing. It's endowed with a good plasticity, good transparency and very good build.

More technical information and safety data are listed in appendices.

3.4 Data Analysis Method

The responses between the two fan conditions in chambers hereby referred to as No Fan and Fan On. The first part of assessment in results showed the percentage of people dissatisfied, the level of air acceptability, odour intensity, nose irritation and the level of the perceived air freshness by applying the two fan conditions (No Fan and Fan On) between all wood samples, including all subjects, and both fan conditions were compared as two values using *t*-test analysis method. This method has been used to address research hypothesis 1 & 2 to measure the effect of (No Fan and Fan On) on perceived air quality, and whether the level of pollutant of each sample and level of dissatisfaction will change by changing the fan conditions.

The same analysis method was applied to the two fan conditions when assessment was separated to be presented as round 1 in first subjects group and round 2 in second subjects group. In both groups the four values of odour intensity, nose irritation, air freshness and air acceptability were assessed to test if there was considerable difference statistically observed among all samples. Therefore, results have addressed research hypothesis 1 in terms of the highest level of wood samples pollutant among the two rounds. Moreover, the separated analysis of round 1 and 2 will have consistency in results with gender comparison assessment.

The responses between the two genders (Male vs. Female), the two groups (GRP 1 vs. GRP 2) assessing the four variables of the perceived air quality were also compared and analyzed using *t*-test under the two fan conditions (No Fan and Fan On) to address research hypothesis 2.

The tested wood products were also compared as two samples versus each other on *t*-test to check the statistical difference and the effect between the compared two wood samples on perceived air quality. ANOVA analysis method was used to compare the mean values for the 5 tested scenarios to assess air acceptability, odour intensity, nose irritation and air freshness to address research hypothesis 1 and 2. The final data was presented in figures and in tabular form for both *t*-test and ANOVA method to conclude statistical analysis.

3.5 Limitations of the Study

The study is limited to the use of Medium Density Fiberboard (MDF) wood panels, despite the available of a wider range of wood panels and treatments such as High Density Fiberboard (HDF), Plywood and Particleboard, and some of these wood panels however, may have been subject to different levels of polyurethane products, solvents, additives, stains and curing. The study is restricted to sensory pollution assessment by subjective measurement without comparing it to physical measurement assessment. However, all the above mentioned limitations are mainly caused by time constrains.

CHAPTER 4: RESULTS

Chapter 4: Results

4.1 The Effect of (No Fan and Fan On) on Perceived Air Quality

Subjects in Group 1 and 2 assessed four values on the measurement scale: odour intensity (OI), nose irritation (NI), freshness of air (FRESH) and air acceptability (ACC). Figure 4.1 illustrate the percentage of people dissatisfied by applying the two fan conditions (No Fan vs. Fan On) among all samples, including all subjects. The Urea-Formaldehyde (UF) shows more disstatisfied subjects with No Fan condition, while by changing the chamber condition into Fan On, the percentage reduced to 5.8%. In empty chamber, the percentage reversed, and the Fan On condition showed slightly higher percentage of dissatisfaction at 7.1%. In oil sample, the percentage reduced to 18% by changing the chamber condition to Fan On, and the highest percentage of dissatisfaction scored on oil sample. On the other hand, the water sample was significantly lower than oil and subjects showed more satisfaction in Fan On condition, while the percentage reduced to 13%. The normal sample percentage shows similarity in percentage to empty chamber. The subjects scored more dissatisfaction by 5% in Fan On condition.

Figure 4.1.1 shows the level of air acceptability between the two fan conditions (No Fan vs. Fan On) including all subjects. The acceptability of air increased in UF to reach 0.51 on scale by changing the chamber condition to Fan On, while in oil and water sample, the same result appeared and the acceptability of air enhanced in Fan On chamber. Conversely, the acceptability of air in empty chamber and normal sample reduced slightly in Fan On state, but the value was not less than just acceptable on assessment scale. However, with all this variation, there was no significant difference observed statistically among all samples in both fan conditions. Figure 4.1.2 shows the odour intensity levels among all samples by comparing the two fan conditions including all subjects. In all samples, except for TYP 4 (Water), there was no significant difference observed statistically ($P>0.05$) when changing the fan conditions. However, the only significant variation was found in water sample ($P<0.05$). The remaning sample showed slightly difference in odour intensity levels. Figure 4.1.3 illustrates the nose irritation differences among all samples in the two fan conditions, including all subjects. Figure 4.1.4 demonstrates the assessment of the perceived air freshness among the two fan conditions including all subjects. Both figures indicated that the air freshness levels among all subjects showed no significant difference statistically by changing the chamber condition from No Fan to Fan On ($P>0.05$). In all samples, the change of air freshness appears to be slight. UF, oil and water samples of air freshness increased slightly in Fan On condition, while the empty chamber and normal sample showed slightly decreased values on assessment scale when shifting the chamber state to Fan On.

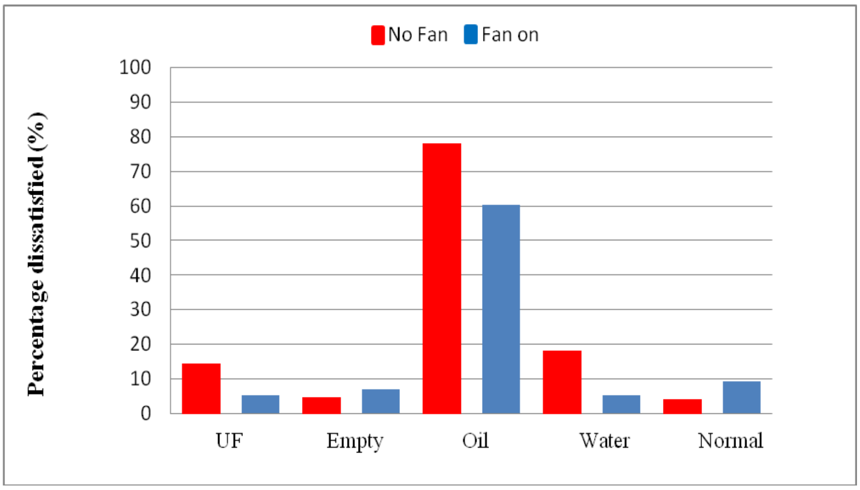


Figure 4.1 Percentage of people dissatisfied with No Fan or Fan On.

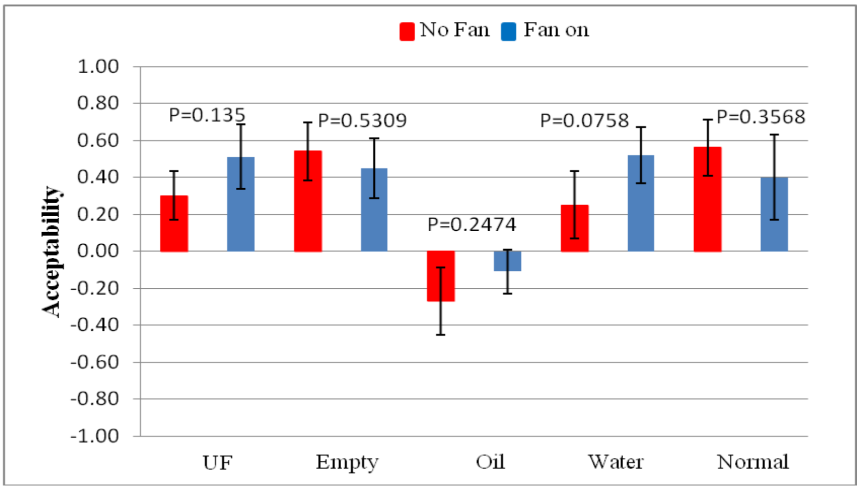


Figure 4.1.1 Subjects rating of the air acceptability coming out of the chamber with No Fan or Fan On.

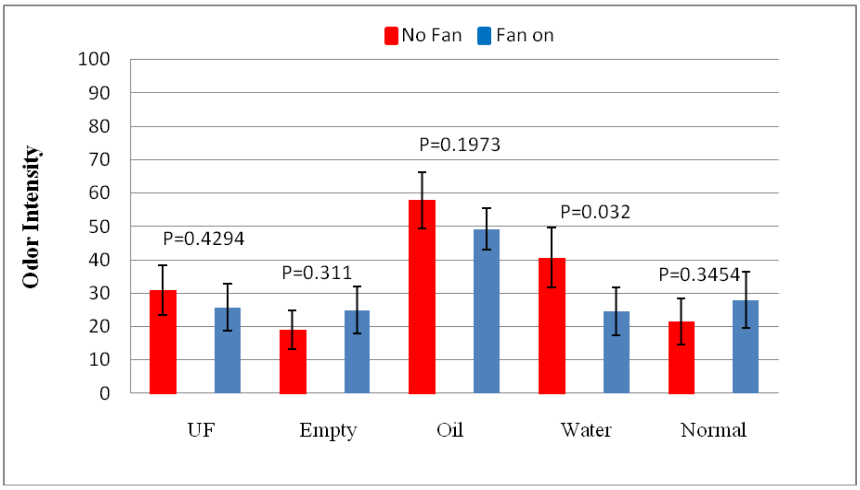


Figure 4.1.2 Subjects rating of the odour intensity released of the chamber with No Fan or Fan On.

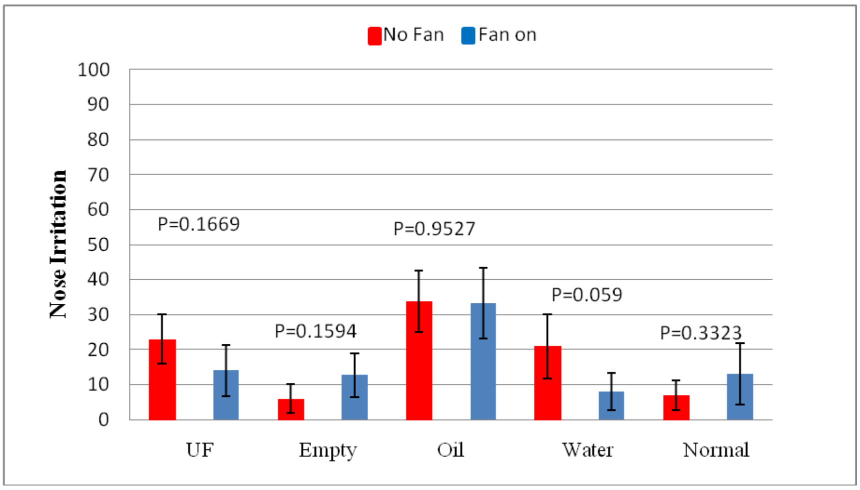


Figure 4.1.3 Subjects rating of the nose irritation released of the chamber with No Fan or Fan On..

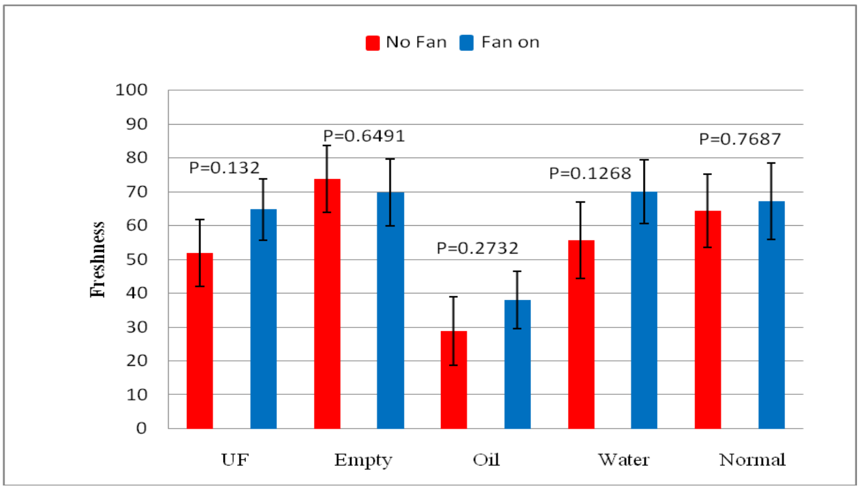


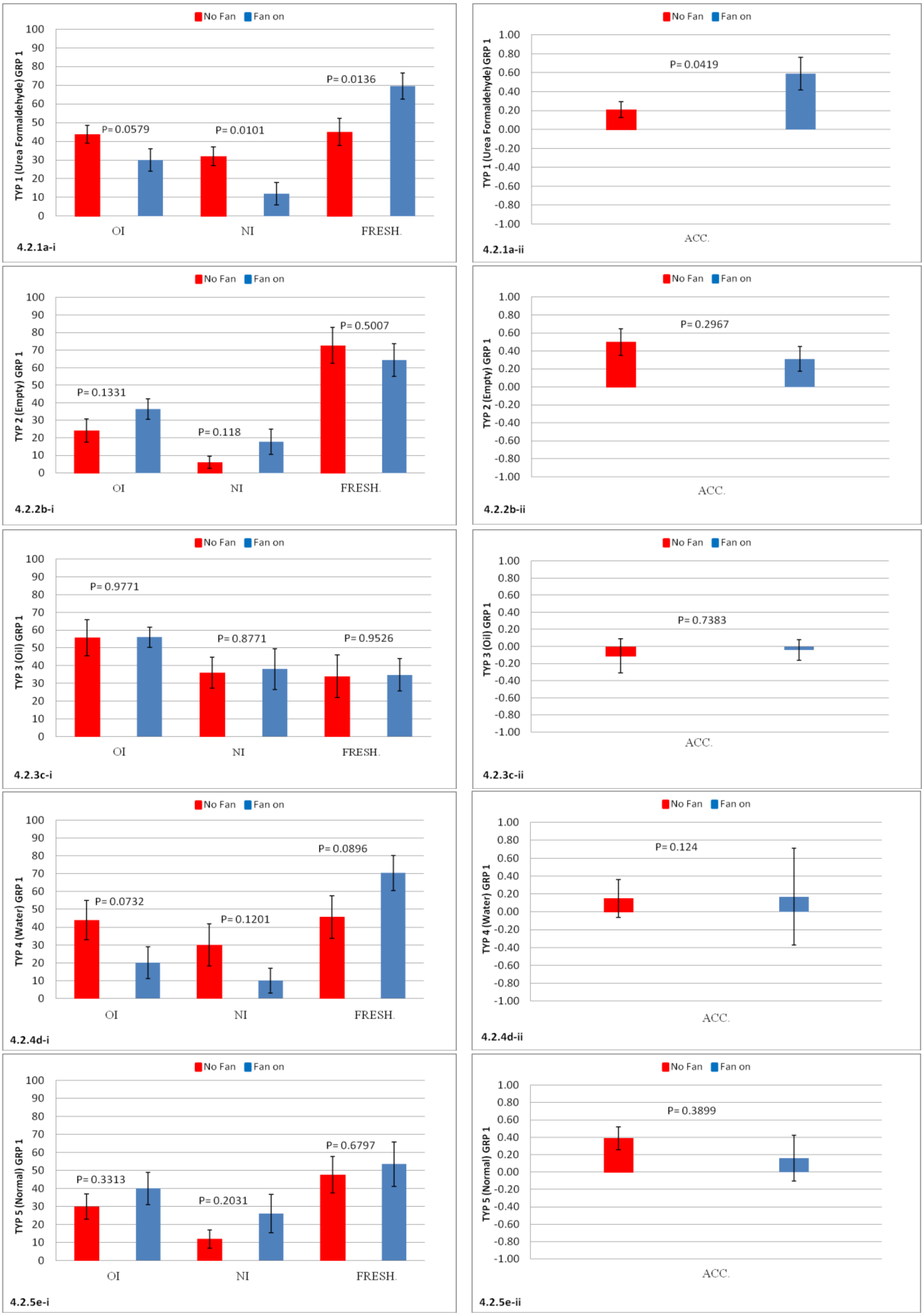
Figure 4.1.4 Subjects assessment of the air freshness coming out of the chamber with No Fan Or Fan On.

Figure 4.2 shows the assessment of the four values between the two fan conditions (No Fan vs. Fan On) for each sample separately in group 1. In Figure 4.2a-i (UF sample), the mean value of odour intensity in No Fan condition is moderate with 43 on the measurement scale and at Fan On, the results was slightly lower at 30. Although the odour intensity in No Fan chamber was higher than Fan On chamber, there were no significant difference in the results ($P>0.05$). For nose irritation, the mean value in No Fan is 32 on scale which is close to moderate irritation on the measurement scale, while in Fan On, the percentage decreased drastically by 26.6% and the assessment showed 12 on scale for nose irritation, with substantial difference shown statistically ($P<0.05$). Freshness of air in No Fan vote scored 45.1 on measurement scale, while in Fan On, freshness was better at 69.5, with a significant difference ($P<0.05$) between air freshness levels detected. In terms of air acceptability (ACC), Figure 4.2a-ii showed the No Fan state resulted in 0.21, which is slightly close to just acceptable on the measurement scale, while in Fan On condition, Group 1 assessed the air quality by 0.59 which is more close to clearly acceptable. The difference between No Fan and Fan On in terms of air acceptability is significant by 38% ($P<0.05$).

In Figure 4.2b-i, sample 2 is presented (empty chamber). Odour intensity in No Fan condition showed slight odour by 24.1, while Fan On illustrates an increased value of 36.30. However, the Fan On condition showed increased value in terms of responses than the No Fan, but there was substantially no difference in results ($P>0.05$). The mean value of nose irritation in No Fan is 6 which are more close to no irritation on the measurement scale. In Fan On, nose irritation reached a mean value of 17.7, which indicate slight irritation on the measurement scale. Although, the percentage of Fan On was higher than No Fan by 11.7%, there was no significant difference statistically on result ($P>0.05$). For air freshness, Group 1 response in No Fan and Fan On were slightly similar (72.65, 64.3 on measurement scale) and more close to fresh air on measurement scale and no significant variation observed (P>0.05). Figure 4.2b-ii demonstrated the acceptability of air among the two fan conditions, where No Fan value shows 0.5 and Fan On shows 0.31, and these values indicate that there was no significant difference between the two conditions in TYP 2 (P>0.05).

In TYP 3 (oil-based paint), Figure 4.2c-i shows the odour intensity value in considerable similarity for both fan conditions (55.7, 56) which indicate strong odour on the measurement scale. Thus, no significant difference in odour intensity results were detected among fan conditions in Group 1 (P>0.05). Nose irritation mean values in both fan conditions were also extremely similar (36, 38%) with moderate irritation, and marginal difference in results (P>0.05). The vote scale of air freshness also shows parallel percentages, with No Fan at 34 and Fan On at 34.8, and this indicates that air freshness was more close to stuffiness and no significant difference appears by changing the fan condition (P>0.05). Figure 4.2c-ii presents the acceptability of air, while in both fan conditions, the subject responses in Group 1 exceeded by a slight difference to just unacceptable. In No Fan chamber, the value was measured at -0.11 and in Fan On condition, the value was at -0.04. However, the variation was slightly big but the results showed minimal difference between the two fan conditions (P>0.05). In TYP 4 (water-based paint), Figure 4.2d-i shows the odour intensity value in No Fan condition with moderate odour (44) and in Fan On state, the percentage reduced by 22% and the subjects' vote scored a slight odour (20). While there was no significant difference on the results of odour intensity (P>0.05), the percentages between the two fan conditions was moderately high. For nose irritation, the No Fan chamber vote was slightly close to moderate irritation on measurement scale and in Fan On chamber, the subjects' response of nose irritation reduced moderately to score 10, which is intermediate between no irritation and slight irritation on measurement scale and subsequently indicated no statistical difference (P>0.05). Air freshness in No Fan condition scored 45.7 which are slightly moderate on the measurement scale between stuffiness and freshness. By changing the chamber condition into Fan On, the air freshness enhanced and subjects vote showed increased value by 70.4, or closer to fresh air. The variation between the two fan conditions was 24.3% but there was no significant difference on results observed (P>0.05). Figure 4.2d-ii demonstrated the air acceptability on each fan chamber conditions. In No Fan and Fan On conditions however, the values were considerably similar (0.15, 0.17), or close to just acceptable on scale, with a slight difference observed (P>0.05).

Figure 4.2e-i illustrates TYP 5 (Normal MDF) mean values. The odour intensity shows slight similarity among the two fan conditions. In No Fan chamber, the subjects' responses average is 30 and by running Fan On mode, the average increased slightly to reach 40, which also indicated no significant difference in results (P>0.05). Nose irritation in No Fan condition scored 12 which is more close to no irritation and showed increased average by 14% in Fan On chamber. With a variation of 14% between fan conditions, there was no significant difference noted among results (P>0.05). In air freshness, both fan conditions showed no significant differences, while 47.6 for No Fan and 53.5 on scale for Fan On (P>0.05). The acceptability of air in Figure 4.2e-ii also demonstrated no significant difference (P>0.05) when setting No Fan (0.39) and running Fan On modes (0.16). The two values are slightly close to just acceptable on measurement scale.



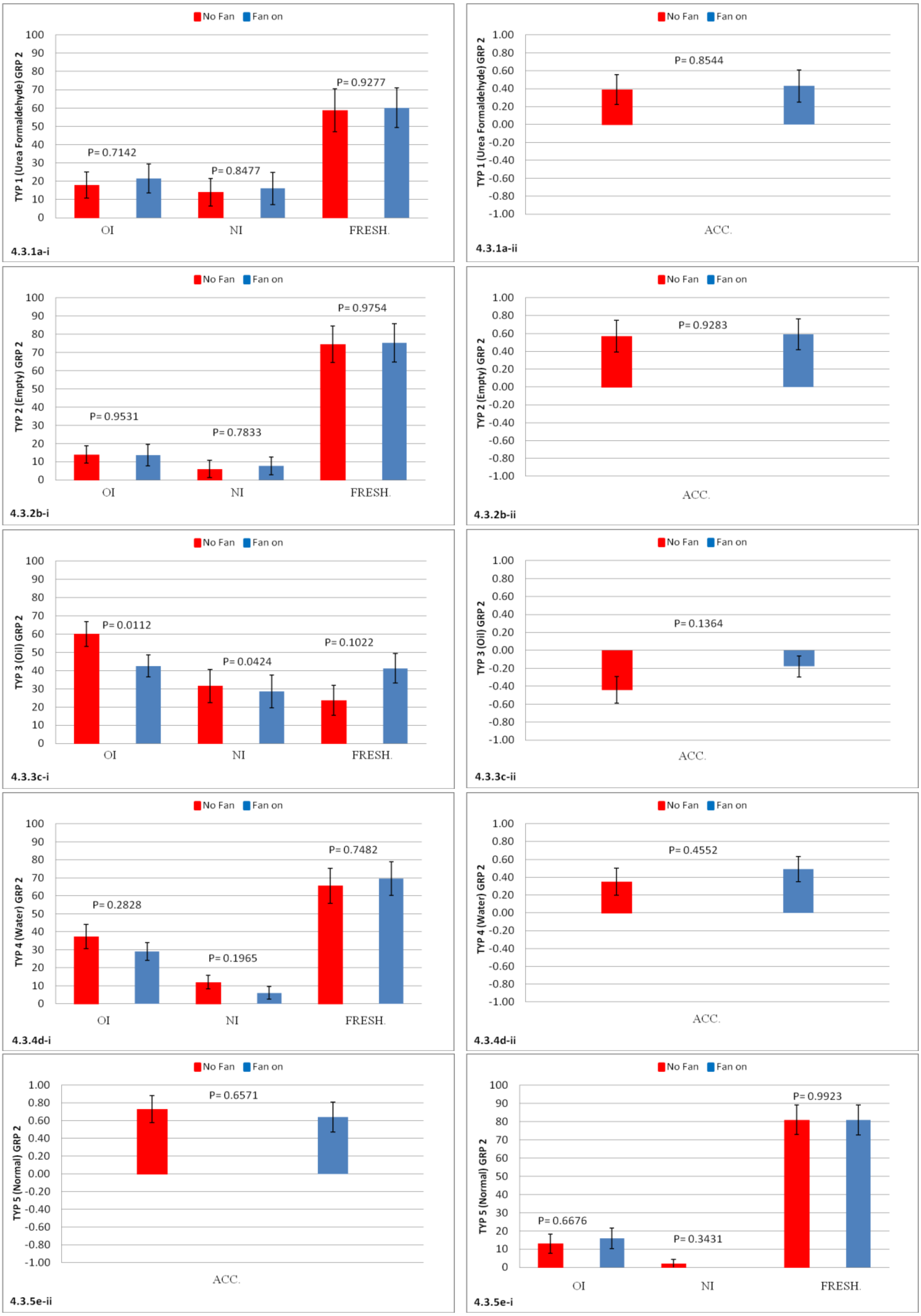
Figures 4.2 Group 1 subjects assessment of the perceived air quality released of the chamber with No Fan or Fan On.

Figure 4.3 shows the assessment between the two fan conditions (No Fan vs. Fan On) for Group 2 subjects. Figure 4.3a-i shows TYP 1 (UF) subject responses, while in No Fan chamber, the odour intensity value scores 18, which indicate slight odour on measurment scale and the value increased slightly in Fan On condition to reach 21.5 but with the same assessment on scale (slight odour). This denoted negligible difference among the two conditions for odour intensity (P>0.05). Nose irritation is similar to the odour intensity mean value, where no significant difference was statistically observed among the two fan states (P>0.05) and both fan conditions showed similarity in terms of scale assessment with slight irritation (14, 16 on scale). Air freshness mean value were almost parallel, where subjects scored 58.8 on scale during No Fan state, and scored 60 during Fan On, which also indicated no significant variation in results (P>0.05) and Group 2 perceived the air quality to be more fresh in TYP 1. Figure 4.3a-ii shows that the air acceptability varies in the range of clearly acceptable and just acceptable among the two fan conditions with very slight difference among values (0.39, 0.43 on scale) and no significant variation observed statistically (P>0.05).

In TYP 2 (Empty chamber) Figure 4.3b-i shows the odour intensity with very slight odour on scale by the value 14 in No Fan condition and was reduced very slightly to 13.6 value in Fan On state. Nose irritation indicated the value 6 and 7.7 on scale in both fan states which indicate no irritation on measurement scale. Both results indicated no difference statistically (P>0.05). For air freshness, almost smilar values were presented statistically at (P>0.05), with no significant difference and the air freshness on measurement scale was high considerably in both fans' state (74.4, 75.3). In terms of air acceptability, the No Fan chamber is similar to Fan On chamber in figure 4.3b-ii, where in both states, the values were close to clearly acceptable on measurement scale (0.57, 0.59) with no significant difference (P>0.05). TYP 3 shows strong odour intensity in figure 4.3c-i in No Fan condition and was reduced to 17.5% by runing the fan on to reach moderate odour on measurement scale. However, the two values between No Fan vs. Fan On was 17.5%, but the statistical results showed significant difference (P<0.05). The nose irritation values ranged between slight to moderate irritation by 31.5 in No Fan chamber and 28.5 in Fan On chamber. Although, the difference between values were very slight but there was significant variation statistically between the two fan conditions for nose irritation. Moreover, air freshness vote scored 23.6 on measurement scale in No Fan and the value increased by 17.6% in terms of the perceived fresh air by running the fan on, which yielded no significant difference among results (P>0.05). Figure 4.3c-ii illustrates No Fan state in the range between just acceptable and clearly unacceptable by the value (-0.04) on measurement scale. While in Fan On state, the value reduced slightly ro reach (-0.11), but no significant dissimilarity was statistically founds (P>0.05).

Figure 4.3d-i demonstrate TYP 4 (Water) subject responses in the same Group (2). The odour intensity is more likely to be moderate on measurement scale by the value (37.3). In Fan On chamber, the odour intensity was almost similar and nose irritation values in both fan conditions ranged between no irritation to less than slight irritation on scale, but both perceptions demonstrated no significant observed difference (P>0.05). For air freshness, no considerable variation was statistically observed (P>0.05) and both values of fan conditions showed similarity in terms of values, while the perceived air is more likely to be fresh. Figure 4.3d-ii shows no statistical variation (P>0.05) in terms of air acceptablility for the two fan conditions. Furthermore, the range of value on measurement scale ranged between clearly acceptable and just acceptable for both fan states (0.35, 0.49).

TYP 5 (Normal) in Figure 4.3e-i showed no statistical different among all variables (odour intensity, nose irritation and air freshness) while no negative or poor values observed between the two fan conditions result ($P>0.05$). Figure 4.3e-ii demonstrated air acceptability for both fan conditions and no considerable variation were indicated statistically and both fan states were slightly close to clearly acceptable on the measurement scale.



Figures 4.3. Group 2 subjects assessment of the perceived air quality released of the chamber with No Fan or Fan On.

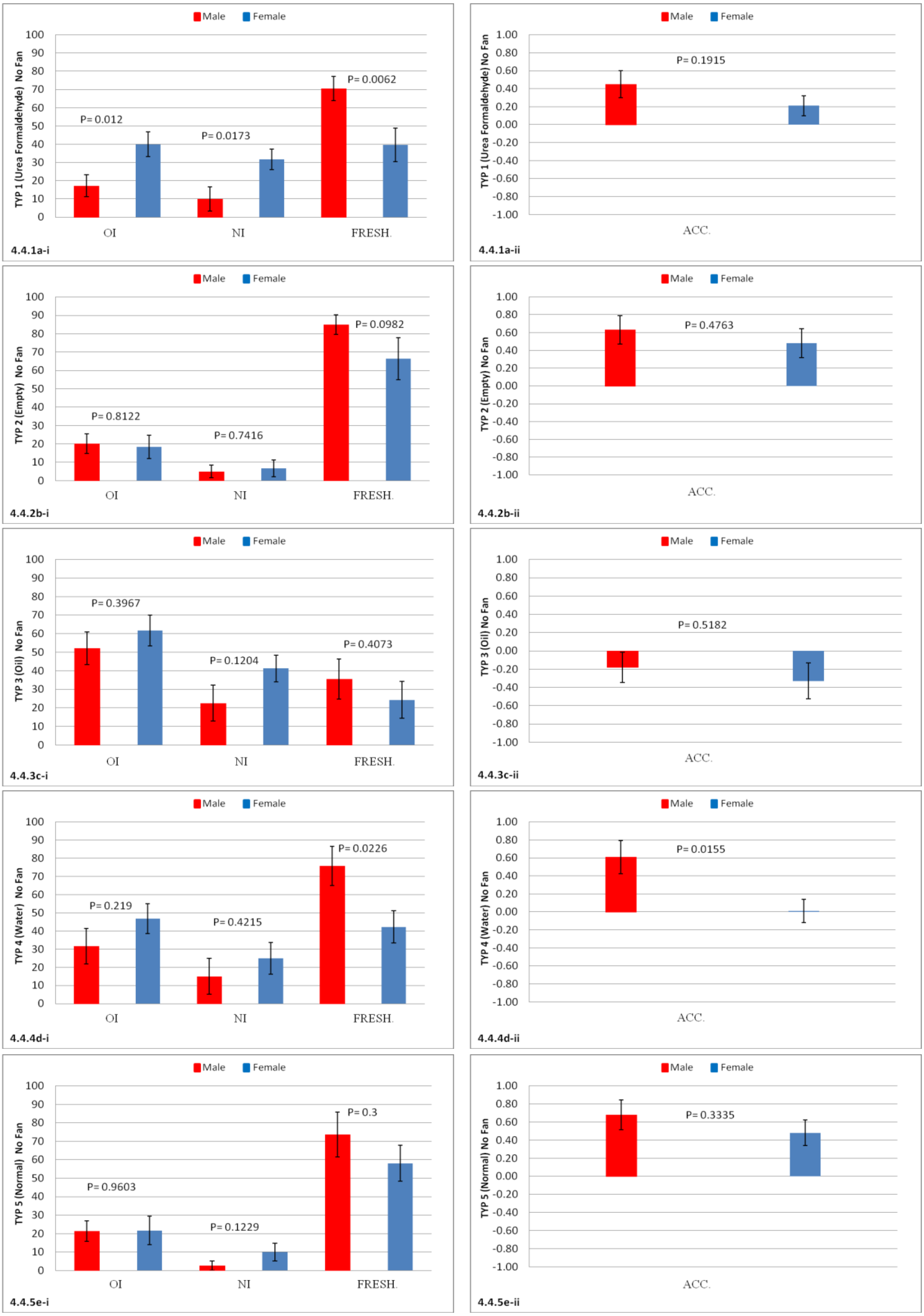
4.2 The Effect of Subjects Gender on Perceived Air Quality

Figure 4.4 illustrates the comparison between genders (Male vs. Female) in No Fan condition for each wood samples separately and by combining the 2 groups together. Figure 4.4a-i shows the male and female assessment of TYP 1 (UF) in Fan Off chamber. Males assessed slight odour in the UF sample, while females assessed moderate odour by 40 on scale. The difference between the two genders in terms of odour intensity is 22.75%. The same scenario goes for nose irritation, as male's vote scored 10 on assessment scale and female's vote was 31.67 on scale. For air freshness, males perceived the air more fresh on scale assessment 70.5 and female assessment reduced by 30.93%. All the mean values of TYP 1 (odour intensity, nose irritation, freshness of air) show significant differences statistically among the two genders ($P<0.05$). Figure 4.4a-ii illustrates the results of both genders among clearly acceptable and just acceptable measurement scale. Male's vote scored 0.45 and female's vote was 0.21. Although, the female vote was lower than male by 24% but no substantial difference was observed among the two genders in terms of acceptability of air.

In TYP 2 (Empty), Figure 4.4b-i shows approximately similar results among the mean values of the three variables between genders, while no poor assessment was observed and no significant variation was statistically found ($P>0.05$). Moreover, in Figure 4.4b-ii, the acceptability of air remains consistent with the previous Figure (4.3a-ii) and the result showed the range of assessment between clearly acceptable and just acceptable between genders ($P>0.05$). Figure 4.4c-i demonstrates the assessment of TYP 3 (Oil), and for both genders the odour intensity was found to be strong, although the female assessment was increased by 9.54% but no statistical significance was observed ($P>0.05$). The nose irritation assessment shows male result with slight irritation and female with moderate irritation with 18.75% difference. The perceived air in both genders' vote scored more stuffy air and both genders perceived poor air in results. However, the difference was slight between genders in nose irritation and air freshness, but no considerable variation was statistically scored (P>0.05). Figure 4.4c-ii shows the male and female acceptability of air in the range between just unacceptable and clearly unacceptable (-0.18/M, -0.33/F). Nevertheless, the variation was 15% with no substantial difference among results (P>0.05).

Figure 4.4d-i illustrates TYP 4 (Water) results, and the assessment shows slight differences between odour intensity and nose irritation values, and no statsitical variation observed (P>0.05). Females assessed the water-based paint sample with moderate odour in No Fan chamber (46.67 on scale) and males was less by 15%. For nose irritation, males were found to be 15 on scale and the females 25 on scale. On the other hand, the air freshness perceived by 75.75 on scale by male assessment, while female score reduced by 33.5% which yielded a significant difference between the two genders (P<0.05). Figure 4.4d-ii shows significant difference statistically among genders (P<0.05), while male assessed the air quality by the value 0.66 which shows more clearly acceptable air on measurement scale, while female vote was found to be close to 0 just acceptable. Thus, the perceived air assessment between male and female was found to be varied in water-based paint sample in No Fan chamber.

Figure 4.4e-i illustrates TYP 5 (Normal) assessment among genders, while odour intensity shows similar results for males and females and the value was 21 on scale which indicate a slight odour. The same goes to nose irritation. While no irritation was observed between genders, female vote increased by 7.5%. For air freshness, males perceived the air more freshly than females (73.63/M vs 58.08/F) and the difference was 15.55%. However, no major difference statistically was found among the three mean variables (P>0.05). Figure 4.4e-ii shows the acceptability of air and both genders assessed the air more close to clearly acceptable with slight observed differences (P>0.0.5).



Figures 4.4 Subjects gender assessment of the perceived air quality coming out of the chamber with No Fan condition.

Figure 4.5 illustrates the comparison between genders (Male vs. Female) in Fan On condition for each wood sample separately. Figure 4.5a-i shows that by changing the chamber condition into Fan On, the results reduced sligtly in TYP 1 (UF) sample but the odour intensity of the sample in male remains lower than female (15/M, 32.92/F). While, female vote was found to be more close to moderate odour. In nose irritation, the female vote scored slight irritation and male vote was no irritation. Both variables, odour intensity and nose irritation, show significant differences statistically among genders ($P<0.05$). The perceived air for TYP 1 was more fresh in male vote (75.63 on scale), and female vote was found to be less by 18.05%. However, the percentage was less by 18% but no substantial differences were observed between genders for air freshness ($P>0.05$). Figure 4.5a-ii shows that the air acceptability among genders varies between clearly acceptable and just acceptable on assessment scale and no significant differences were found ($P>0.05$).

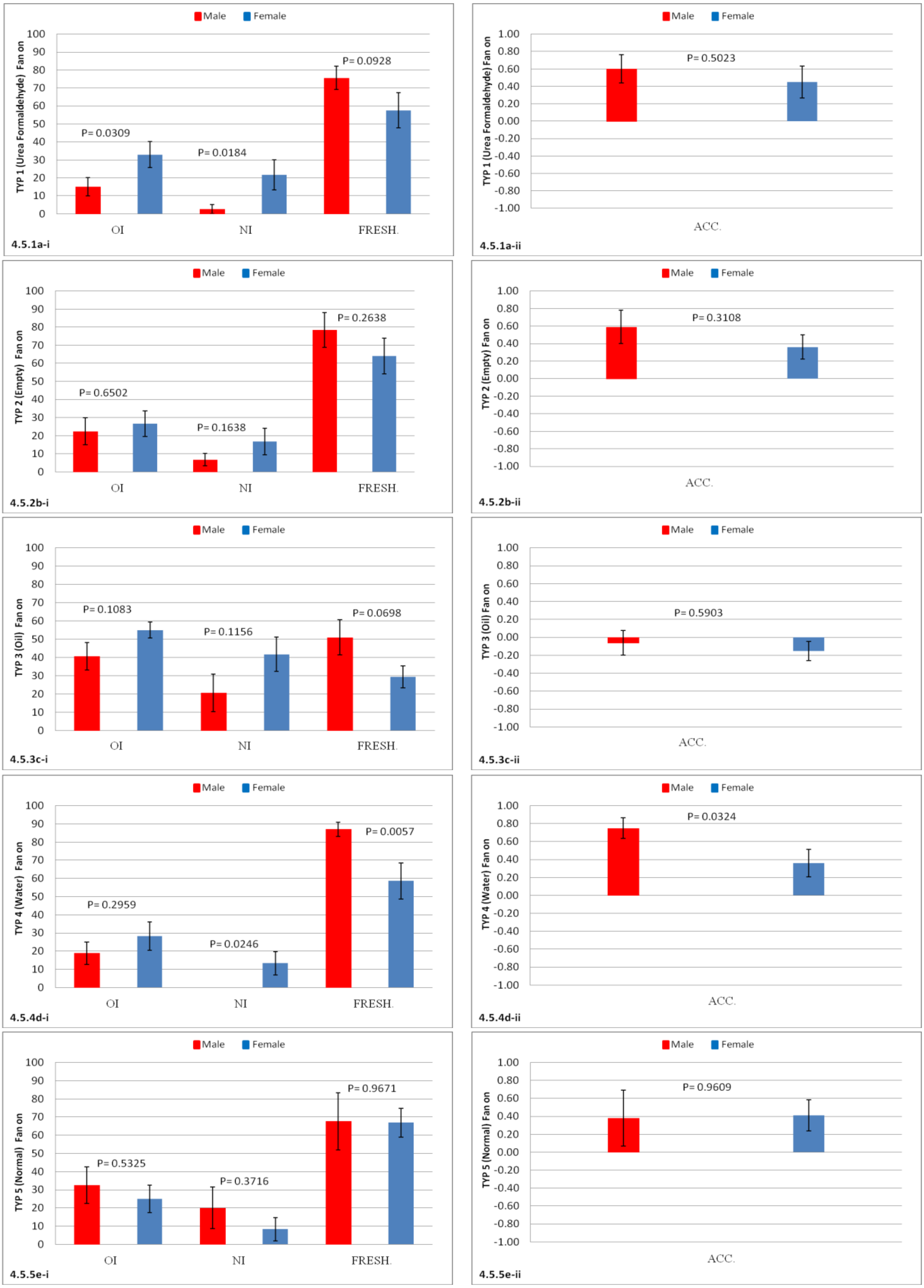
Figure 4.5b-i shows the mean values of TYP 2 (Empty) sample, while for the three variable, odour intensity, nose irritation and freshness of air, the assessment was slightly similar between genders and no poor results were observed. Moreover, the results indicate that no significant differences were found ($P>0.05$), although the female vote was slightly higher than male by appoximately (4% - 12%). Figure 4.5b-ii illustrates almost similar results to the previous Figure 4.3b-i, despite the marginal differences ($P>0.05$) and the range of the assessed air quality varied between clearly acceptable and just acceptable for both genders.

Figure 4.5c-i demonstrates TYP 3 (Oil) assessment with no substantial differences observed statistically ($P>0.05$) among all variables, but the female vote shows higher values than male in all variables. For odour intensity, female vote was found to be close to strong odour, while male was moderate odour. Nose irritation for female vote scored moderate irritation while male was slight irritation. Air freshness for female and male vote was at 29.33 and 51 respectively on scale and this indicates that female perception was higher by approximately 20%. Figure 4.5c-ii shows the acceptablity of air. Both genders vote scored the value just unacceptable with minor statistical differences found ($P>0.05$).

Figure 4.5d-i indicates TYP 4 (Water) mean values. The female vote shows more slightly moderate odour than male, while in male vote the value was found to be slight odour. While no considerable differences were observed statistically for odour intensity among genders ($P>0.05$), the nose irritation values however, showed almost 0 for male on scale, while for female the vote was approximately close to slight irritation, thus significant difference was found for nose irritation results ($P<0.05$). Air freshness results shows that male perceived the air more freshly at 87 on scale while female was less at 28.4 and significant difference was observed statistically between genders for TYP 4 ($P<0.05$). Figure 4.5d-ii shows that the acceptability of air in male vote scored more clearly acceptable value 0.75 on scale, while for female the value was less and shows 0.36 on scale which is more close to just acceptable on scale ($P<0.05$).

Figure 4.5e-i shows TYP 5 (Normal) assessment among genders. The results show no significant differences statistically observed among the three variable between the two genders, but the slight difference appeared to be in odour intensity, while the male value was slightly higher than female by 7.5% and in nose irritation the male vote was also higher by 11.67% than female. However, the difference was slight but the male assessment in TYP 5 sample shows the male for the first time complain more than female under the Fan On chamber condition.

Figure 4.5e-ii shows that the acceptability of air for both genders were approximately the same (0.38/M, 0.41/F) and close to just acceptable on assessment scale. No considerable variation was found statistically among genders in terms of air acceptability ($P>0.05$).



Figures 4.5. Subjects gender assessment of the perceived air quality coming out of the chamber with Fan On condition.

4.3 Comparison of GRP1 and GRP2 on Perceived Air Quality

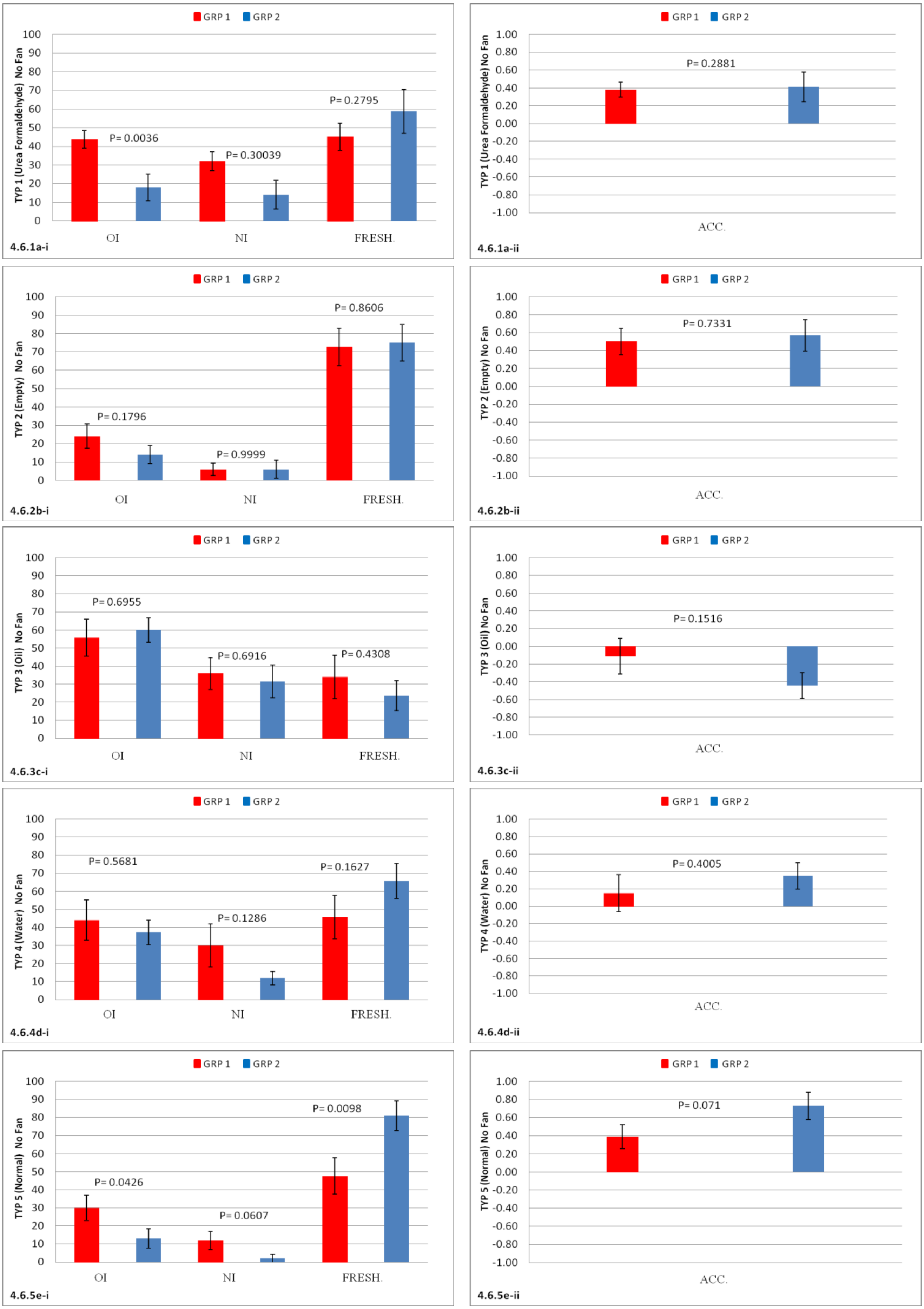
Figure 4.6 shows the assessment between groups (GRP1 vs. GRP2) in No Fan condition for each sample separately. Figure 4.6a-i shows that the odour intensity value is considerably higher in Group 1 with moderate odour and scored 43.8 on scale, and Group 2 result shows 18 on scale which indicates slight odour. The statistical difference was significaty high (P<0.05). Nose irritation shows that Group 1 vote was closer to moderate irritation 32 on assessment scale, while in Group 2, the vote was between "no to slight irritation", or 14 on scale. However the difference was 18% with no significant difference observed (P>0.0.5). For air freshness, there was no major difference in values, and both groups scored the middle range of assessment on measurement scale which ranges between fresh and stuffy (P>0.05). Figure 4.6a-ii shows similarity in values for acceptability of air, while in both groups, the assessment was more close to just acceptable on measurement scale with no considerable difference (P>0.05).

Figure 4.6b-i shows the values of TYP 2 (Empty), and also demonstrated no significant differences among the three variable in both groups. The odour intensity in Group 1 was slighty higher than Group 2 and reached slight odour at 24 on scale. The nose irritation was similar by 100% by no irritation observed and air freshness and was almost similar and close to fresh air in both groups (72.65/GRP1, 74.9/GRP2). Figure 4.6b-ii also shows similarity in terms of air acceptability rating with no significant difference observed (P>0.05) and the value ranged between clearly acceptable and just acceptable on assessment scale.

Figure 4.6c-i illustrates TYP 3 (Oil) values, no substaintial differences statistically observed among the two groups for the three variable. Odour intensity in Groups 1 and 2 was close to strong odour, while nose irritation values were more close to slight to moderate for both groups. The air freshness was perceived to be more stuffy for both groups as well. Figure 4.6c-ii shows that Group 1 value was at -0.11 while Group 2 at -0.44 and both groups vote ranges between just unacceptable and clearly unacceptable but no significant difference was found (P>0.05). TYP 4 (Water) also shows that no significant variation among the three variables (P>0.05) between the two groups (Figure 4.6d-i). While moderate odour was dominant in Groups 1 and 2, nose irritation shows that Group 1 vote scored 30 on scale which ranged between "slight – moderate" irritation, Group 2 was at 12, which is more close to no irritation on scale. However, the difference was 18% but no significant difference was statistically observed (P>0.05). The same value was found for air freshness, where the only difference is that Group 2 perceived the air more freshly at 65.60 on scale than Group 1 with lower value at 45.70 on scale, however no considerable differences developed (P>0.05). Figure 4.6d-ii shows that the air acceptability value was slightly similar among the two groups, whereby Groups 1 and 2 scored values at 0.15 and 0.35 on scale respectively. This indicates that both groups were close to just acceptable on assessment scale with no significant variation statistically (P>0.05).

Finally, Figure 4.6e-i shows TYP 5 (Normal) assessment values. In Group 1, the odour intensity assessment observed to be 30 on vote scale which is more likely to vary between slight to moderate odour, while in Group 2, the vote shows 13 on scale which indicates no odour. Thus, there was substantial difference between the two groups in terms of odour intensity (P>0.05). Nose irritation values show that Group 1 was higher at 12 on scale and Group 2 is less at 2 on scale, but no significant results were observed (P>0.05) and both groups were close to no irritation value. The significant difference appeared among the two groups in air freshness ($P<0.05$).

Group 1 perceived air to be more stuffy at 47.60 on scale and Group 2 vote perceived air to be more fresh and scored 81 on scale. Figure 4.6e-ii shows the acceptability of air among the two groups for TYP 5. The result illustrates that Group 1 was more close to just acceptable on assessment scale at 0.39, and Group 2 vote scored 0.73 value which indicate more clearly acceptable air on assessment scale.



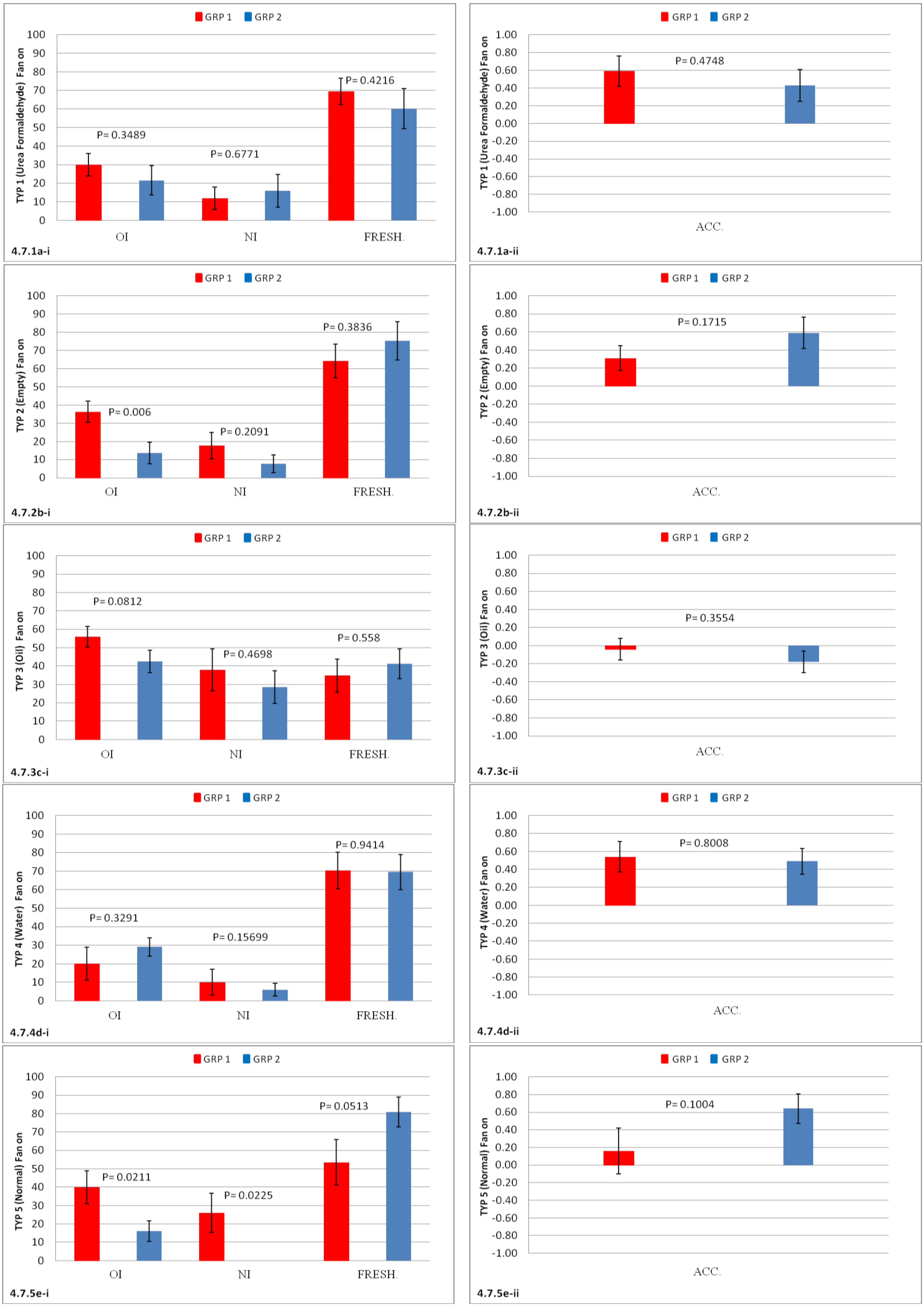
Figures 4.6 Groups assessment of the perceived air quality with Fan Off condition.

Figure 4.7 shows the assessment between groups (GRP1 vs. GRP2) in Fan On condition for each sample separately. Figure 4.7a-i shows the assessment of TYP 1 (UF) sample among the two groups. Generally, no major difference was observed among the three variables in both groups ($P>0.05$). In Groups 1 and 2, the observed odour intensity values were approximately close (30/GRP 1, and 21.5/GRP2) on measurement scale and these values illustrate that the average odour measured between slight to moderate on scale. The nose irritation was similar for both groups (12/GRP1 and 16/GRP 2) with no irritation on assessment scale. The air freshness for both groups was observed to be slighty fresh (69.5/GRP1, 60.01/GRP2) on scale. Figure 4.7a-ii shows that in both groups, the acceptability of air was marked in the middle of the scale as clearly acceptable and just acceptable with no significant variations statistically found ($P>0.05$).

Figure 4.7b-i shows TYP 2 (Empty) assessment, while for odour intensity, Group 1 scored 36.6 which indicate moderate odour on measurement scale, and Group 2 vote on scale was 13.6 which indicate no odour. The values of odour intensity show significant difference statistically among the two groups ($P<0.05$). For nose irritation and air freshness, no significant variances were statistically observed among the two groups ($P>0.05$) and values showed slight irritation in Group 1 and no irritation in Group 2. The air freshness perceived with approximately the same values among the two groups (64.3/GRP1 and 75.3/GRP2). Figure 4.7b-ii shows that air acceptability in both groups were assessed to be among clearly acceptable and just acceptable on measurement scale, with lower value for Group 1 at 0.31 that is more close to just acceptable and 0.59 for Group 2 that is more close to clearly acceptable.

Figure 4.7c-i illustrates TYP 3 (Oil), while in all three variables showed no substantial variation statistically (P>0.05) and values were approximately close to each other. For odour intensity, Group 1 vote scored 56 that is more likely to be strong odour on scale, and Group 2 vote scored 42.5 that is indicated as moderate odour on scale. Nose irritation for Group 1 was more near to moderate value on scale 38, and Group 2 demonstrated a value of 28.50 that varies among slight to moderate. The air freshness in both groups was perceived to be more stuffy with approximate similar values (34.8/GRP1 and 41.2/GRP2). Figure 4.7c-ii indicates that air acceptability for both groups was more close to just unacceptable (-0.04/GRP1 and -0.18/GRP2) with no substantial difference (P>0.0.5). Figure 4.7d-i demonstrates TYP 4 (Water) assessment in Fan On condition as well. No considerable variations were found statistically among the three variable in both groups assessment. Odour intensity values in Groups 1 and 2 were similar and showed slight odour (20/GRP1and 29.1GRP 2), nose irritation were almost similar with no irritation observed on scale (10/GRP1 and 6/GRP2). Air freshness values in Groups 1 and 2 were almost the same and the values show more fresh air perceived in Fan On condition (70.4/GRP1 and 69.5/GRP2). Figure 4.7d-ii shows the acceptability of air among the two groups for TYP 4, and both groups voted the value ranges on the middle mark of scale between clearly acceptable and just acceptable and no significant difference statistically demostrated (P>0.05).

Figure 4.7e-i shows TYP 5 (Normal) assessment. In Group 1, the odour intensity value was found to be moderate on scale at 40, while Group 2 indicated a value at 16 which ranged among “no – slight odour” on measurement scale. This variation indicated significant differences statistically between Group 1 and Group 2 in Fan On condition (P<0.05). The same results were observed for nose irritation, whereby Group 1 provided a value of 26 on the assessment scale, which is an exceedingly slight irritation, and in Group 2, the value was absolute (0) with no irritation observed at all, and this result showed considerable variation statistically among the two groups. The air freshness in Group 1 vote scored 53.5, placing it on the middle mark of the scale between stuffy and fresh, while in Group 2, the air freshness vote scored 80.9, and that indicates that the perceived air was more fresh in this group. However, the difference was 27.4% with no substantial observation statsitically for air freshness ($P>0.05$). Figure 6.7e-ii illustrates that the air acceptability in Group 1 was almost just acceptable on assessment scale 0.16, while for Group 2 the assessment was closer to clearly acceptable (0.64). However, the discrepancy between the two groups in terms of air acceptability was 48% but no major difference was found stastistically ($P>0.05$).



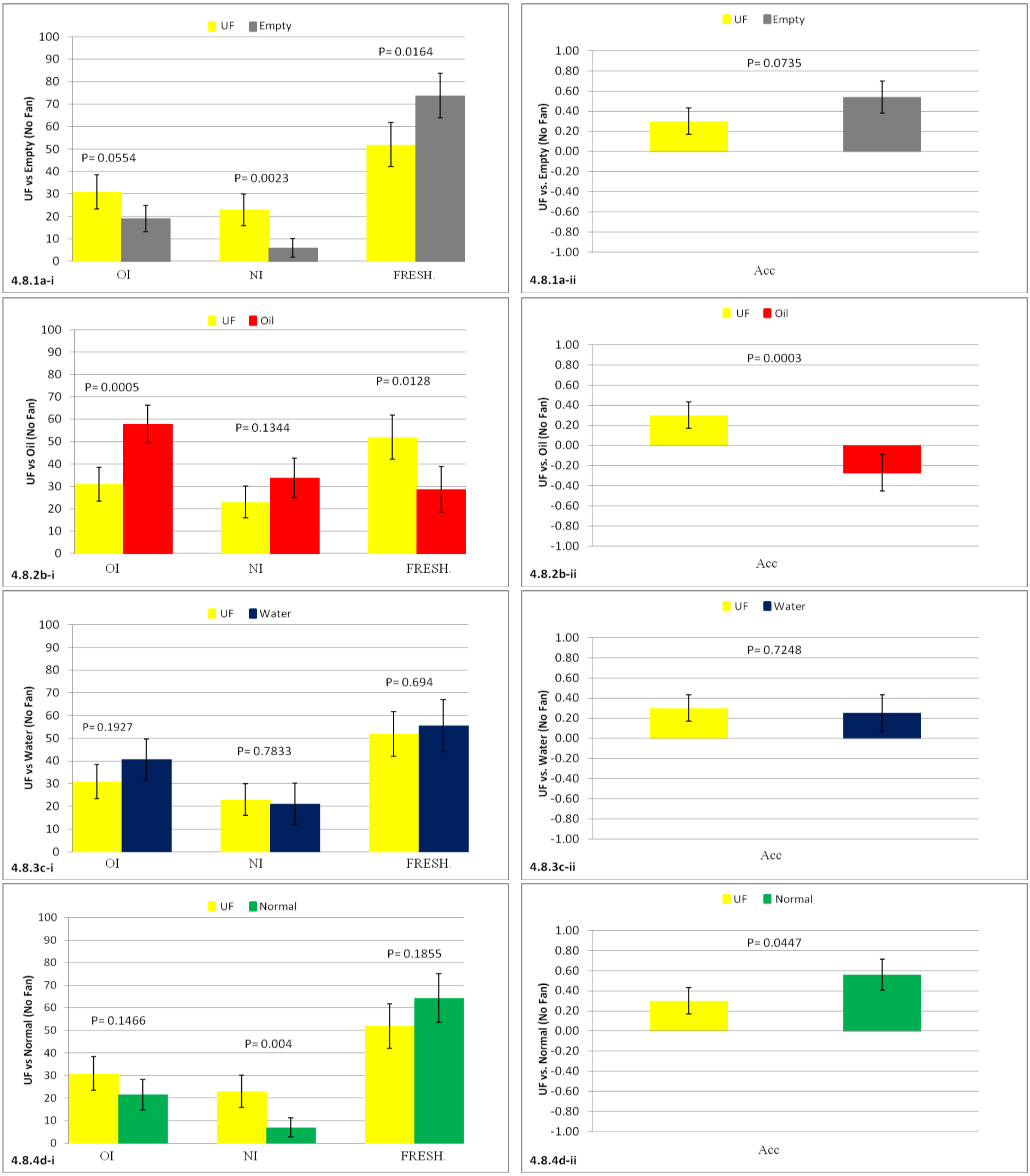
Figures 4.7. Groups assessment of the perceived air quality with Fan On condition.

4.4 Effect of Wood Samples on Perceived Air Quality

Figure 4.8 shows sample assessment between TYP 1 (UF) and the other samples (TYP 1, TYP 2, TPY 3, TYP 4) in No Fan condition including all subjects assessment. Figure 4.8a-i illustrates the difference between TYP 1 (UF) and TYP 2 (Empty). Odour intensity value for UF is 30.9 on scale which is slightly close to moderate odour, while Empty sample value is 19.05 which is more close to slight odour on scale. However, results of both samples have shown no significant differences statistically among the two sample in No Fan conditions ($P>0.05$). For nose irritation, UF sample value shows moderate irritation 23 on assessment scale, and Empty sample shows no irritation on scale 6. This indicates that TYP 1 and TYP 2 are drastically different statistically on nose irritation results ($P<0.05$). Air freshness results for both samples are considerably dissimilar statistically ($P<0.05$), while in TYP1 the value is on the middle mark of scale 51.95 between stuffy and fresh, but the Empty sample held a value that was more close to fresh air at 73.78 on scale. Figure 4.8a-ii shows the acceptability of air among UF and Empty sample, where no important differences were observed statistically and both values were indicated between clearly acceptable and just acceptable on measurement scale with slight difference between TYP 1 (0.3) and TYP 2 (0.54).

Figure 4.8b-i shows the assessment between TYP 1 (UF) and TYP 3 (Oil) with the same chamber condition (No Fan). Odour intensity in UF was slightly close to moderate odour, while in oil sample the value increased significantly to reach 57.85 which indicates strong odour on scale, showing significant difference among the odour intensity results ($P<0.05$). In nose irritation, the oil sample value measured at 33.75 which is close to moderate irritation was also higher than UF 23 on scale, with no difference observed ($P>0.05$). Air freshness values show considerable variation statistically ($P<0.05$), while in oil sample value the result shows more stuffy perceived air than UF at 55.65 on scale. Figure 4.8b-ii illustrates the acceptability of air, while the difference was significantly high ($P<0.05$), and the value in oil sample is among just unacceptable and clearly unacceptable -0.27 on assessment mark scale, while in UF the value ranges among clearly acceptable and just acceptable 0.3. The assessment between TYP 1 (UF) and TYP 4 (Water) is shown in Figure 4.8c-i, while odour intensity values between the two samples (30.9/UF, 40.65/Water) were in the moderate odour on mark scale and displayed no significant difference ($P>0.05$). Nose irritation shows similarity in values result as well and no considerable difference was found, and both samples showed slightly irritation on marking scale. Air freshness values were also similar, and both samples average was on the middle ranking of scale between stuffy and fresh (51.95/UF, 55.65/Water) and no significant results were found ($P>0.05$). Figure 4.8c-ii shows the air acceptability of UF and water sample, and both values were close to just acceptable on measurement scale with no significant differences statistically ($P>0.05$).

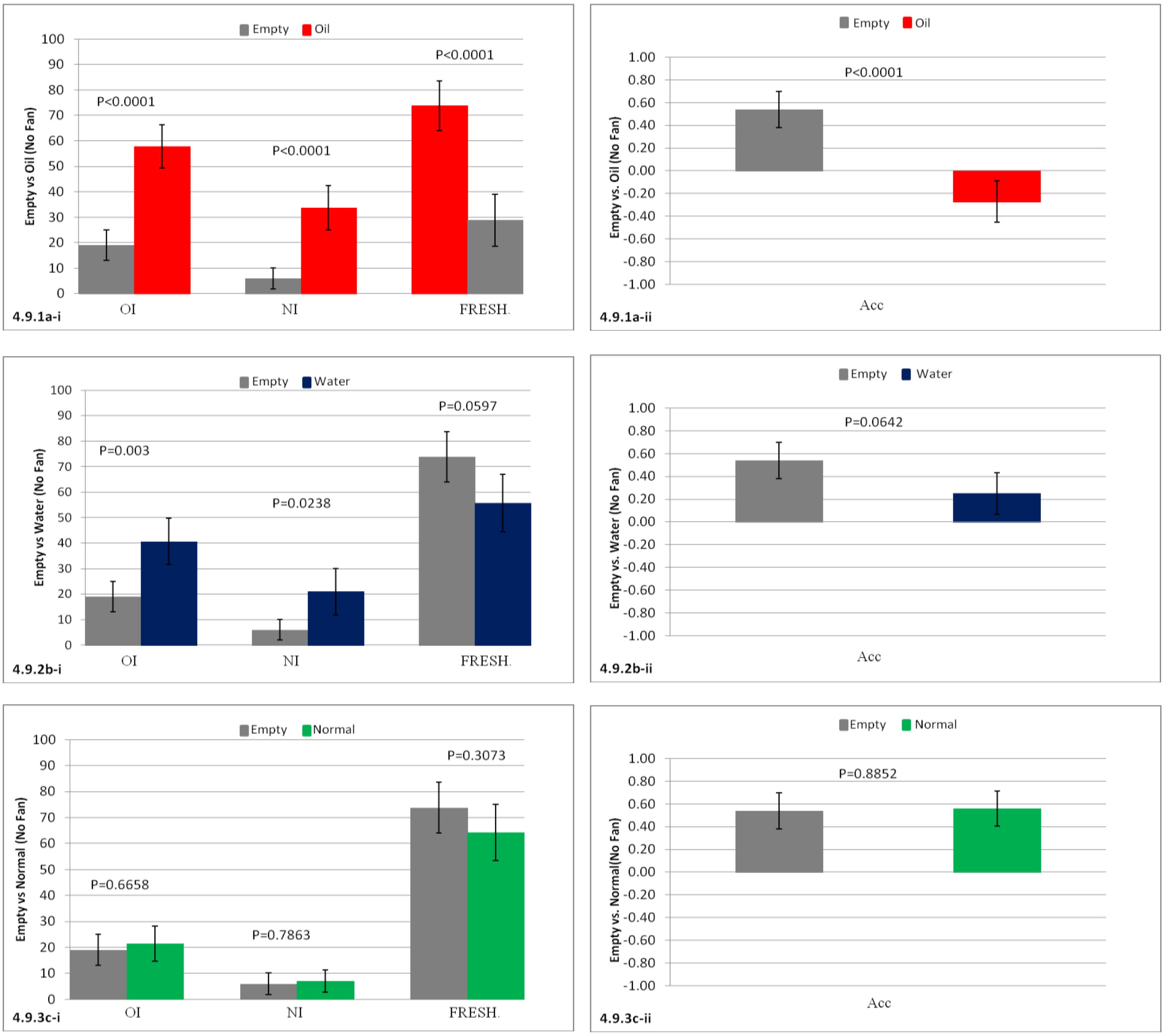
Figure 4.8d-i illustrates the assessment between TYP 1 (UF) and TYP 5 (Normal), the odour intensity shows no signficant variations and the values were to some extent similar with slight to moderate odour on the assessment scale (30.9/UF, 21.5/Normal). TYP 1 (UF) shows slight irritation in comparison to TYP 5 (Normal) with no irritation marked on scale, and this indicates that results are considerably significant ($P<0.05$). Air freshness shows approximately similar values, while in UF (51.95) and Normal value (64.3) increased to be more close to fresh on scale with no substantial variation ($P>0.05$). Figure 4.8d-ii compares the air acceptability among UF and normal sample, while the values are significantly different statistically ($P<0.05$) although both samples are in the range of clearly acceptable and just acceptable (0.30/UF, 0.56/Normal).



Figures 4.8 Samples assessment TYP 1 (UF) vs. All TYPs with No Fan condition.

Figure 4.9 shows sample assessment between TYP 2 (Empty) and the other samples (TYP 3, TYP 4, TPY 5) in No Fan condition. Figure 4.9a-i shows the comparison among Empty chamber and oil sample, the odour intensity shows extremely different values, while in Empty chamber, slight odour was observed on results, while in oil sample, strong odour was detected on marking scale and results indicated significant statistical difference ($P<0.05$). The same applies for nose irritation and air freshness; in oil sample, the nose irritation value was slightly close to moderate irritation, and the perceived air was almost stuffy, displaying a result of 28.8 on the measurement scale, thus indicating a significant difference statistically among the two samples ($P<0.05$). Figure 4.9a-ii shows that empty chamber air acceptability value was very close to clearly acceptable on the assessment scale, while in oil sample the air acceptability value -0.27 on scale which is closer to just unacceptable, thus demonstrating signficant difference in results ($P<0.05$).

Figure 4.9b-i shows the assessment within empty chamber and water sample. Odour intensity showed considerable discrepancy statistically among the two samples ($P<0.05$). In empty chamber, the value at 19.05 on scale showed slight odour, while in water sample, the value showed moderate odour. For nose irritation, water sample value was significantly higher ($P<0.05$) and showed slight irritation, while in empty chamber no irritation was observed. Air freshnesss was perceived with no major results statistically among the two samples ($P>0.05$). However, the TYP 4 (water sample) value was in the middle of the assessment scale between stuffy and fresh, and the TYP 2 (Empty) was closer to fresh air, indicating 73.78 on scale. Figure 4.9b-aii shows that while there was no difference ($P>0.05$) among the two sample TYP 2 and TYP 4 in terms of air acceptability, the difference between the two samples on the assessment scale was double. In water sample, the value 0.25 on scale was closer to just acceptable, while empty was in the middle range, with a value of 0.54 on scale, thus making it closer to clearly acceptable. Figure 4.9c-i shows the comparison between TYP 2 (Empty) and TYP 5 (Normal) with no great difference scored among the three variables ($P>0.05$) and the values show similarity on results between them with minimal complaints about odour intensity, nose irritation, or air freshness. Figure 4.9c-ii shows air acceptability among TYP 2 (Empty) and TYP 5 (Normal), but no significant difference was found ($P>0.05$) and the values on scale were more close to clearly acceptable.

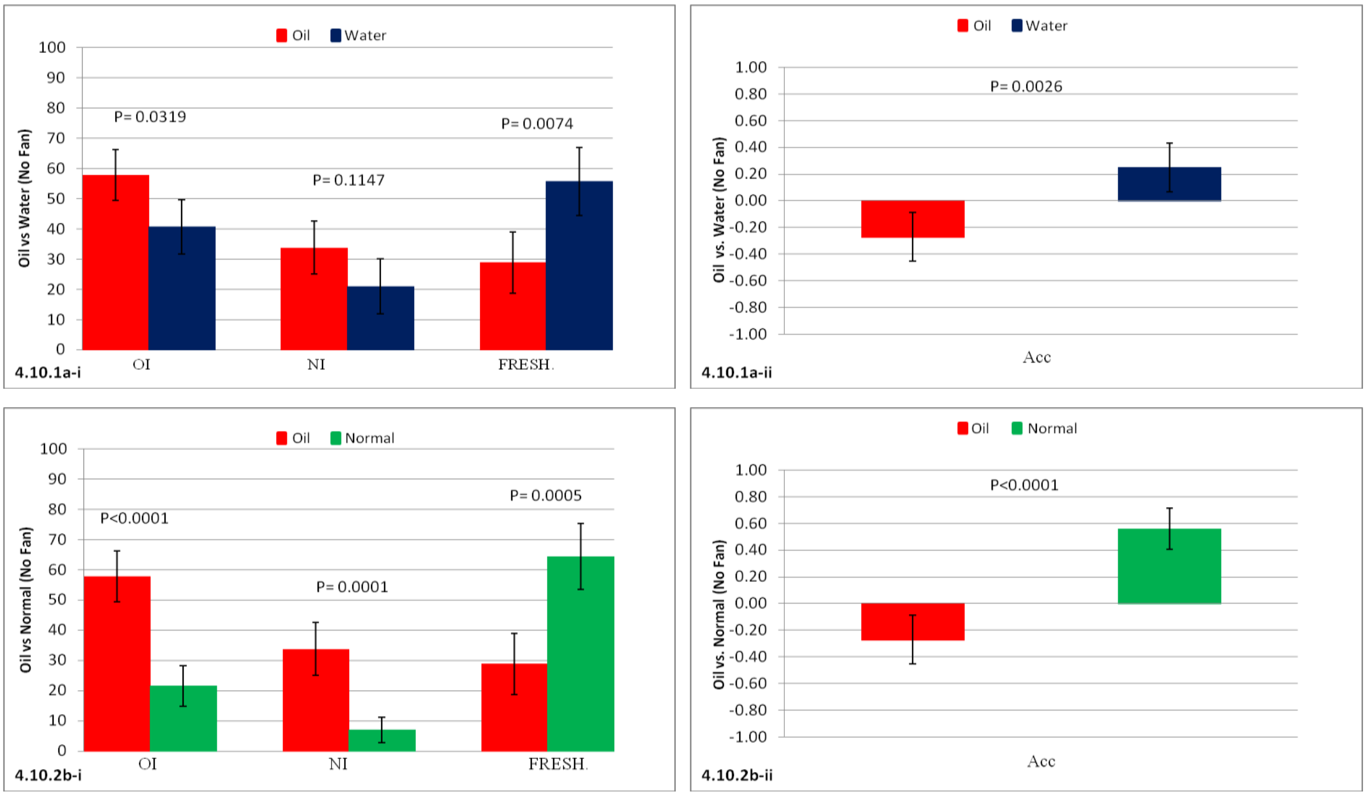


Figures 4.9 Samples assessment TYP 2 (Empty) vs. All TYPs with No Fan condition.

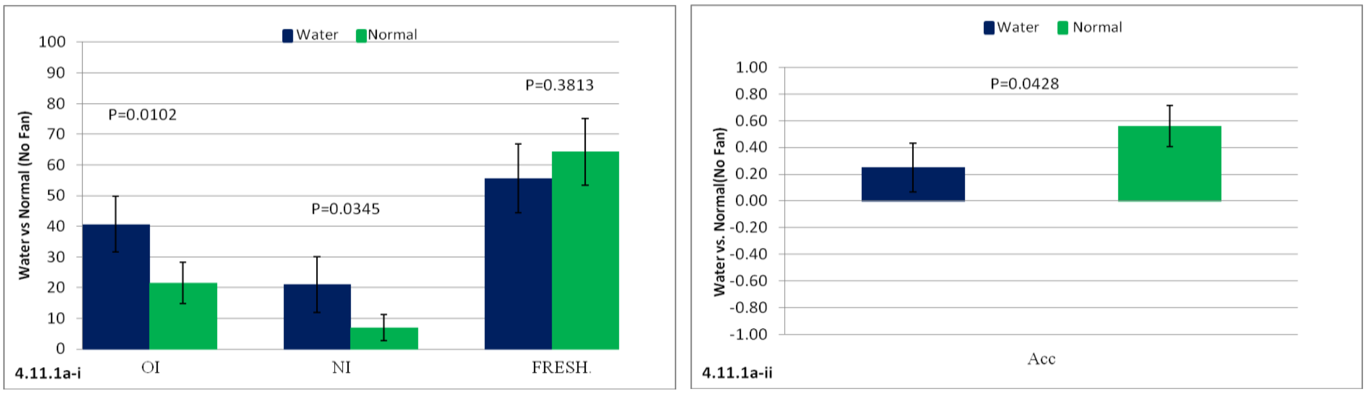
Figure 4.10 shows sample assessment between TYP 3 (Oil) and the other samples (TYP 4, TYP 5) in No Fan condition. Figure 4.10a-i illustrates the comparison among oil and water samples. In terms of odour intensity, the oil was higher and demonstrated strong odour on scale, while water sample was less at 40.65 and showed moderate odour. These values illustrated significant difference statistically ($P<0.05$). In nose irritation, both samples concluded slight to moderate irritation with no significant variation statistically ($P>0.05$). The freshness of air was assessed to be more stuffy in oil sample 28.80 on scale, while water was in the middle of scale that ranged between stuffy to fresh at 55.65 with the results showing significant difference statistically ($P<0.05$). Figure 4.10a-ii illustrates the air acceptability between oil and water samples, and the result showed significant difference statistically ($P<0.05$). In oil sample, the value -0.27 on the measurement scale was indicated just unacceptable, while in water sample, the value 0.25 is closer to just acceptable.

Figure 4.10b-i demonstrated the variation between oil and normal sample, and in all three variables the results naturally showed significant differences statistically ($P<0.05$). Odour intensity is very strong in oil sample 57.85 on assessment scale, while in normal sample, slight odour was observed. Nose irritation also appeared to be of moderate irritation in oil sample and no irritation was observed on scale in normal sample. The air freshness was perceived to be more stuffy in oil sample at 28.80, while was closer to fresh air in normal sample at 64.30 on scale. Figure 4.10b-ii illustrates the acceptability of air among the two samples despite the significant difference statistically ($P<0.05$), with the acceptabiltiy of air in normal sample considerably better at 0.56 and measured as just unacceptable on scale at -0.27 in oil sample.

Figure 4.11 illustrates the difference among TYP 4 (Water) and TYP 5 (Normal) in No Fan condition, including all subjects assessment. Figure 4.11a-i shows that there is considerable difference statistically between odour intensity and nose irritation results ($P<0.05$). Water sample indicated an odour intensity as moderate on assessment scale, and in normal sample appeared to be slight with less odour intensity at 21.5. Nose irritation scale in water sample shows slight irritation with no irritation indicated on assessment scale in normal sample. Air freshness for both samples show similar results on the measurement scale with values ranging between stuffy and fresh (55.65/Water, 64.30/Normal) and no observed difference ($P>0.05$). Figure 4.11a-ii illustrates the acceptability of air among water and normal sample. The acceptability of air was closer to just acceptable in water sample, and in normal sample, the value was doubled to reach 0.56 on scale, close to clearly acceptable, which indicated significant difference statistically among the two samples ($P<0.05$).



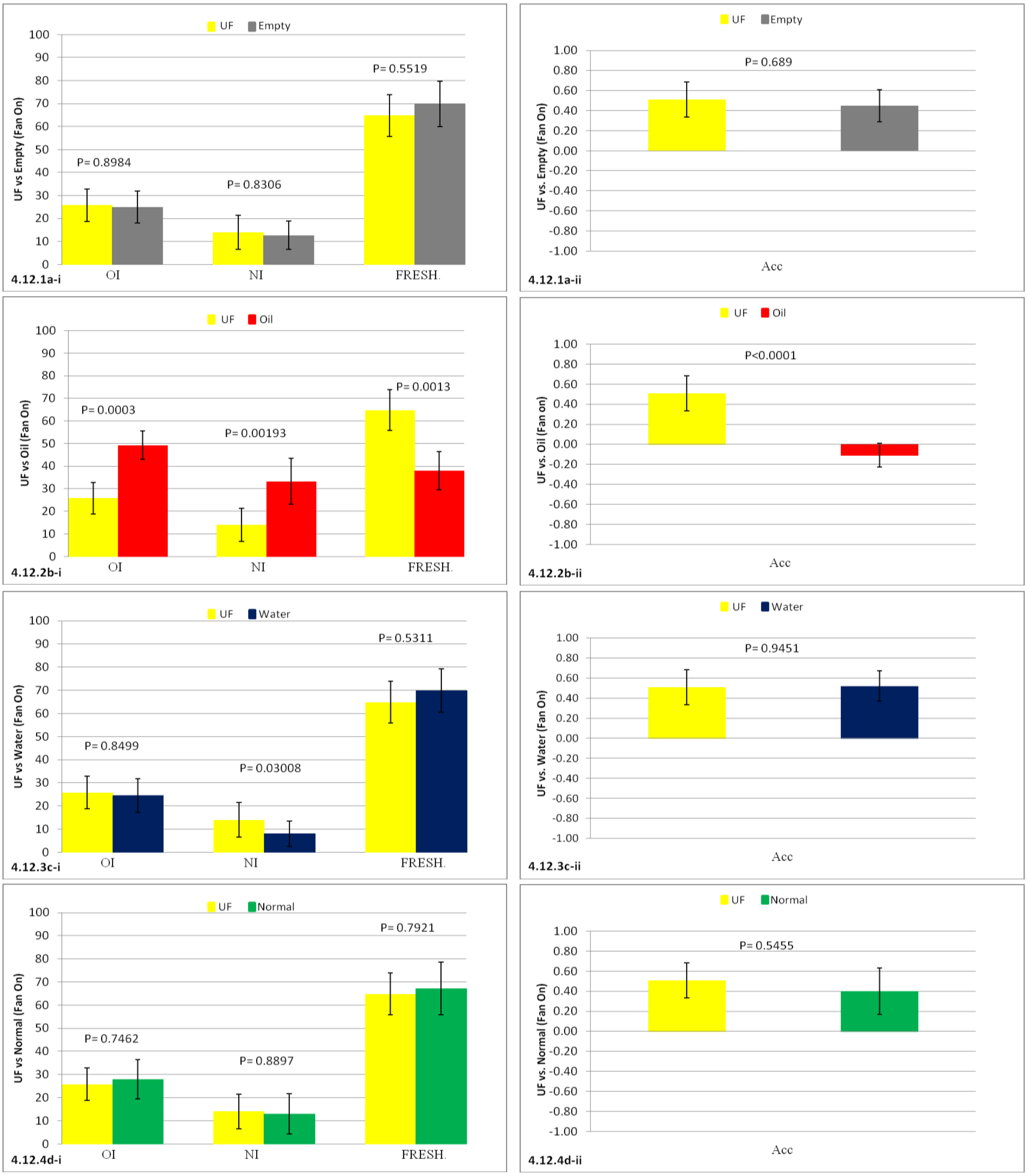
Figures 4.10 Samples assessment TYP 3 (Oil) vs. All TYPs with No Fan condition.



Figures 4.11. Samples assessment TYP 4 – (Water vs. Normal) with No Fan condition.

Figure 4.12 shows the assessment of TYP 1 (UF) with other samples (TYP 2, TYP 3, TYP 4 and TYP 5) in Fan On conditions including all subjects. By changing the chamber condition into Fan On, the UF sample in Figure 4.12a-i indicated that odour intensity was reduced to slight odour, and became approximately similar to TYP 2 (Empty) with no significant difference observed statistically ($P>0.05$) among the two samples in odour intensity, nose irritation and air freshness. The nose irritation reduced as well in UF sample to 14 on scale and indicated no irritation similar to TYP 2. The same result is shown for the perceived air, while the UF and empty chamber air freshness value increased to 64.8 and 69.8 respectively on scale. Figure 4.12a-ii illustrates the air acceptablity between UF and TYP 2 where no significant difference was detected among the two types ($P>0.05$). The UF sample shows increased value in Fan On condition, reaching 0.51, coming closer to clearly acceptable on the assessment scale, and TYP 2 value was reduced slightly to 0.45 on scale.

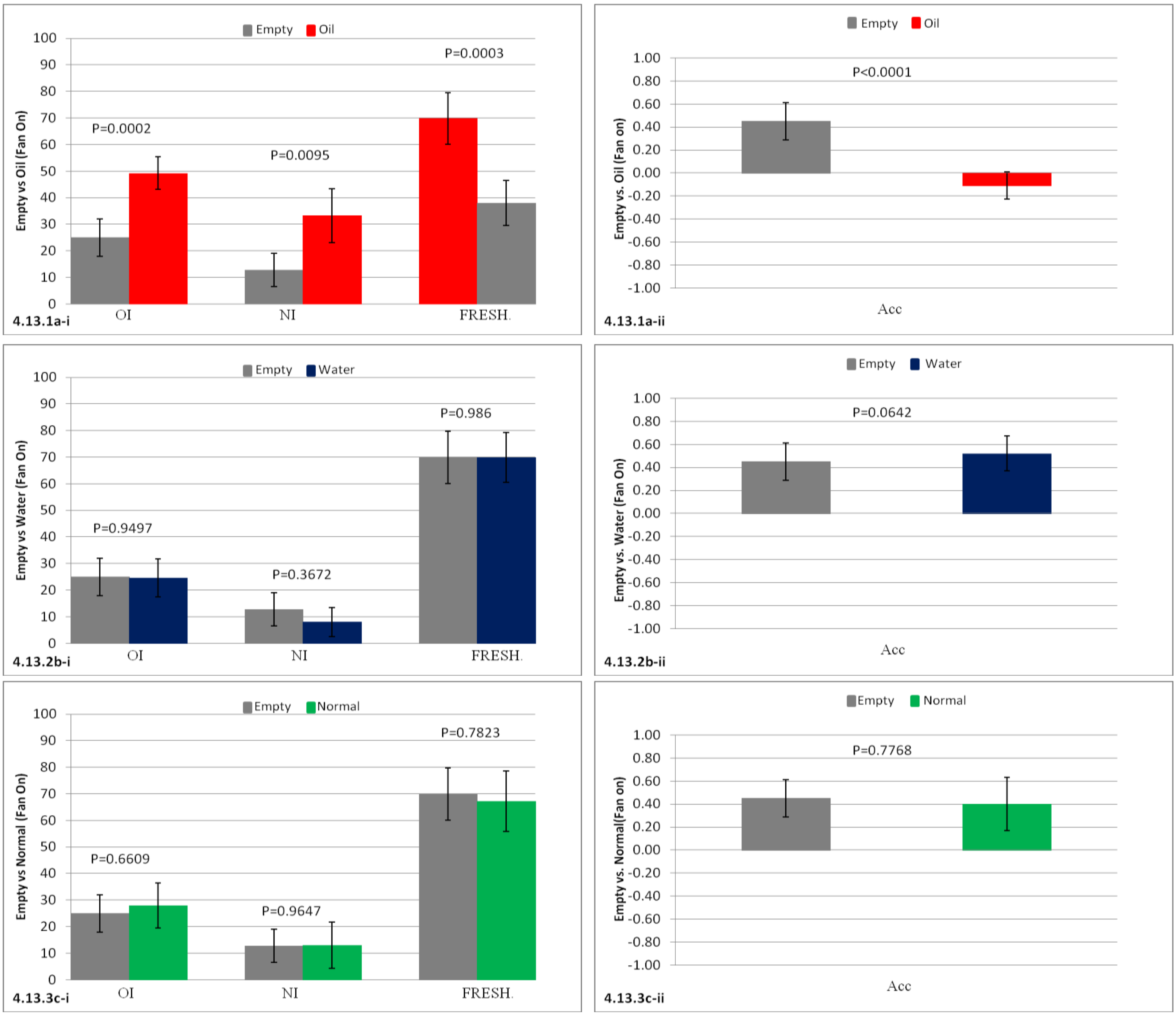
In figure 4.12b-i, the assessment between TYP 1 (UF) and TYP 3 (Oil) showed that both samples values increased slightly but with significant difference statistically between them ($P<0.05$) in terms of odour intensity, nose irritation and freshness of air. Moreover, with the Fan On condition, the UF odour intensity value reduced to slight odour, in comparison to oil sample that is also reduced to moderate odour but with a higher value than UF. The same decreased values are displayed with nose irritation. In air freshness however, the perceived air of UF sample is increased to more fresh, and in oil sample the value increased slightly to 38 on scale but still close to stuffy on assessment scale. Figure 4.12b-ii shows the acceptability of air between UF and oil samples, where the UF sample in Fan On chamber increased to 0.51 on scale and more inclined to clearly acceptable, and in oil sample showed slight increase in value but remained close to just unacceptable. However, the result showed major statistical difference ($P<0.05$) between the two samples in air acceptability assessment. Figure 4.12c-i illustrates the assessment between UF and Water sample in Fan On chamber. In all three variables, no significant difference was found between them but the result showed slight reduction in UF and Water but remains approximately similar in values for odour intensity and nose irritation, both showing slight odour and no irritation. The perceived air in both samples increased to more fresh with no significant difference ($P>0.05$). Figure 4.12c-ii illustrates the acceptability of air among the UF and water samples with no substantial difference observed ($P>0.05$) and the value increased to be in the upper middle range of clearly acceptable of assessment on scale. Finally, Figure 4.12d-i shows the assessment among UF and Normal samples, and observed no major difference ($P>0.05$). Normal sample showed slight increase in all variables with no impact on results. The same scenario was repeated in Figure 4.12d-ii, with no considerable variation among the two sample in air acceptability ($P>0.05$). The only observed difference is a slight enhancement in the acceptability on air in the UF sample and slight reduction in the acceptability in normal sample.



Figures 4.12 Samples assessment TYP 1 (UF) vs. All TYPs with Fan On condition.

Figure 4.13 shows the assessment between TYP 2 (Empty) and (TYP 3, TYP4, TYP 5) samples with Fan On condition, including all subjects group. Figure 4.13a-i shows the assessment between TYP 2 (Empty) with TYP 3 (Oil), the odour intensity and nose irritation shows slight decrease in empty chamber and slight increase in oil sample by changing the chamber condition into Fan On. However, the changes in values still show significant difference statistically among the two samples. The same state appears in air freshness; in empty chamber, the perceived air reduced slightly but was still close to fresh air, while in oil sample, the vote increased slightly with no changes observed (more close to stuffy), despite the substantial statistical difference that remained between the two samples results ($P<0.05$). Figure 4.13a-ii also shows slight reduction in empty chamber air acceptability but the range is still between clearly acceptable and just acceptable on assessment scale. In oil sample, the result increased slightly but remained close to just unacceptable at -0.11 on scale, and no changes were observed in statistical results with both samples still considerably different ($P<0.05$).

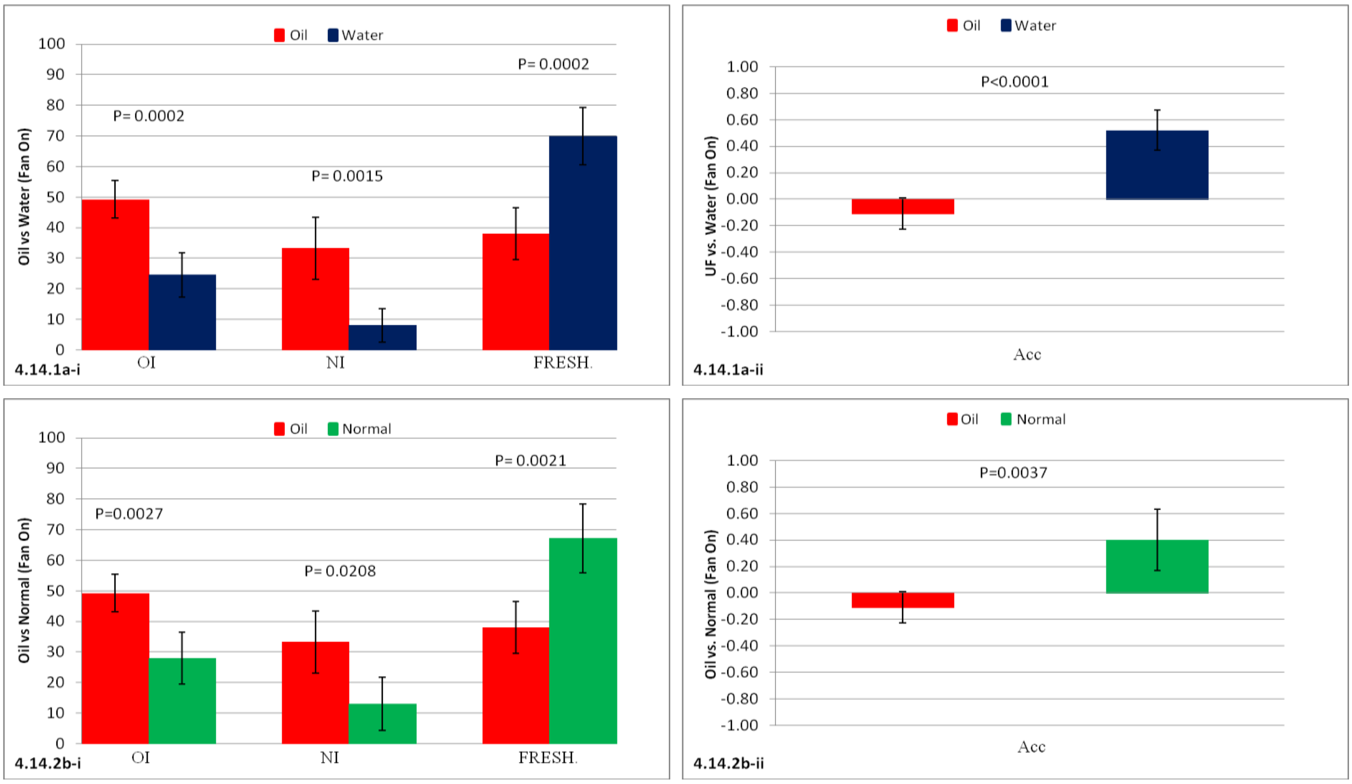
Figure 4.13b-i illustrates the appraisal between empty chamber and water sample. As previously mentioned, the values of empty chamber in Fan On increased slightly for odour intensity, nose irritation and air freshness but in water sample reduced to reach approximately similar values to empty chamber with no differences found ($P>0.05$). Figure 4.13b-ii shows the same variable between empty chamber and water sample and the limited variation ($P>0.05$), demonstrating that the acceptability of water sample increased slightly 0.52 on scale, or more closer to clearly acceptable. In Figure 4.13c-i, the comparison between empty chamber and normal sample shows slight increases in all variables without any significant difference statistically ($P>0.05$) apparent. Figure 4.13c-ii demonstrated that by changing the chamber condition to Fan On, the acceptability of air reduced slightly in empty chamber and normal sample with considerable variation ($P>0.05$). However, in all variable increases, there was no significant result or major value to mention, while all the increases were slight and do not affect the perceived air quality assessment.



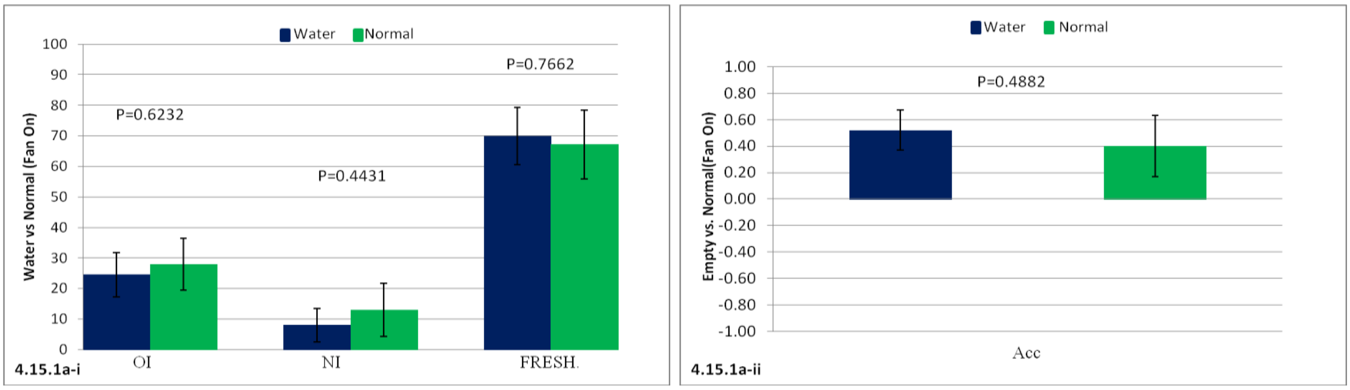
Figures 4.13 Samples assessment TYP 2 (Empty) vs. All TYPs with Fan On condition.

Figure 4.14 shows the comparison between TYP 3 (Oil) with TYP 4 (Water) and TYP 5 (Normal) in Fan On condition including all subjects. In Figure 4.14a-i, the oil sample value in odour intensity reduced slightly to 49.25 on scale and the water sample reduced to 24.55 on scale by changing the chamber condition to Fan On. Furthermore, the nose irritation remained the same in oil sample and was reduced slightly in water sample. The perceived air in oil sample showed slight increase at 38 on scale but remained close to stuffiness on assessment scale, while water sample value increased slightly to 69.95, indicating a closer value to fresh air. However, with all these slight changes on values, there was still significant difference statistically originating between the two samples ($P<0.05$). Figure 4.14a-ii shows the same samples but the assessment of air acceptability enhanced slightly despite the significant difference observed ($P<0.05$).

Figure 4.14b-i shows the comparison of oil sample with normal sample, and there is no significant variation observed statistically for all variables ($P>0.05$) although the values of normal sample increased slightly in Fan On chamber. In Figure 4.14b-ii, the oil and normal samples' air acceptability assessment is shown, highlighting that air acceptability in oil enhanced slightly but the normal sample was reduced slightly, with the results continuing to show significant difference statistically among the two samples ($P<0.05$). Figure 4.15a-i shows the assessment of TYP 4 (Water) against TYP 5 (Normal), the odour intensity in water sample reduced to reach a level less than normal (24.55/Water, 28/Normal) in Fan On condition. The same state repeats in nose irritation appraisal (8/Water, 13/Normal on measurement scale) however, with these changes, no significant differences were detected statistically among all variables ($P>0.05$). The air freshness value in water sample increased to 69.95 on scale and was more inclined to freshness, while was reduced slightly in normal sample to 67.20 on scale but still in the zone of fresh air. Figure 4.15a-ii shows that the acceptability of air in water sample increased slightly in Fan On chamber to reach closer to clearly acceptable, and in normal reduced slightly to 0.4 on scale but remained in the average of clearly acceptable and just acceptable with no significant variation statistically on results ($P>0.05$).



Figures 4.14 Samples assessment TYP 3 (Oil) with Water and Normal sample in Fan On chamber.



Figures 4.15 Samples assessment TYP 4 (Water) with Normal sample in Fan On chamber.

Figure 4.16 demonstrates the assessment between all samples (TYP 1, 2, 3, 4, 5) in No Fan condition, including all groups' vote. Figure 4.16a-i shows that UF sample value at 30.9 on scale varied between slight to moderate odour, while empty chamber value was 19.05 on scale with slight odour. Oil sample scored the highest value at 57.85 on scale with strong odour. The water sample is less than oil and scored 40.65 on scale and showed moderate odour. Normal MDF sample showed slightly similar value to empty chamber at 21.5 on scale with slight odour. The odour intensity among the five samples showed significant difference statistically ($P<0.05$). For nose irritation, the values reduced slightly between all samples but the oil sample remained significant with moderate nose irritation, while the UF and water samples were approximately similar in value (23/UF, 21/Water on scale) with slight nose irritation.

The empty chamber and normal sample displayed the lowest value with no nose irritation scored, but all samples showed substantial differences statistically in nose irritation variables ($P<0.05$). Furthermore, the perceived air quality showed considerable variation statistically ($P<0.05$) as well and the stuffy air was observed on oil sample scale 28.80. The highest value of fresh air perceived is shown in empty chamber and normal sample, and the values were slightly close to each other. The UF and water samples remained intermmediate in terms of air freshness and the value of each averaged between stuffy and fresh on assessment scale. Figure 4.16a-ii illustrates the acceptability of air among all samples. The oil sample showed the lowest value by -0.27 on scale close to just unacceptable, while the ranking between clearly acceptable and just acceptable on scale varied between UF, water, normal samples and the empty chamber simultaneously. In air acceptability, all samples showed significant differences statistically ($P<0.05$).

Figure 4.17 illustrates the same sample but the chamber condition is changed to Fan On including all subjects' vote. However, Figure 4.17a-i shows that by changing the chamber state to Fan On, all the values of samples reduced slightly except in the case of empty chamber and normal sample where the value increased slightly. But the oil sample remained the highest among all samples in terms of odour intensity, nose irritation and air stuffiness, showing considerable variation statistically among all samples ($P<0.05$). Figure 4.17a-ii shows the acceptability of air among all samples, while the same scenario of Figure 4.17a-i appears. The oil sample air acceptability assessment were enhanced but the value was still in just unacceptable on the measurement scale. The UF and water showed slight increases between clearly acceptable and just acceptable on average, but the empty chamber and normal sample values were slightly reduced but continue on average similar to UF and water.

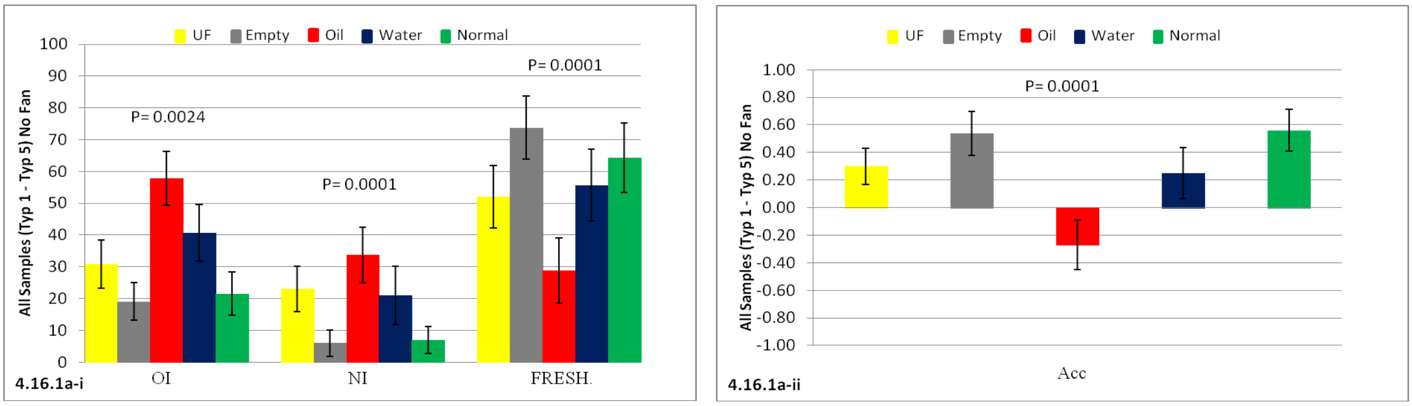


Figure 4.16. Samples assessment (TYP 1 – TYP 5) with No Fan condition.

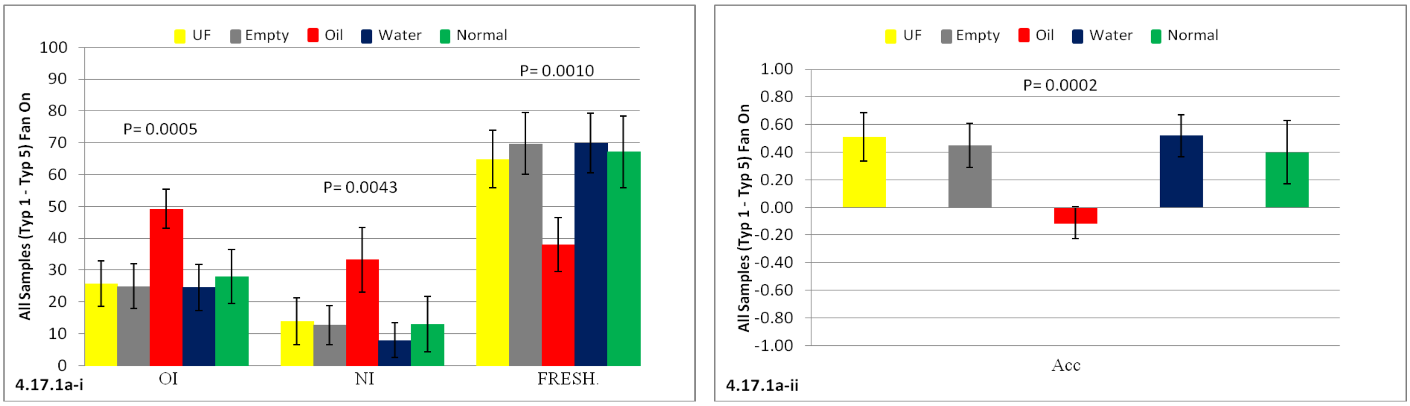


Figure 4.17 Samples assessment (TYP 1 – TYP 5) with Fan On condition.

4.5 Discussion

Figure 4.1 showed that the highest percentage of people who were dissatisfied was in the Oil sample, while in UF and Water samples, findings were similar with low percentage and the minimum percentage was observed in Normal sample and Empty chamber, which both showed relative similarity in dissatisfaction. Figure 4.1.1 showed that in empty chamber state (No Fan) the acceptability of air between all subjects was slightly similar to the results scored in Fan On condition of UF, Water, and Normal sample. This indicates that the subject's sensory perception about the potential existence of hazardous materials is high, while the impact of increasing the air temperature may result in less acceptability to indoor air, according to Hedge (1996). Moreover, these results showed slightly similar values in odour intensity assessment.

Figure 4.1.2 subjects perceived the odour of UF sample as similar to normal sample which could be linked to the experience's expectation and subject's lifestyle. In nose irritation, Figure 4.1.3 demonstrated that the only significant value appears to be in the oil sample due to the high chemical compositions of this product. This result is pointed by the study of Kim *et* al (2010), while the most common available VOCs emitted in indoor air found to be toluene, ethylbenzene, xylene and styrene. These compounds form the reactions of different coats used for MDF and PB surfaces especially in oil based paint.

Freshness levels in Figure 4.1.4 shows no considerable gap in results among all samples in both fan conditions. However, oil sample was noted to be stuffier in terms of perceived air quality with slight improvement in Fan On condition.

The odour intensity assessment of UF sample in Group 1 of fan conditions comparison (Figure 4.2a-i) showed no significant difference. Unpredictably, this indicates that subjects in Group 1 are highly accustomed to this odour level in the indoor environment where they live, study and work. Moreover, subjects' experience expectation of this odour seems to be consistent, although the sample was not visible during the chamber test to rely on sensory perception assessment, but the perceived odour showed no serious problem to mention. Nevertheless, the nose irritation assessment was significantly different, especially in No Fan chamber, where the level of irritation was higher but the level of assessment in both chamber conditions was slightly low with no severe irritations scored. The same scenario was repeated in the perceived air quality measurement, whereby changing the chamber condition to Fan On aided people to perceive air to be fresher. These results were more emphasized in the air acceptability measurement as illustrated in Figure 4.2a-ii. This indicated that subjects are more likely to accept the air quality of the UF sample, although slight odour and irritation scored but the level of sensory pollution is not high.

In Group 2, Figure 4.3a-i showed how the same sample (UF) was assessed under the two chamber fan conditions but the results showed less sensory pollution than Group 1. However, there was no significant difference statistically in Group 2, but the perceived air quality with all other variables showed slight improvement by supplying air into the chamber (0.3 m/s ±0.2). This helps to support the theory that controlling the air change rate on real buildings to manageable levels will increase the acceptability of air, reduce odour and irritation intensity and cause the air to be perceived as more fresh.

The reviewed study of Wargocki *et* al (2000) in interior office space helped to support this factor, whereby increasing the air supply from 3, 10, 30 l/s per person, the level of satisfactory between subjects increased and the air quality, odour intensity of material and furniture, and the perceived air quality were deemed better with less complaints. These results are matching the effect of (No fan and Fan On) on perceived air quality, while by changing the chamber condition from ‘’No Fan to Fan On’’ the level of perceived air quality was improved. Even though the level of assessment in Groups 1 and 2 showed no significant problem in terms of sensory pollution perception of the UF sample, the possibility of having the same results on real buildings cannot be predicted, although it is very important to conduct small scale chamber test to assess the impact of pollution caused by the use of different building materials indoors. In comparison between genders in No Fan, Figure 4.4 chamber shows that females perceived higher sensory pollution than males between all samples. However, the only substantial difference statistically observed was in water-based paint sample (TYP 4), but in all samples the difference shows increased rates for females than males. The oil sample shows the highest sensory pollution between all samples, since there was no significant difference among genders due to the high level of sensory pollution caused by oil sample. The lowest values scored were in empty chamber and normal sample with no negative impact. The results of UF and water-based paint sample were perceived with relatively similar assessments in both genders, considering that females scored lower acceptability to air, less air freshness, higher odour intensity and nose irritation values. These results were applicable in Fan On chamber as well where females scored higher sensory pollution than males in all samples except for water-based paint, while in both chamber conditions the male perceived lower air quality.

According to Lang et *al* (2008), people perception of sensory pollution is significantly affected by several factors in their personality such as anxiety, mental outlook and expectations in terms of the possibility of health risks. These factors are more discovered in female characters and this was evident in their perception assessment of all samples. Moreover, when comparing the two groups, Group 1 scored slightly higher levels of sensory pollution among all variables in both fan conditions generally, except in oil sample Figure 4.6c-i, since the odour intensity and air freshness perceived had slightly lower value than Group 2 with no significant difference. The air acceptability also shows a slight increase in Group 2 assessment than Group 1 in Fan On condition (Figure 4.6c-ii and Figure 4.7c-ii). This is due to having more females in Group 1 (7 females) than in Group 2 (5 females), and this is consistent with the results of gender comparison where females are naturally more perceptive to certain conditions than males. Hedge (1996) mentioned that the perception of indoor air quality conditions in people is dependent on different sensory development. For instance, the consequential sensation of irritation in eye, nose and throat are a direct signal of bad indoor air condition. High intensive odours are also indicators of poor indoor air quality. However, in some cases, the sensory system cannot perceive contaminated air. It is often the case that the human sensory system sends out reactive messages when exposed to risky environments or inhaled unhealthy air conditions, resulting in a psychogenic form of sickness reflected by building occupants. This fact has appeared in the empty chamber test, whereby changing the chamber condition from No Fan to Fan On, subjects perceived less air quality, indicating that they had a feeling of potentially hazardous air that was blowing from inside the chamber. This type of illness can increase extremely among people since the sensory perception of irritation and odours is not constant but differs between people and shows various reactions in time, especially given people's awareness on the possible risk of exposure to harmful material and conditions.

In TYP 4 (water-based paint), subject results in Group 1 (Figure 4.2d-i) and Group 2 (Figure 4.3d-i) were relatively similar. However, water-based paint products are ranked as more environmentally friendly according to the data sheet provided by the supplier in the UAE. TYP 4 results surprisingly showed to some extent similar assessment to the UF sample in both fan conditions in Group 1 and 2. This contradicts with the research hypothesis 1 and 2, while UF sample sensory pollution results were slight and comparable to water-based paint. Furthermore, by comparing the two samples (UF vs. Water) in Figure 4.8c-i (No Fan) and Figure 4.12c-i (Fan On), no significant variation was detected among all subjects. This illustrates that subjects perceived the sensory pollution of UF sample similar to water sample with no substantial impact on the perceived air quality.

The highest sensory pollution observed was in TYP 3 oil-based paint. Figure 4.2c-I and Figure 4.3c-i in Groups 1 and 2 showed that oil paint is dominant. However, the level of sensory pollution was slightly reduced in Fan On condition for both groups, but the implication was significantly high even by providing air flow. The air acceptability of oil sample in Group 1 (Figure 4.2c-ii) and Group 2 (Figure 4.3c-ii) showed slight improvement in Fan On assessment than No Fan, but the results remained constant between just unacceptable and clearly unacceptable on measurement scale. According to Singer *et* al (2006), the use of oil-based paint intensified the concentration levels indoors even by increasing the air change rate, thus it is important to consider the use of material coats and finishes with less polluted compounds to balance the air flow rates and material emissions. The oil-based paint results showed consistency with the research Hypothesis 1 and 2, since the oil-based paint is a relative pollutant to the indoor air even by increasing the air change rate values. According to the reviewed study of Kim *et* al (2011), oil-based paint at low weight coats emits benzaldehyde, while at higher weight surface (between 121 g/m² and 300 g/m²), the generated organic compound were formaldehyde, acetaldehyde, acetone, propionaldehyde and benzaldehyde. All these compounds contribute to high pollution indoors, as the oil-based paint is made of petroleum derivatives. These results are more highlighted in the comparison between samples under the two fan conditions (Figure 4.10 and Figure 4.14). The oil sample showed the lowest freshness of the perceived air between other samples and was not affected by changing the chamber condition from No Fan to Fan On. The results of water and UF wood samples perceived better fresh air than oil wood sample and were relatively similar. The study conducted by Uhde and Salthammer (2007) argue that it is very critical to reduce VOC emission caused by wood materials and their reactions, and a proper test is required for each product prior to installation to minimize the pollution sources and reduce health complaints. Different types of paint are applied as wood treatment and finishing, and many toxic compounds are included in the main compositions of these paints. The application of paint in many wood-based products varies between oil and water-based paint because the composition and the emitted chemical reactions of each differ widely from the other. Large areas of wood surfaces are coated, and the potential of contaminants emission in indoor air will occur decisively.

On the other hand, the acceptability of air, odour intensity, nose irritation and air freshness in TYP 5 (normal), or Figure 4.2e-i and Figure 4.3e-i, were similar to the empty test chamber in Figure 4.2b-i and Figure 4.3b-i in terms of sensory pollution, since no negative effects were observed among the two fan conditions. The results of comparing the normal and empty chamber samples (Figure 4.9c-i and Figure 4.13c-i) under the two fan conditions showed fluctuated similarity with no considerable difference. However, it is essential to mention that in Fan On conditions between normal sample and empty chamber, odour intensity, nose irritation, air freshness and air acceptability were increased slightly, most probably due to the chamber being customized only a few weeks before the experiment with all new materials. Conversely, these results can also confound the estimating outset of pollutants and dissatisfaction levels in this certain chamber condition.

Consequently, a very rational method of achieving better perceived air and less sensory pollution in a room is to replace the significant polluting products with a low polluting substitute and increasing air exchange rates. This is why providing different ranking of materials is appropriate for assessing the comparative impacts on sensory pollution in real buildings.

The effect of using low polluting materials indoors and controlling air change rate can enhance people's satisfactory levels and increase their performance. Thus, the perception of sensory pollution can perceive better air quality and enhance people's personal factors.

CHAPTER 6: CONCLUSION

Chapter 6: Conclusion

The need to perceive fresh air in interior spaces has been an area of great focus by professionals to achieve comfort health in indoor environment. In fact, improving the indoor air quality in entire interior spaces will contribute to reducing the risk of Sick Building Syndrome (SBS). Different building materials are used with little attention to the negative impact on perceived indoor air quality. This study examined the impact of wood-based panels used in the UAE industry on perceived sensory pollution of people. The samples were treated with three different finishes and the following scenarios were studied and evaluated: (i) wood panel with water-based paint, (ii) wood panel with oil-based paint, (iii) wood panel with melamine urea formaldehyde (MUF), (iv) normal MDF sample (Medium Density Fiberboard) without any additives, (v) empty chamber. Thus, measuring the sensory pollution from these treated wood products can assess the perceived air quality and determine human comfort level.

An experimental method was conducted by manufacturing an aluminum chamber to perform a test on 20 subjects from both genders by filling a survey questionnaire about the perceived air from each sample. Faculty Research Ethics Associate Committee in the British University in Dubai has confirmed the use of human subjects for the conducted experiment. Subjects were inhaling the samples' smell through a PVC pipe with two scenarios; No Fan air velocity 0m/s and Fan On air velocity ±0.2 0.3m/s. The chamber was hidden by a cloth cover and the only visible part was the PVC pipe to prevent any bias and rely on subjects' sensory perception.

To summarize, the following part illustrates the pointed research hypothesis and objectives and discuss the findings of the study. The study aimed to examine the impact of wood-based panels on perceived sensory pollution of people, and the first method applied in results analysis focused on the effect of the two chamber conditions (No Fan and Fan On) on perceived air quality. The followed method in results analysis considered the effect of subject's gender (Male and Female) on the inhaled air in both fan conditions. Moreover, this result was accomplished by considering the comparison between GRP 1 and GRP 2, while in group 1 number of female (7) was bigger than number of male (5), and equal in group 2 (5F/5M). Finally, all samples were compared to address the effect on perceived air quality and to mention if there was any significant difference statistically appeared under the two fan conditions (No Fan and Fan on).

Research Hypothesis 1

1. "*The level of pollutants can appear higher in oil-based paint and urea formaldehyde wood samples due to the high quantities of VOCs used as solvents in these products and can result in high odours, polluted indoor air and sensory irritation****''****.*

Objective 1

1. *To examine the correlation between variations in air change rate (Fan On/No Fan) on studied treated wood products and their impacts on human subjects' perceived odour intensity, sensory irritation, and air acceptability.*

Concerning the variation of air change rate, the results showed that by changing the fan chamber from No Fan to Fan On, the perceived air was improved in oil based-panel, water-based panel and Urea formaldehyde. Those findings are consistent with research objective 1 while by adding air flow (±0.3 m/s) into the chamber the results improved slightly and human subjects' perceived odour intensity, sensory irritation, and air acceptability with better results for the above mentioned samples. The Urea-Formaldehyde

(UF) shows more disstatisfied subjects with No Fan condition, while by changing the chamber condition into Fan On, the percentage reduced to 5.8%. In oil sample, the percentage reduced to 18% by changing the chamber condition to Fan On, and the highest percentage of dissatisfaction scored on oil sample. On the other hand, the water sample was significantly lower than oil and subjects showed more satisfaction in Fan On condition, while the percentage reduced to 13%. Despite improving the air quality in some samples, but the improvement didn't exceed unacceptable on the measurement scale, specifically for oil-based paint and this finding is consistent with research hypothesis 1 and 2 while both pollutant and dissatisfactory levels were increased significantly in oil wood sample. Therefore, it is necessary to consider proper materials selection parallel to applying adequate levels of air change rate. The oil sample scored the highest value in terms of dissatisfaction among the other samples and indicated significant difference.

Research Hypothesis 2

2. ***"****The level of dissatisfaction may increase significantly in oil-based paint wood products and melamine urea formaldehyde based product based on previous studies that have been conducted with various effect between genders (Subjective measurement)****"***

Objective 2

2. *To examine the significant difference in perceived air quality between gender assessments of pollutant emitted by four commonly available treated woods based products in the UAE.*

The results of gender comparison showed consistency with research objective 2 and a significant difference in perceived air quality between gender assessments of pollutant has been observed. Female results in gender comparison showed higher levels of sensory pollution to all samples except for water-based paint, where the male assessment was higher and perceived less fresh air. Moreover, this result was more focused in groups' comparison, while GRP 1 showed less acceptability and perceived less fresh air from all samples than GRP 2 due to the number of female (7) and (3) male, where in GPR 2 they were Equal (5/F, 5/M). The female experience, expectation and anxiety were also higher than that of males, and most probably due to predetermined gender comparison.

On the other hand, the perceived air was slightly reduced when changing the chamber condition to Fan On in normal and empty chamber and this is caused by the subject's perception about a potential hazardous materials exist in the chamber when blowing air. Unpredictably, the UF sample assessment was equal to water based-paint sample in both chamber conditions, this indicated that subjects are accustomed to this odour in their standard of living and experience expectations, this result contradict with research hypothesis 2, where human subject's perceived the air quality of UF sample in both chamber conditions with no serious impact on sensory pollution to mention.

6.1 Recommendation and Future Research

This study focused a certain common type of wood-based product (MDF) due to time constraints, while many other wood panels are used extensively in the UAE industry such HDF (High Density Fiberboard), Particleboard, Chipboard and Plywood. Different types of pressing, coating and bonding agents are used in these materials that have various emission rates and chemical reactions. For instance the plywood panels are considered to be one of the major materials to be used in building products (wall paneling, furniture and door skins) and their impact on health can vary due to the indoor environment conditions and type of finishes and bonded agent used. Applying various adhesives type to plywood panel such as phenol resin used for moisture resistant indoors can impact the perceived indoor air quality, thus it is essential to conduct proper study on these different application prior to installation. The fact of using different adhesives, lamination and finishes to the wood based panels or any other products is relying on the use of synthetic materials in components and treatments. Therefore, the author recommends conducting further research on other wood-based panels with different finishes because the impact of one type of wood to other may vary extensively especially when changing the type of finishing and coating. In addition, physical measurement could be integrated to the study by using different instruments to measure the level of VOCs parallel to the subjective measurement and provide additional comparisons and more detailed observations.

The implication of the treated wood-based products on sensory pollution could be measured with integrating other materials indoors, while there is a vast amount of materials used that can emit different chemical reactions and negatively impact the perceived air quality. This is due to different reactions that can appear from the primary and secondary emission of materials. Measuring these materials in different indoor conditions such as changing the relative humidity, air change rate and air temperature values can have various effects on perceived air quality and different assessments and implications can be concluded.

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APPENDICES

The Effect of (No Fan and Fan On) on Perceived Air Quality

Table (1) the comparison between two fan conditions (No Fan/Fan On) among the two subjects group.

Fan Comparison	Group Type	Sample TYP	OI	NI	FRESH.	ACC.
No Fan vs. Fan On	Group 1	TYP 1	0.0579	0.0101	0.0136	0.0419
		TYP 2	0.1331	0.118	0.5007	0.2967
		TYP 3	0.9771	0.8771	0.9526	0.7383
		TYP 4	0.0732	0.1201	0.0896	0.124
		TYP 5	0.3313	0.2031	0.6797	0.3899
	Group 2	TYP 1	0.7142	0.8477	0.9277	0.8544
		TYP 2	0.9531	0.7833	0.9754	0.9283
		TYP 3	0.0112	0.0424	0.1022	0.1364
		TYP 4	0.2828	0.1965	0.7482	0.4552
		TYP 5	0.6676	0.3431	0.9923	0.6571

Table 1 shows the comparison between the two fan conditions (No Fan and Fan), while in group 1 the nose irritation, air freshness and air acceptability in sample (TYP 1-UF) the result illustrated significant difference when blowing air into the chamber. The same improvement appeared in sample (TYP3-Oil) for group 2 assessment, while odour intensity and nose irritation showed considerable difference statistically in results.

The Effect of Subjects Gender on Perceived Air Quality

Table (2) the comparison between (Male/Female) among the two fan conditions "No Fan/Fan On"

Gender Comparison	Fan Condition	Sample TYP	OI	NI	FRESH.	ACC.
Male vs. Female Group 1 & 2	NO FAN	TYP 1	0.012	0.0173	0.0062	0.1915
		TYP 2	0.8122	0.7416	0.0982	0.4763
		TYP 3	0.3967	0.1204	0.4073	0.5182
		TYP 4	0.219	0.4215	0.0226	0.0155
		TYP 5	0.9603	0.1229	0.3	0.3335
	FAN ON	TYP 1	0.0309	0.0184	0.0928	0.5023
		TYP 2	0.6502	0.1638	0.2638	0.3108
		TYP 3	0.1083	0.1156	0.0698	0.5903
		TYP 4	0.2959	0.0246	0.0057	0.0324
		TYP 5	0.5325	0.3716	0.9671	0.9609

Table 2 illustrates the comparison of subject's assessment between the two fan conditions (No Fan and Fan On). In No Fan chamber results have shown marked difference between genders in TYP 1(UF) in odour intensity, nose irritation and air freshness. In TYP 4 (Water-based Paint) the air freshness and air acceptability observed to be statistically various in the same chamber condition. By changing the chamber condition to Fan On, TYP 1 (UF) assessment remained significantly difference statistically in terms of odour intensity and nose irritation. Additionally, the water sample in Fan On chamber also observed to be high with considerable difference statistically especially for nose irritation, freshness and air acceptability.

Comparison of GRP 1 and GRP 2 on Perceived Air Quality

Table (3) the comparison between (GRP1/GRP2) among the two fan conditions "No Fan/Fan On"

Group Comparison	Fan Condition	Sample TYP	OI	NI	FRESH.	ACC.
GRP 1 vs. GRP 2	No Fan	TYP 1	0.0036	0.00399	0.2795	0.2881
		TYP 2	0.1796	0.9999	0.8606	0.7331
		TYP 3	0.6955	0.6916	0.4308	0.1516
		TYP 4	0.5681	0.1286	0.1627	0.4005
		TYP 5	0.0426	0.0607	0.0098	0.071
	Fan On	TYP 1	0.3489	0.6771	0.4216	0.4748
		TYP 2	0.006	0.2091	0.3836	0.1715
		TYP 3	0.0812	0.4698	0.558	0.3554
		TYP 4	0.3291	0.5699	0.9414	0.8008
		TYP 5	0.0211	0.0225	0.0513	0.1004

Table 3 demonstrates the comparison between the two groups' assessment in both chamber conditions (No Fan and Fan On). In No Fan Chamber TYP 1 (UF) showed significant difference in odour intensity and nose irritation, while by changing the chamber to Fan On no variation observed for TYP 1. Additionally, in TYP 5 (Normal) there was a marked result observed in odour intensity and air freshness when setting the chamber on No Fan. The same scenario of result appeared in Fan On chamber for TYP 5 but the significant difference observed on odour intensity and nose irritation.

Effect of wood Samples

Table (4) the comparison between (No Fan/Fan On) among all wood samples (TYP 1 – TYP 5).

TYP (1) – TYP (5)/ All Wood Samples				
Fan Condition	OI.	NI.	FRESH.	ACC.
No Fan	0.0024	0.0001	0.0001	0.0001
Fan On	0.0005	0.0043	0.0010	0.0002

In wood samples assessment table 4 shows that in both fan conditions (No Fan and Fan On) there was considerable difference observed. Especially that TYP 3 (Oil-based paint) showed significant difference when comparing it to other samples in both chamber conditions and scored the highest level of pollutant and dissatisfactory among all samples.

Detailed comparison between all samples for both chamber conditions (No Fan and Fan On)

Table 5 shows the comparison between all samples in No Fan and Fan On condition and the highlighted results showed the marked difference of the four measured factors of the perceived air quality; odour intensity, nose irritation air freshness and air acceptability.

Table (5) the assessment of all wood samples (TYP 1 – TYP 5) - (No Fan/Fan On).

Fan Condition	Sample Comparison	OI	NI	FRESH.	ACC.
No Fan	UF vs. Empty	0.0554	0.0023	0.0164	0.0735
	UF vs. Oil	0.0005	0.1344	0.0128	0.0003
	UF vs. Water	0.1927	0.7833	0.694	0.7248
	UF vs. Normal	0.1466	0.004	0.1855	0.0447
Fan On	UF vs. Empty	0.8984	0.8306	0.5519	0.689
	UF vs. Oil	0.0003	0.00193	0.0013	<0.0001
	UF vs. Water	0.8499	0.3008	0.5311	0.9451
	UF vs. Normal	0.7462	0.8897	0.7921	0.5455
No Fan	Empty vs. Oil	<0.0001	<0.0001	<0.0001	<0.0001
	Empty vs. Water	0.003	0.0238	0.0597	0.0642
	Empty vs. Normal	0.6658	0.7863	0.3073	0.8852
Fan On	Empty vs. Oil	0.0002	0.0095	0.0003	<0.0001
	Empty vs. Water	0.9497	0.3672	0.986	0.614
	Empty vs. Normal	0.6609	0.9647	0.7823	0.7768
No Fan	Oil vs. Water	0.0319	0.1147	0.0074	0.0026
	Oil vs. Normal	<0.0001	0.0001	0.0005	<0.0001
Fan On	Oil vs. Water	0.0002	0.0015	0.0002	<0.0001
	Oil vs. Normal	0.0027	0.0208	0.0021	0.0037
No Fan	Water vs. Normal	0.0102	0.0345	0.3813	0.0428
Fan On	Water vs. Normal	0.6232	0.4431	0.7662	0.4882

The following figures showed the chamber during the venting period between each sample to flush out any accumulated odour from the tested wood samples.

Figure 1 ‘the chamber’ during and after venting between each wood sample assessment

Figure 2 ‘the chamber’ prior to sample installation for assessment

Research Ethics Form (Low Risk Research)

To be completed by the researcher and submitted to the Vice chancellor

i. Applicants/ Researcher's information

Name of Researcher/student	Taher Salah ElDanaf
Contact telephone No.	0097150 537 2637
Email address	Ta_deco@live.com 100112@student.buid.ac.ae
Date	

ii. Summary of Proposed Research

BRIEF OUTLINE OF PROJECT (100-250) words; this may be attached separately. You may prefer to use the abstract from the original bid):	The use of building materials in different indoor spaces plays a major role in indoor air pollution and quality. However, in the United Arab Emirates (UAE) with 'huge' construction industry and enormous market demand, control of emissions from building materials and potential impacts on building users have not been receiving attention it deserves. Where there is a lack of study in providing sufficient statements about their level of impact on user's health. Moreover, the use of wood based products as part of building materials in the UAE buildings, schools, homes, and fitting – out work are common extensively. This study aims to examine the effects of short term exposure to emission of chemicals from treated wood based products used in UAE market on sensory irritation, odour intensity, and air acceptability. Thus, objectives of this study are: (i) to examine the significant difference in gas phase concentration of pollutants emitted by four commonly available treated wood based products in the UAE; (ii) To examine the correlation between variation in gas phase pollutants concentrations emitted by studied treated wood products and their impacts on human subjects' perceived odour intensity, sensory irritation, and air

	acceptability.
MAIN ETHICAL CONSIDERATION(S) OF THE PROJECT (e.g. working with vulnerable adults; children with disabilities; photographs of participants; material that could give offence etc...)	• Healthy males and females university students aged between 20- 30 years • No illness and not on medication • Non-smokers only No vulnerable adults; children with disabilities; photographs of participants. For further information attached consent form.
DURATION OF PROPOSED PROJECT (please provide dates as month/year):	8 months (start date: 9/2012 and End date: 4/2013)
Date you wish to start Data Collection:	start date: 9/2012
Date for issue of consent forms:	12/2012

iii. Declaration by the Researcher

I have read the University's Code of Conduct for Research and the information contained herein is, to the best of my knowledge and belief, accurate.

I am satisfied that I have attempted to identify all risks related to the research that may arise in conducting this research and acknowledge my obligations as researcher and the rights of participants. I am satisfied that members of staff (including myself) working on the project have the appropriate qualifications, experience and facilities to conduct the research set out in the attached document and that I, as researcher take full responsibility for the ethical conduct of the research in accordance with the Faculty of Education Ethical Guidelines, and any other condition laid down by the BUiD Ethics Committee. I am fully aware of the timelines and content for participant's information and consent.

Print name:

Signature:

Date:

iv. Endorsed by the Faculty's Research Ethics Sub Committee member(following discussion and clarification of any issues or concerns)

v. Approval by the Vice Chancellor or his nominee on behalf of the Research Ethics Sub Committee of the Research Committee.

I confirm that this project fits within the University's Code of Conduct for Research and I approve the proposal on behalf of BUiD's Ethics Committee.

Print name:

Signature:

Date:

Note: If it is considered by the Faculty or University Research committee that there may be medium or high risk, the forms and procedure for that level of risk must be followed.

vi. **Project title**

Impacts of wood based product treatments commonly used in the United Arab Emirates on perceived air quality and human comfort

vii. **Principal Investigator and co-investigator(s) if any, with the contact number and organization.**

Principal Investigator: **Taher Salah ElDanaf**

Department/Faculty: **Engineering**

Institution: **The British University in Dubai**

Email: ta_deco@live.com

Telephone: **+97150 537 26 37**

viii. **What is the purpose of this research?**

You are invited to participate in this research. This information sheet provides you with information about the research. The Principal Investigator (person in charge of this research) or his/her representative will also describe this research to you and answer all of your questions. Read the information below and ask questions about anything you don't understand before deciding whether or not to take part.

Brief explanation of the research

The use of building materials in different indoor spaces plays a major role in indoor air pollution and quality. However, determining these materials in early stages prior to installation with conducting the proper study to examine their impacts on human health and wellbeing is a major concern due to exposure to emissions from these products.

However, in the United Arab Emirates (UAE) with 'huge' construction industry and enormous market demand, control of emissions from building materials and potential impacts on building users have not been receiving attention it deserves. Where there is a lack of study in providing sufficient statements about their level of impact on user's health. Moreover, the use of wood based products as part of building materials in the UAE buildings, schools, homes, and fitting – out work are common extensively. The available and frequent local wood based materials are divided between; wood with water based paint, wood with oil based paint and the wood with adhesive formaldehyde.

The common interior wood building materials and furniture fit outs used in the UAE are; High Density Fibreboard (HDF), Medium Density Fibreboard (MDF), wood based particleboard and plywood applied with different grades of treatment and paint coats to assure durability and resistant. The moisture resistant wood (MR) is bonded with melamine urea formaldehyde synthetic resin. Another grade is the boiling water resistant (BWR) bonded with phenol formaldehyde synthetic resin, in addition to the final finishes which may vary between oil and water based paints.

This study aims to examine the effects of short term exposure to emission of chemicals from treated wood based products used in UAE market on sensory irritation, odour intensity, and air acceptability. Thus, objectives of this study are: (i) to examine the significant difference in gas phase concentration of pollutants emitted by four commonly available treated wood based products in the UAE; (ii) To examine the correlation between variation in gas phase pollutants concentrations emitted by studied treated wood products and their impacts on human subjects' perceived odour intensity, sensory irritation, and air acceptability.

However, little or no studies have been done in the UAE to examine this concern. The proposed research attempts to bridge the knowledge gap in the understanding whether there be a significant difference in gas phase concentration of pollutants emitted by four commonly available treated wood based products in the UAE and how would the variation in gas phase pollutants concentrations emitted by studied treated wood products correlates with their impacts on human subjects' perceived odour intensity, sensory irritation, and air acceptability.

ix. Who can participate in the research? What is the expected duration of my participation? What is the duration of this research?

Who can participate in the research?

- Healthy males and females university students aged between 21- 33 years
- No illness and not on medication
- Non-smokers only

Expected duration of each subject: 30 hours

Duration of the research: 8 months (start date: 9/2012 and End date: 4/2013)

x. What is the approximate number of participants involved? 20 subjects

xi. What will be done if I take part in this research?

A total of 20 subjects The subjects will evaluate the level of acceptability of air flow in the chamber based on constant acceptability measure scale which varies from (-1) obviously unacceptable to (+1) obviously acceptable. Secondly, the odor intensity level that will be evaluated based on constant intensity scale that varies from "No odour" (zero) to excessive "overpowering odour". Additionally, added points to be marked on the measurement scale are; "Slight odour" (20), "Moderate odour" (40), "strong odour" (60) and "very strong odour" (80). Nose and eye irritation levels will follow continuous evaluation scale that varies from "No irritation" (0) reaching to "Overpowering irritation" (100). Complementary points marked on the measure are; "Slight irritation" (20), "Moderate irritation" (40), "Strong irritation" (60) and very "Strong irritation" (80).

Before entering the field laboratory housing the test chamber, each subject will inhale air coming from fan placed outside the field laboratory The inhale air from the fan will serve as a reference of what fresh air should be. Subjects will be required to hold on to the inhale air and exhale the air just before smelling air coming out of the test chamber.

xii. If biological samples are taken, what will be done with my samples?

Not applicable

xiii. How will my privacy and the confidentiality of my research records be protected?

Names of subjects will be taken from the subjects themselves, when seeking their consent to participate in the research. It is important to note that only the principal investigator will have the name of the subjects and this will not be released to any other person, including members of the research team. This identifiable information will never be used in a publication or presentation. All the identifiable health information and research data will be coded (i.e. only identified with a code number) at the earliest possible stage of the research.

xiv. **What are the possible discomforts and risks for participants?**

Possible discomfort and risks for participant will include: perceptual responses on the air quality, level of odor and irritation to the mucous membranes, other indoor environmental parameters such as air stuffiness and dustiness; and the intensity of SBS symptoms, i.e. 1) breathing system-related symptoms, *namely nose dryness, level of blocked nose, flu-like symptoms and chest tightness, 2) eyes-related symptoms, such as eyes dryness, eyes aching, and watering eyes, 3) dryness symptoms, namely throat, mouth, lips, and skin dryness, and 4) neurobehavioral-related symptoms, namely headache, thinking difficulty, dizziness, mood, fatigue, difficulty to concentrate, depression, alertness/ arousal level, and tension.*

xv. What is the compensation for any injury?

No injury and/or compensation is expected

xvi. Will there be reimbursement for participation?

Not applicable, all subjects are volunteers.

xvii. What are the possible benefits to me and to others?

There is no direct benefit to subjects in this research. The knowledge gained will benefit the public in future. A better understanding of the impact of the commonly used wood based products in UAE and their impact on human health, level of concentration and sensory perceptions.

xviii. Can I refuse to participate in this research?

Yes, you can. Your decision to participate in this research is voluntary and completely up to you. You can also withdraw from the research at any time without giving any reasons, by informing the principal investigator and all your data and samples collected will be discarded.

xix. Whom should I call if I have any questions or problems?

Please contact the Principal Investigator (Attn: name: Taher Salah at telephone: +97150 537 26 37 or email: ta_deco@live.com) for all research-related matters and in the event of research-related injuries.

Consent Form

I hereby acknowledge that:

1. My signature is my acknowledgement that I have agreed to take part in the above research.

2. I have received a pamphlet (or a copy of this information sheet) that explains the exposure of subjects to evaluate the level of acceptability of air flow in the chamber based for a continuous 4-hour working session in the Field Chamber. I understand its contents and agree to participate in this research.

3. I can withdraw from the research at any point of time by informing the Principal Investigator and all my data and samples will be discarded.

4. I will not have any rights to any commercial benefits that result from this research. I also agree that I will not derive any monetary or other benefits from this research.

____________________________ ____________

Name and Signature (Participant) Date

____________________________ ____________

Name and Signature (Consent Taker) Date

Survey for Studying Sensory Pollution

Date:	Subject No:
Gender:	Age:

Imagine that during your daily work you are exposed to this air:

1. How do you ass the air quality?

Please mark on the scale

Notice the distinction between

Acceptable and Unacceptable

1 — Clearly Acceptable

0 — Just Acceptable

0 — Just Unacceptable

-1 — Clearly Unacceptable

2. How do you assess the Odour Intensity?

- No odour
- Slight odour
- Moderate odour
- Strong odour
- Very strong odour
- Overpowering odour

Nose Irritation?

- No Irritation
- Slight Irritation
- Moderate Irritation
- Strong Irritation
- Very Strong Irritation
- Overpowering Irritation

3. How do you perceive the air?

(100) Fresh ———————— (0) Stuffy