An Experimental Study of Dry Onion Skins as Renewable Materials for Interior Finishes and their Impact on Indoor Environment

دراسة تجريبية حول قشور البصل الجافة و استخدامها كمواد متجدده في المساحات الداخلية واثرها على البيئة في الاماكن المغلقة

By

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Abstract

The interior and exterior materials of the building have major effects on the environment. Interior designers can absolutely make our environment green and sustainable by responsibly selecting and approving the interior materials which will be used during the construction like the floor and wall materials, fabrics, furnishings, and lighting systems. Utilization of green sustainable principles in the design works will greatly minimize the release of carbon footprints.

This research study aimed to explore the natural materials, which have potentials to be used in the interior finishing and spaces. This can be a replacement for the existing synthetic materials that may contribute pollutants to the indoor air and at the same time affect the comfort and health of the occupants. This study will also explore the relationship between the interior natural materials used in buildings and the human comfort, and it will focus specifically on the effects of these materials on the human comfort levels as there are many factors influenced by the interior natural materials leading to negative effects. Finally, it will identify the environmental impacts of the interior natural materials in hand by determining the emotions of VOCs (Volatile Organic Compounds) and other harmful gases (e.g. Ozone, Carbon Monoxide, Carbon Dioxide), and indoor conditions, i.e. Relative Humidity and Temperature.

In this research study, mixed-method technique was used in order to allow the researcher to collect more evidence to analyze a research problem that neither a qualitative nor quantitative method alone could deliver. The research study used an instrument, which monitors the indoor air quality indicators, called Direct Sense – IAQ. This instrument was used to measure the concentration levels of Indoor Air Quality (IAQ) on three customized specimens, (30 x 30 x 1) cm^3 boards of MDF (Medium Density Fiberboard), layered on one side with three different materials (Formica layer and wood veneer layer) both glued with chemical adhesive, and (onion's dry skin layer) glued with eco-friendly adhesive.

An experimental study was conducted over three days in the Fab Lab in the engineering college at Ajman University of Science and Technology (AUST) in Ajman. The lab's temperature was set at 21°c and Relative Humidity 45%. A small chamber borrowed from the British University in Dubai (BUiD) was used, in which the three specimens

were placed to be further tested. The chamber was made of 6mm clear glass and supported by 4.5cm aluminum frames, which hermetically sealed the chamber from the edges, with dimensions of 60cm (L) x 60cm (W) x 60cm (H) = 0.216 m^3 .
Another experimental study was conducted in the media lab at (AUST) to test and measure the ability of the onion skin board of sound absorption and insulation. The research study utilized a Sound Level Meter called PYLE PSPL01, in order to measure the ability of a (30 x 30 x 1) cm^3 panel fully made of dry onion's skin bonded with PVA adhesive to insulate the sound when used as a partition that separates two spaces.

For the sound absorption experimental test, two mock up boxes measured of (30 x 30 x 30) cm^3 were fabricated, the first one was fully lined with (1 x 30 x 30) cm^3 onion skin panels pressed and bonded with an eco-friendly adhesive, and the second one was lined with (1 x 30 x 30) cm^3 of Rockwool panels. While for the sound insulation experimental test, a mock up box measured (30 x 30 x 60) cm^3 was fully lined with 1 cm Rockwool rolls or panels. This box was divided into two equal parts; once by the panel of onion's dry skin and the other time by the panel of Rockwool in order to measure the sound insulation properties for both materials, and later to make a comparison between them.

Findings showed that the onion's dry skin has a good performance in layering MDF surfaces as a replacement of wood veneer or Formica in some places. It has also good acoustic performance and is comparable against that from the conventional synthetic absorber.

Abstract (Arabic) الملخص

إن المواد المستخدمة داخلياً وخارجياً في أي بناية لها تأثير رئيسي على البيئة. إن المصممين الداخليين يمكنهم أن يجعلوا بيئتنا خضراء ومستدامة بشكل كامل وذلك بألتزامهم المسؤولية في إختياروقبول أستخدام مواد داخلية أثناء البناء مثل الأرضيات ومواد الجدران، الأقمشة، التأثيث ومنظومات الإنارة. إن إستخدام المبادئ الخضراء المستدامة في أعمال التصميم سوف يقلل بشكل كبيرمن آثار الأنبعاث الكاربوني.

إن هذه الدراسة البحثية تهدف لأستكشاف المواد الطبيعية، التي من الممكن أستخدامها في الأعمال النهائية الداخلية والفضاءات. هذا سيكون بديلاً عن المواد الأصطناعية الحالية التي قد تساهم بتلوث الهواء الداخلي وتؤثر على راحة وصحة الأشخاص الموجودين. كما وأن هذه الدراسة تستكشف العلاقة بين المواد الطبيعية الداخلية المستخدمة بالبناء وبين مستوى الراحة البشرية حيث إن هناك العديد من العوامل المتأثرة بالمواد الطبيعية الداخلية تقود الى عوامل مضادة. و أخيراً فأنها ستشخص التأثيرات البيئية للمواد الداخلية الطبيعية وذلك بتحديد الأنبعاثات (المركبات العضوية المتطايرة) والغازات المضرة (مثل ألاوزون ،أول أوكسيد الكاربون، ثاني أوكسيد الكاربون، الرطوبة النسبية ودرجة الحرارة).

في هذه الدراسة البحثية تم أستخدام تقنية الطرق المختلطة لغرض تمكين الباحثين من جمع أدلة أكثر لتحليل وبحث المشكلة بدلاً من الطريقتين النوعية أو الكمية كلٌ على حدة وما يمكن أن تقدمانه من نتائج. إن هذه الدراسة البحثية أستخدمت جهاز يراقب مؤشرات جودة الهواء الداخلي، ويسمى التحسس المباشر- Direct Sense – IAQ . أستُخدم هذا الجهاز لقياس مستويات تركيز جودة الهواء الداخلي IAQ في ثلاثة عينات صنعت خصيصاً لهذه التجربة وهي عباره عن الواح MDF بقياس (30×30×1) سم مكعب، بطبقات من جهة واحدة بثلاث مواد مختلفة (طبقة فورميكا وطبقة القشرة الخشبية) كلاهما ملتصقان بواسطة مادة لاصقة كيمياوية و(طبقة قشرة البصل الجافة) ملصقة بمادة لاصقة صديقة (ملائمة) للبيئة.

تم أجراء دراسة تجريبية خلال مدة ثلاثة أيام في مختبر (فاب) في كلية الهندسة بجامعة عجمان للعلوم والتكنولوجيا في عجمان. تم ضبط درجة حرارة المختبر على 21 مْ ورطوبة نسبية 45%. تم وضع العينات الثلاثة بحجرة تم أستعارتها من الجامعة البريطانية في دبي، بمقاسات 60 سم طول × 60 سم عرض × 60 سم أرتفاع = 0.216 م مكعب. الحجرة مصنعة من زجاج شفاف سُمك 6 ملم مثبت بأطارات من الألمنيوم قياس 4.5 سم لأُحكام غلق حافات الحجرة.

تم أجراء دراسة تجريبية أخرى في مختبر وسائل الأعلام بجامعة عجمان لأختبار و قياس قابلية الأمتصاص والعزل لطبعات قشرة البصل. أستخدمت هذه الدراسة البحثية (جهاز تحديد مستوى الصوت) يسمى PYLE PSPL01،لغرض قياس قابلية الطبقة المصنعة كلياً من قشرة البصل الجافة (30×30×1) سم مكعب المتصلة بلاصق PVA ، على عزل الصوت عندما تُستخدم كحاجز بين فضائين.

أما تجربة أمتصاص الصوت فقد تمَّ تصنيع صندوقين مجسمين لقياس (30×30×30) سم مكعب، الصندوق الأول تم تبطينه بالكامل بطبقات قشرة البصل قياس (30×30×1) سم مكعب مضغوطة

ومتصلة بلاصق صديق (ملائم) للبيئة، والصندوق الثاني مُبطن بطبقات قياس (30×30×1) سم مكعب من مادة الصوف الحجري. أما لتجربة العزل الصوتي فأن صندوق مُجسم قياس (30×30×60) سم مكعب تم تبطينه بالكامل بلفات أو طبقات من الصوف الحجري. تم تقسيم الصندوق الى قسمين متساويين:- مرة بطبقات من قشرة البصل الجافة ومرة أخرى بطبقات الصوف الحجري لغرض قياس قابلية العزل الصوتي للمادتين ولاحقاً أجراء المقارنة بينهما.

النتائج أظهرت أن قشرة البصل الجافة أداءها جيد في تبطين سطوح MDF كبديل عن طبقة القشرة الخشبية أو الفورميكا في بعض الأماكن. كما وأظهرت أداء جيد بالمجال الصوتي ومقارنة ضد المواد المصنوعة من مواد الأمتصاص التقليدية.

Dedication

To Jamil Al Shawaf's precious soul, my father; whose wish was that I prosper further in my studies.

To someone who lives inside myself till the end of my life.

I dedicate this work.

I am overwhelmed by a feeling of gratitude and appreciation towards all those who stood beside me and literally prove the saying of "a friend in need is a friend indeed". Their encouraging words will always be ringing in my ears, reminding me that I have all of them to lean on when I am in need of support and for them I am grateful.

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CHAPTER 1: INTRODUCTION

1.1 Background

Due to issues such as pollution, endangered natural species and diseases, environment concerns were raised in the past years. Those concerns involved the design industry, food industry, clothing industry, and in all aspects of life. Those concerns were shown in news, display billboards, boxes of cereals, toothpaste boxes, and soap boxes. While those initiatives are great, it is important to comprehend the real aspect of sustainability. And hence, lots of deliberations regarding changes in the environment have been raised in the daily lives of people, which signify that changes need to be effected in different design industries with relation to sustainability. It is a known fact that it is a human responsibility to cause drastic changes in the environment. These changes should positively affect all aspects of life here on Earth. Therefore it is the people's responsibility to apply the best practices of sustainability as stressed out by (Moxon, 2012).

It is essential to know that sustainability is much more than a marketing strategy, it is a genuine practice of improving and depending on ways including the prevention of abusing our natural resources. One of those major sustainability concerns is the interior design. Indoor artificial products can affect people because they are existing in restricted spaces e.g household, office, etc … and hence people might breath, touch or come into close contact with undesired artificial chemicals and emissions.

The interior and exterior materials of the building have major effects on the environment. Interior designers can absolutely make our environment green and sustainable by responsibly selecting and approving the interior materials which will be used during the construction like the floor and wall materials, fabrics, furnishings, and lighting systems. Moxon (2012) recommended that utilization of green sustainable principles in the design works will greatly minimize the release of carbon footprints.

The principle of sustainable development has been an area of attention by numerous interior designers and it is fast emerging. This offers a broad array of present opportunities and enthusiastic future possibilities. (Kibert 1999, p,1) highlighted the first explanation of the word 'sustainable development' and introduced it in 1987 at the World Commission on Environment

and Development' which defined it as the 'development that satisfies the requirements of the present as well as meeting the needs of the future generations'.

Kang & Guerin (2003), Loftness (2007), USGBC in (Cross Cain 2007) defined sustainable interior design practices as the balance between the interior design practices and the utilization of the resources from the Earth that gives benefit to humans and the world in the present and future times.

However all this can be worthless if not applied with the right industries. Moxon (2012) emphasized that interior designers are supposed to be properly coordinating with other industries in the construction field to mitigate the present environmental problems, or at the minimum to give attention to the present time's requirements while meeting the future needs at the same time.

1.2 Problem Statement

The importance of Environmental Interior Design vs. Conventional design is a major issue to be discussed taking into account the impact on the Indoor Air Quality (IAQ) and hence on the users. Environmental sustainability has become a primary issue within the field of interior design because of the wide-range of resources required for the interior use as mentioned by Ruff & Olson (2009) in (Bacon, 2011). Rider (2005) stressed out that sustainable interior design practices are activities that reduce the impacts to environment due to material selection, site selection, energy use, and water use. Taking into consideration all these points mentioned above will allow interior designers to make a healthy indoor environment psychologically and physiologically.

The harsh effects of the conventional interior design and the construction of buildings on the environment are devastating and most of the cases generate a persistent impact even after the building life span is over as stated by Cargo (2013). Montoya (2011), in Cargo (2013), mentioned that in the US the built environment utilizes 71 percent of the total electric power, consumes 30 percent of the total raw materials, and produces 30 percent of the total wastes outputs. The building industry is a major cause of the problems in the environment, as an example, the heat island caused by global warming as well as the increase in water and air

pollution, primarily due to absence of initiatives to implement sustainability. Thus interior designers play an important role in these situations.

Every year, there are three billion tons of raw materials that are consumed for making walls, foundations, and building finishes. These affect our natural environment to suffer extremely. Hence, this statistic could intensely be reduced if interior design professionals would spend their efforts and time to practice improving their knowledge about sustainable products and materials as pointed out by Foster (2007), in Cargo (2013).

Interior designers are in the position to bring a major influence on sustainability. Guerin (2003) in (Cross Cain 2007) argued that, sustainable interior designers focus on design plans which are environmentally responsible. These design plans specify and implement solutions for the interior environments that shows care and concern for both the earth's environment and the human's quality of life.

1.3 Research Scope

Part of healthy and environmentally friendly design practices are materials with long life-cycle and are durable, materials which can be renewed quickly, and specifying materials which are manufactured locally. Winchip (2007) investigated design practices that are sustainable for both residential and commercial interiors.

Cargo (2013) investigated a new method to interior design industry that is termed environmental interior design that takes care of the wellbeing of the building tenants while decreasing the harsh effects to our mother earth due to the traditional way of constructing the building.

In completion, interior designs which are environmentally sustainable decrease hazardous effects and increase positive impacts on the environment all throughout the life span of the building as pointed out by Kang & Guerin (2009) in (Bacon, 2011), and that can be achieved by mixing the techniques of the past with the fresh technologies of the present as vented out by Loftness et al (2007). Pilatowicz (1995) in (Bacon, 2011) cited that sustainable interior designs which are made with a sensibility, addressing the effects of all their elements, parts, and functions to the global environment. Further, he pointed out that interior designers who are environmentally attentive

practice their professions ensuring that indoor spaces are created in a manner as healthy and environmentally sustainable for the building occupants as possible.

The scope of this dissertation report is to experiment, analyze, study, and determine the effects of onion skin when used as a furniture finish layer and as an acoustic board to the building interior and its occupants.

1.4 Aim and Objectives

The aim of this research study is to explore the natural materials, which are possible to be used in the interior finishing and space. This will be a replacement to existing synthetic materials that might contribute pollutants to the indoor air and affect the comfort and health of the occupants. The study will also explore the relationship between the interior natural materials used in buildings and the human comfort, and it will focus specifically on the effects of these materials on the human's comfortable level as there are lots of factors influenced by the interior natural materials leading to opposing effects. And finally, it will identify the environmental impacts of the interior natural material in hand by determining if they emit VOCs and harmful gases.

The objectives of the research are as follows:

- To discuss the use of natural fibers of the abundant renewable and inexpensive dried onion's papery outer skin: as a tough acoustic material, and as an interior finishing material.
- To investigate and examine this natural material, which is originally from the food waste, and to identify their potentials and benefits of such a product with applications in the interior space.
- To provide recommendations about the new product for future studies.

1.5 Research Questions

The following questions were generated as an essential part of this report:

The research primary questions at hand are:

1. Why do people need to take food waste in consideration as renewable material?
2. What are the potential applications of renewable materials (for example onion's dry skin) in the interior finishes and spaces?
3. The impact of these applications on the indoor environment quality and on the occupants' comfort.

The research will have a secondary question:

What would be the barriers that might confront us in terms of the financial resources requirements? A budget might be needed for manufacturing the mock up boxes and the new material from the (onion's dry skin). Conducting the experimental study method will require special measuring tools which will also require a budget.

1.6 Research Methodology

The experimental study is one of the methodologies which will be used and it will require some sample specimen material to be tested in a particular fabricated environment that represent a real interior space. The material will either be used as a coating material or a wall finishing material. Explicit characteristics have to be weighed in like the variability in temperature and climactic condition to further investigate the reaction of the occupant and the effect on their comfortableness and eventually gather evidence-based information and data. Further details about this methodology will be interpreted in the methodology chapter. Another supportive methodology will be utilized which is the literature review - an approach that used collective information and knowledge that is directly related to the research topic from other people's work, in order to prove the original argument. The literature review is an important aid in studying the research questions based on a wider context of knowledge.

Beside those two strategies, conducting interviews with people and some experts in the field of interior design and indoor materials will be accomplished for more data gathering. Moreover, questionnaire-based Surveys will be selected to be one of the research methods in latter stages of the research to be used when the new product applied in a real interior space. Survey questionnaires can be conducted with the occupants of the building regarding the impact of renewable natural materials used in the interior of their building.

1.7 Study Limitations

- The collection of the natural raw materials is one of the main obstacles in this research report. As we need a big amount of it to make a small specimen, although it is a waste from vegetables and it is available in every single house and restaurant, etc. People are not aware of such kind of natural materials, and they were confused and astonished from the idea of onion waste collection.
- The other main difficulty is the adhesive resin, which is used with the raw materials during the bonding process. As the conventional adhesives available in the market are formaldehyde based which is mostly made up of chemicals, this test prefers the glue from natural resources. An alternative is to find some environmental-friendly product or to make an organic home-made adhesive from natural materials.
- Obstacles occur in fabricating the specimen and the chamber due to carpentry delay issues.
- The lack of availability of testing equipment is also a factor, which will be used to determine whether the material works.
- Limited number of published previous researches that investigated the usage of waste and raw materials in interior spaces applications.

1.8 Expected Outcomes

The past decades showed that environmental-friendly and 'green' building materials has been a significant issue for the built environment. The objective of 'green' building materials is to conserve energy and to lessen their effect on climate change as well as reduce the level of consumption of the natural resources. A 'green' building material has a minimal or no influence at all on our mother earth as mentioned by Bäcklund (2011).

Cargo (2013) stated that recycle, reuse, and reduce is a simple concept that is linked with sustainability efforts, and it is absolutely applicable to the built environment. This standard promotes a reduction in the production of new materials by reusing remaining interior materials and materials having recycled content.

Specification of the interior materials is one of the aspects where interior designers have an important role to the sustainable design efforts. However, a challenging task for the interior designer is the assessment of interior materials for cost efficiency and sustainability. Malin and Wilson (1997) in (Cross Cain, 2007) emphasized that a reliable non-biased referenced resources and education about sustainability are necessary to help designers in accomplishing this task.

(Bäcklund, 2011) further assured that there are lots of definitions for the words 'green building materials', however all of the definitions focuses on the habitat, wastes, materials, water, and energy. There are several materials today that are considered green building materials such as turf, bamboo, hemp, various kinds of grass, native stones, mud, and clay.

It is probable to have a proper blending of the previous knowledge and principles and the ever-changing new concepts and technologies on the design of great buildings which will result to successful sustainable outcomes. This new approach will guide the interior design professionals to change the materials used in their projects like the furnishing and lighting systems that have a great effect on the comfort of the tenants (Cross Cain 2007).

Sustainable materials like pre-fabricated materials and layers may be used to satisfy a successful sustainable design project. Utilization of sustainable green standards in design concepts helps to increase favorable effects to the human comfort and environment like conservation of energy, optimum usage of materials, and generation of 'clean energy'. The sustainable green concepts

should be utilized all throughout the whole area irrespective of the type and size of the buildings to achieve its advantages and benefits to our environment (Cross Cain 2007).

Typically, the concern of an interior design professional is a one-aspect practice outcome which is to provide appealing improvements in the interior space for customers. However, the last 25 years has shown a paradigm shift in the interior design profession particularly in the design techniques and strategy because it focuses now on the main goal of providing a healthy and sustainable environment for the people to live, work and play as pointed out by Bonda & Sosnowchik (2007). Our present time is starting to show that each person has a role for the overall environment condition, and the interior designer is responsible to the human's change in their lifestyle as argued by Mazarella (2011) in (Cargo, 2013).

People not only recognize their responsibilities and roles as well as effects on the environment, but they begin to search interior environments that promote environmental concern. This awareness in the environmental responsibility is the reason for the perspective and requirement for environmental interior design as confirmed by Jones (2008). Kang and Guerin (2009) in (Cross Cain 2007) defined environmental interior design as the interior design with all materials and systems integrated as a whole to achieve the goal of reducing negative effects on our environment and the tenants as well as increasing the positive effects on the environment, the business- related sector and the social systems during the life span of the building.

1.9 Structure of the Dissertation

This research report is divided into six chapters, which are further divided into subheadings. Chapter one is the introduction chapter, which tries to give a general view of the background issues of this research project. The problem statement and the scope are defined. Further, the aims and objectives are described and the limitations are also clarified in this chapter.

Chapter two is a significant part of the research, comprises a comprehensive study of literature review in order to gather summaries and outlines of earlier conducted reports, which are relevant to the research topic. It provides a background to this experimental study. Green building materials are discussed and a background to onion papery peels as green building components

are presented.

In chapter three, different research methods are being discussed, and the two selected methods will be explained in more details.

Chapter four gives an overview of how the onion peels were used, manufactured and tested. It also classifies the methodology used in this research. The procedure of manufacturing the materials is explained and the appliances used in manufacturing the panel are presented. This chapter also identifies the features of the field experimental method, subjects, and the appropriate requirements needed to apply chamber test, in addition to the system used for analyzing the data. The materials used in this research are described. Testing equipment is also described and the three different test methods are explained.

In Chapter five, the Results of the field experiments are being collected and comprehensive discussions are presented.

Chapter six presents the Conclusion of the study and gives an objective answers to the research questions. Furthermore, this chapter emphasizes the importance of the study, and highlights how this study is interrelated with the supported literature and its practicality in the interior design field and to the professionals not only in the UAE market but also worldwide.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Awareness is rising day by day regarding the environmental changes, and has reached everyone old and young, through all the means of communication. This call has reached us being interior designers and we are obliged to respond to this by cooperating with other construction trade professionals in making a difference to help the environment. Our role as interior designers is to alter our design strategies into a manner less harmful, in order to either resolve what environmental disaster we are in or preserve what we have today and prevent future damage (Moxon, 2012).

Human beings have disturbed our eco-system in a bad way, one of them for example is the problem of utilizing man made reinforcement fibers. Using natural fibers is an option that has become defused in the present time, such as flax plant stem, jute and hemp which are most frequently used.

Due to their properties, natural fibers have become a competitor with glass fibers because of their feasibility which made them diffused in the biomaterial sector and composite industry as argued by Moriana et al (2014). Mohanty et al (2002) emphasized that natural fibers from renewable resource would be an absolute solution for several issues affecting our environment.

Making design choices should be done in a way that focuses on resources (materials and energy sources) that have a reduced impact, but at the same time doesn’t fail to provide equal terms of service along the life cycle of a product.

Its required for a designer to keep in mind that it may be necessary to redesign an entire product system drastically in order to really positively affect the environment and reduce the environmental impact. We may, for this reason need to choose different transformation technologies, distributed structures to reduce harm on nature, and different design products that require less resources, as all of these things if not done would normally lead to production of hazardous and toxic emissions especially during end of life treatments. Thus, the aforementioned changes are necessary.

Although the most crucial thing to look at for the environmental sustainability point is always looking to save resources for the future generations, this means that the renewability or non-exhaustibility of the products have a greater importance as explained by (Vezzoli and Manzini, 2008).

2.2 Green Materials

What is a green material? Calrecycle, (2010 in Bäcklund, 2011), stated that it is the kind of material with its general components being renewable materials. Moreover, it must be decomposable and be accessible in the local market to minimize the global transportation when breaking down the material using natural procedures. Over and above, it has to be recyclable and contribute to a positive indoor quality with less impact on the environment with deliberation to the entire life cycle of the material.

Last but not the least, it has to be manufactured to lessen the energy consumption in the building.

(Bäcklund, 2011), further mentioned that in today's conventional buildings no 100 percent renewable components can be found as the most common materials such as concrete, steel, aluminum and wood are still being used. Consequently, it is still necessary for further research about green materials for the visible interior spaces and not only in the structural component of the building.

The US's Environmental Protection Agency EPA defined indoor air pollution as chemical, physical, or biological contaminants in indoor air.

Choosing proper indoor materials maintain a healthy environment by affecting positively on the respiratory and digestive system, and reduce irritation on the eye and skin. Selecting proper materials can also reduce secondary and less significant health concerns caused by transportation energies. Thermal performance, indoor air quality (IAQ) and out-gassing, toxicity, and rot can also be diminish by choosing proper materials as cited by Loftiness, 2007 in (Cross Cain, 2007).

As reported by EPA, that some interior space finishing are sources of air pollution such as paints and coatings, wall coverings, adhesives and sealants, as well as some office furniture and

equipment, wood products, textiles, insulation, and cleaning products as explained by (Spiegel & Meadows, 2006) in (Cross Cain 2007).

Sustainable materials defined by LEED are those made from a fast renewable source, and are sturdy, recyclable, with less or no emissions that don't affect the environment during their entire life from their origin till discarding them. And by considering these factors, designers can decide whether the material is appropriate for the indoor environment or not as mentioned by (LEED, 2010), (Osmani et al., 2007), (Pilatowicz, 1995) in (Cross Cain 2007).

The interior designers' role is to enhance and prevent pollution that lies in the selection of materials, selection and position of furnishing, airflow and fenestration as emphasized by (Wasco & Lindsey, 2003). With regards to materials, they should be sustainable, i.e. durable with longevity as stated by Winchip (2007). When interior designers adapt sustainable applications and methods in interior spaces and especially residential, they should suggest products with minimal impact along its life span starting from extraction stage going through manufacturing, till transportation, use and post-use, as well as considering the embodied energy as stated by Winchip (2007). The concept of recycle and reuse is a principle of sustainable design and it is determined by the selection of the materials used in the project.

A recent study from a national design firm has proved that an average office redecoration including new ceilings, fresh wall finishes, new furniture for the office, interior doors, as well as new floor coverings, but not including lighting, accounts for approximately 850,000 MJ of energy, or about 35 KBtu per square foot of renewed space. Consequently, the embodied energy and carbon in an interior fit out project is rather important.

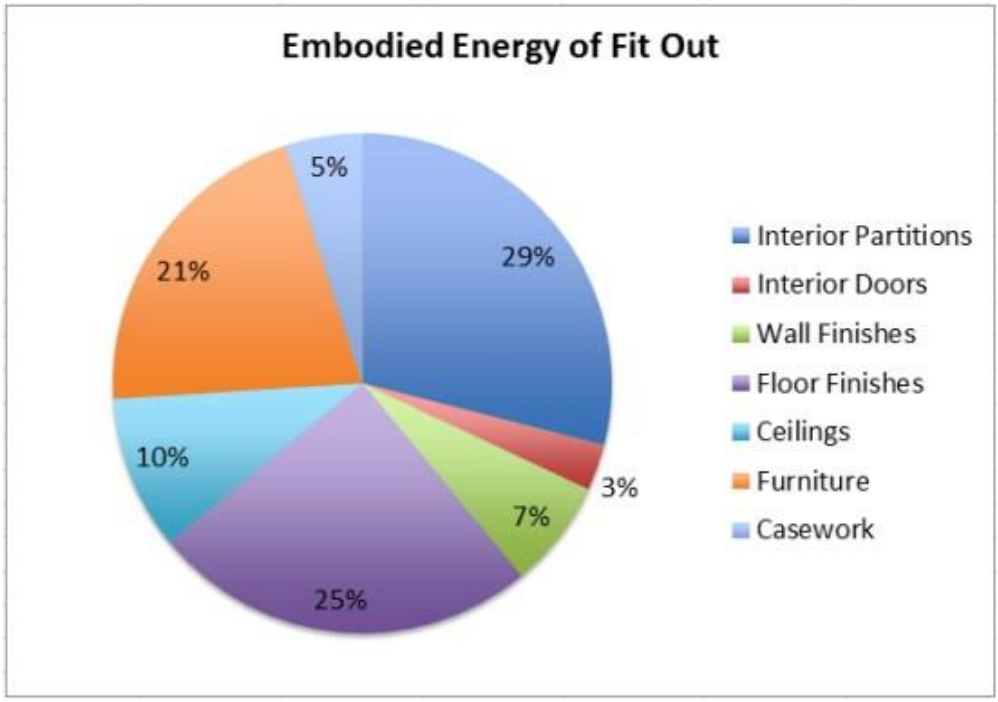


Figure 2.1: Embodied energy of fit out (Newman, J. 2012).

Observing the embodied energy and carbon of the substances used in space renovations can actually be an immensely quick method to emissions reductions for an organization that concentrates on attaining specific greenhouse gas emissions reductions. Furthermore, decreasing the embodied carbon in materials might actually be easier than one perceives Newman, J. (2012).

2.3 Utilizing Natural Material

The main emphasis of environmental interior design is the appropriate selection of products and materials, although its practice has been so far not reached its maximum capability. Motivation, awareness and education are some of the factors, which can affect and play an important role in this selection, as they are essentials in the improvement of the environmental interior design and in the selection of sustainable materials in the future.

A significant change in interior design field has been witnessed in the last few years, in offering a healthy and sustainable green environment for everyone to work, live, and play. This paradigm change is highlighted in the present time in its eventual target as argued by (Cargo, 2013).

Putra et al (2012) stated that the use of synthetic and non-biodegradable material becomes very dangerous when used in the interior spaces due to its contribution to the emissions of green–house gases in the air, which will in turn affect the human health and performance. As a result, studies have been made to address the environment-friendly and sustainable materials to be the replacement to many synthetic ones and especially the acoustic absorber.

(Kireiusa.com,2014) highlighted the uniqueness of Kirei products and their company which focuses on utilizing recycled materials and operates on concepts of sustainability and efficient practices. Kirei is a Japanese term symbolizing beauty, truthfulness and purity; all are reflected in Kirei's natural and beautiful materials seen in the contemporary designs of building constructions. Kirei products are characterized of being made from non-toxic , safe and reused components thus saving the natural resources from being diminished and keeping a healthy and clean environment. An example at hand of their products are the Kirei panels, as an eco-friendly interior design tools, created from fast renewable, recycled agricultural fibers. Other products are Kirei Wheatboard, Kirei Board and Kirei Coco tiles whose origins are sorghum grass, coconut and wheat plant fibers that get harvested from many parts of the world. Mainly are the stalks and coconut husks that make up those products, which would normally get burned and thrown to the landfills instead. As a result an obvious reduction in air pollution and landfill space is noted when those parts are utilized in such a way instead of being wasted.

The Moso bamboo plants are rapidly growing plants used to make Kirei bamboo, a product used to create panels and veneers, which carry modernity in their bamboo appearances. A great advantage at hand with bamboo plants is that the amount of fibers extracted from them is more in quantity than that which forestland wood produces, this in turn helps decreasing the tree cutting phenomena. Another plus point to Kirei products is their certification of having close to nil volatile organic compound (VOC) emissions, which are knowledgably harmful indoor air contaminants to humans. A commonly known VOC is the formaldehyde, known for its presence in all materials in use for building constructions.

Waite (2009) made used of field experimental method which analyzed and studied the components and features of bamboo that makes it environmental-friendly. More so, the study

conducted some interesting questions like: what components do sustainable textiles have? What will be the role and effect of bamboo textiles in the development of sustainability interior design?

Within the coverage of these queries, the paper concluded that there are several benefits discovered after the investigation done on the raw material bamboo and its natural properties such as biodegradability, renewability, small use of water, and least spatial utilization.

Other benefits found on the bamboo fabric are the rough-feel (ramie-like) for mechanically manufactured bamboo fabric or the soft-feel for chemically manufactured bamboo fabric.

The bamboo fabric has properties like anti-static and anti-microbial, as well as moisture-absorbent capability. The features of fabrics, yarns, and fibers are measured based on the following criteria: breaking firmness, moisture-absorbent capability and its ability to dry, breaking and tear force, and the shape of the surface area. However, there is an essential industrial problem the bamboo textile has been facing which is the increased costs during its manufacturing from the use of chemicals, water, and energy.

One of the many agricultural by-products that exhibits great qualities and is able to serve as a building material is wheat straw. Plenty of cultures world-wide are in fact involved in the use of straw as a building material, and for various other purposes as well. Especially in rural areas, it is often used as a roofing material.

A great way to produce ecological sandwich panels is to use straw to make them. Using green panels significantly reduces the global deforestation rate.

Although straw can be used in multiple application areas, it remains a by-product that does not get much attention and is not taken care of, as it is often burnt to get rid of. Whereas it can be made useful and when taken care of, any open field burnings would be avoided. Panels created from the straw material can always be recycled or otherwise changed into energy as mentioned by (Halvarsson et al. 2010).

Some properties of straw is that it is affordable, renewable, ecological, and has good building qualities. This is why people in the building industry value it as a great substitute to wood

materials. In North America alone, approximately 150 million tons of straw are produced per annum, due to the large harvest of cereal grain. The issue is not regarding the quantity of straw raw material production, the issue is actually how to make it popular in the market. What's quite important about the straw products, like strawboard or other panels made of straw, is their technical performance which is essential to the market and its demands as explained by (Fouts, 2011).

Fernandes, et al (2010) focused on the cork, which comes from the bark of oak trees. The paper extraction of cork is being done on a period of every nine to twelve years. The production of cork accounting to greater than 50% is based in Portugal. Cork powder is considered the major secondary industrial product which contributes lots of wastes in the process of cork industry. Cork – Polymer Composite (CPC) materials is a mixed of thermoplastics with the cork powder. Testing and investigations were performed to analyze the effect of this material to our environment, likewise to check the hardness property of this material, its acoustic properties, and its water absorption capabilities.

Fernandes, et al (2010) emphasized the study of the creation of new products from the cork powder, which has significant value to replace the medium density fiberboard or MDF used in flooring systems as part of the interior design industry.

The study demonstrated the new improved cork compound have positive results in its dimensional stability and the distribution of cork. It was also found that it was able to absorbed less water than the MDF, which is another important feature. More so, the acoustic property of the CPC was also acceptable. At low frequencies, the CPC and MDF have same acoustic property and at high frequencies, the CPC has greater acoustic property. However, the cork composites have one drawback, which is evident in its hardness and mechanical performance.

A study by Zah et al (2006) was made revolving around replacement of glass fibers in the automobile industry with Curaua fibers in order to reveal the subsequent economic and environmental effects as well as the social benefits. The study aimed to assess the potential environmental impact of those fibers when applied into the automobile field, whereby the physical properties of Curaua fibers were found to be quite comparative to those of glass fibers. Through the research, social and economical advantages were unfolded. One of the advantages

related to expenses was that Curaua fibers cost 50% less than glass fibers, which thereby is predicted to have a positive effect on the development of the big regions of the Amazon. Although this reduction in cost is only if the composites of Curaua-based fibers were used in a reduced weight than the glass-fiber composites. The Brazilian origin Curaua fiber plant, known as Ananas Erectifolius, usually found at water basins of the Amazon, appears promising with its high properties and affordable price.

Akova (2013) also pointed out in a study that industrial companies considered nowadays the natural fibers as optional reinforced materials to lessen the costs, and to utilize fibers with lower density and better properties. Moreover, the natural fibers have characteristics which are beneficial to the building and automotive businesses, like greater strength feature, chemical and corrosion resistance. Hemp, flax, and jute are fiber-based composites that can be used in thermoplastic polymers or thermoset rather than using human-made fibers. Based on the standard specifications of the fiber industry, natural fiber composites have protraction and very high resistance against breaking. It has various characteristics like twisting capability, acoustic insulation property, impact strength, cash performance, and ease of processing.

The study reviewed the literature of the latest progress and technology in the production of natural fiber strengthened by polymer composites. The study also presented latest literatures regarding the natural fiber composites to determine its usage in the automotive business particularly in its applications in the interior components of cars and cabins of trucks. Plant fibers were used most of the time in the base parts of the cars such as panels, shelves, brake shoes, and trim components because it produced 80% less energy, it is 5% less in costs, and it is 10% lesser in weight.

Nowadays, major car manufacturers such as BMW, Audi, Mercedes, Volkswagen, Opel, Ford, and Peugeot used natural fiber composites in several car applications like the back seats, back door and side panels for Audi, boot lining, headliner panel, and noise insulation panels for some BMW series models. For Volvo cars, it is used for padding of the seats and natural foams. Natural fiber composites are also used for the production of cargo floor tray.

(Montiero Et Al 1998) discussed the development and use of sugarcane bagasse in North Fluminense region in Brazil as reinforced composites. Firstly, due to its availability and its low

cost as a raw material which can be easily manufactured. Secondly, using the bagasse waste as reinforced composites was considered environmentally safe because it doesn't contribute pollution in the region.

Similar to the chopped wood or wood dust clusters fabrication process, the sugarcane bagasse, is fabricated. First, the bagasse is prepared for cleaning from organic residues, then it is cut, filtered and dried to be ready for mixing with adhesive resin.

(Loh et al., 2013) stated that researchers of material science have concentrated on the green materials as they are Eco-friendly and cost less than the manufactured materials, consequently they have recognized that this type of material contribute in lower pollutant indexes. Furthermore (Bäcklund, 2011) assured that green materials would be a cost saving substitute, as well as they are environmentally friendlier.

The successful sustainable design of goods and services, along with fabrication and design, play an important role in the consumer's decisions and choices as pointed out by (Barbut, 2006).

However, due to producer's insufficient improvement in the characteristics of products and lack of services including the waste of resources, high costs of products, and retrogression in the environment, besides the lack of knowledge of properly using this product to get the optimum results, all of these will let the consumers being aware of dealing with such products and prefer to go using another competitive product instead.

2.3.1 Natural Insulation Materials

Sutton et al (2011), have conducted a study about insulation with natural fiber, and the pros and cons of the natural fiber insulation if utilized in building and residential constructions. Natural fiber insulation incorporates a wide range of insulation products, which are fabricated from natural resources such as cotton, wool, flax, cellulose, and hemp, to replace petrochemical-based or mineral-based insulation materials or products. Natural fiber insulation products are portentous acoustic insulation compared to the conventional insulation products, in terms of less health dangers during application, less or zero carbon footprint, useful in regulating relative humidity and can deliver a system which is vapour-permeable. With all these advantages of the Natural fiber insulation materials, it is important to comprehend their benefits and value before

application. Sutton et al (2011) further laid emphasis on some of the natural fiber insulation pros and cons as follows:

Pros:

- Provide high performance in sound absorption and few thermal mass.
- Very low contamination levels, recyclable and disposable, safe impact on human health and comfort.
- Doesn't need protective clothes and masks during installation because it endorses high safety to people.
- It is a strong material in handling or execution, at-site application and shifting from one place to another.
- It absorbs vapor and it is adaptable with some low-impact materials.
- Renewable since it can store carbon throughout its lifespan.

Cons:

- Overseas manufacturing of products

Higher costs than the conventional mineral-based or oil-based fibers, but as demand and supply rises prices are predicted to decrease.

- Required to build thicker walls

2.4 Using Waste Materials

Barbut (2006) stated that researchers' expectations for 20 years ahead is to have about 30 percent rise of resource consumption and waste.

2.4.1 The Global Deforestation

The global deforestation is a significant issue that is seriously threatening our mother earth. It is a huge problem which produces dangerous effects to the environment by damaging the ecological systems, forcing residents to find another places for living and increases landslides. To solve this problem, decisions has been taken to find ways of preserving our forests. Different solutions could be done in different levels, depending on the place and the conditions of living.

Lots of green solutions were done as a replacement of conventional wood materials as mentioned by (Bäcklund, 2011).

One of the well-known building materials is the sturdy, conventional, traditional and sustainable Timber or so called Wood. Forests nowadays are spreading in about 30 percent, approximately 4 billion hectares of the whole woodland area.

Australia, Brazil, Canada, China, The Democratic Republic of Congo, India, Indonesia, Peru, The Russian Federation and United States of America are the ten countries that supplies the world with two thirds of entire woodland area as pointed out by (Kourous, 2008).

Over logging of forest trees is a problematic phenomenon that has worldwide consequences. In some regions of the world, this act of over logging is going at an excessive pace, one which nature cannot cope with anymore. The reasons for this are very high need for wood, an escalating demand for agricultural lands and the dependence or use of wood as an energy source. Tropical areas are the ones that see the greatest deforestation rates and this is mostly due to the need to have large areas for agriculture and growing crops as well as to feed animals. An average of 13 million hectares of forest is cut down annually as emphasized by (Kourous, 2008).

However, the processes of replanting and natural expansions of the existing forests help in slowing down deforestation. The United Nations Food and Agriculture Organization, FAO, has recognized the fact that deforestation rates have been declining throughout the past 10 years, but nevertheless it is still considered to be high. Areas as large as Costa Rica (51, 100 km^2) are harvested on a yearly basis as confirmed by (Un News Centre, 2010).

It is expected that before the second half of the twenty first century, much of the important resources such as oil and gas would have become depleted. Timber on the other hand can be considered a renewable resource, but is threatened as the demand for wooden products is high. It is crucially important, for maintaining healthy and long lived forests, that the cutting down of forests is managed well as argued by (Vellinga et al. 2007). On the bright side, in Sweden, deforestation seems to be well controlled, as during recent years it has managed to increase its forest areas twice as much, all through following a preserving management program. Since

forests store the majority of carbon dioxide, thus replanting of forests following cutting them down is essential to capture that carbon dioxide and maintain a balance.

Our planet is definitely threatened by deforestation, as forests are a big part of the naturally balanced ecosystem, in which many species live. Thus, the logging of forests greatly decreases the bio diversity and threatening the ecosystem's balance. In addition to this, soil erosion is quite an issue, as it brings about floods, avalanches and landslides. Moreover, the survival of some cultures and indigenous populations that depend on exploiting forest resources, is all under a threat because of deforestation as reiterated by (Kourous, 2008).

Taking Borneo, the third largest island in the world, as an example of a region that suffers from deforestation. There we find that half of the lowland forests have been destroyed by cutting down for various reasons, such as illegal logging, oil palm plantations, for agriculture purposes on large scales and due to fires.

World Map Changes in Deforestation

Figure 2.1 demonstrates the changes in deforestation globally. Red colour refers to the regions that are suffering a net loss of forests. As illustrated in the map, these areas; Southeast Asia, Central America, Brazil, Central Africa and Northwestern Russia are endangered of forestation. The dark green colour demonstrates the net gain of forests while the green colour shows the existing forests areas.

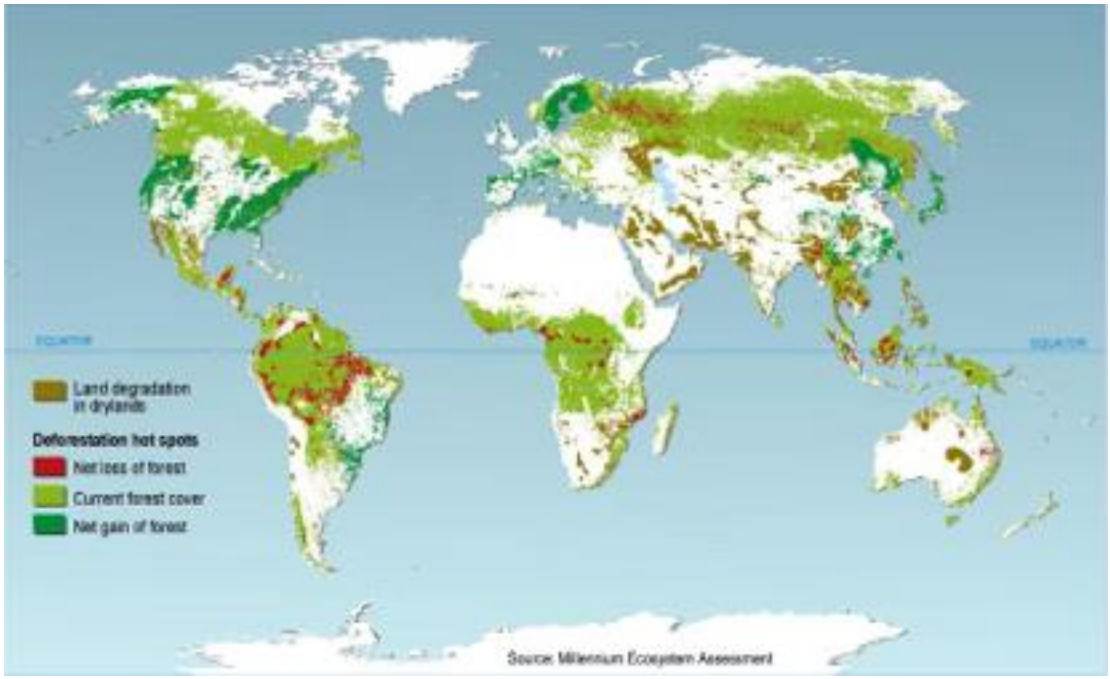


Figure 2.2 World map changes in deforestation. (Climatelab, 2010) (Bäcklund, 2011),

2.5 Onion the Pungent Vegetable

Hubpages (2013) specified the scientific name, type and class of Onions, as Allium Cepa, Cepa group, which categorized as a vegetable. Onions can grow in rich soil with natural ph or any different types of soil. In addition, onions are usually cropped in the cold season and because of their resilience, they are easy to grow. They have also another important property, which is moth repelling, where they repel ants, aphids, flea beetles, mosquitoes and carrot flies.

Researches further declare that onions have anti-asthmatic properties correlated with their organ sulfur components which prevent the inflammatory reactions in asthma as emphasized by (NOA, 2011) (Corzo-Martínez, M. Corzo, N. Villamiel, M. 2007).

Onions are bulbs that have thin paper-like outer coverings to protect the fleshiness of the leaves.

Onion has been cultivated for 5000 years or more as researchers agreed. Undoubtedly, onions were consumed for thousands of years as they grew in different counties.

Onions liability to spoil is less than other vegetables, which made them able to be transported everywhere. They are further easy to grow, in a variety of soils and conditions, which made them one of the initial cultivated crops (Onions-usa.org, 2011)

The world consumption trend was reported by (Onions-usa.org, 2011) as the following: the production of onions is rated annually at about 105 billion pounds. Whereas, the annual average of onion consumption estimates to nearly 13.67 pounds of onions per person worldwide. Libya ranked the highest in consumption of onions with a surprising average per capita of 66.8 pounds.

2.5.1 The Potential of Using Onion Waste

Millions of pounds of waste are produced yearly during the process of picking out of fruits and vegetables, then this waste has to be disposed somewhere.

An enormous amount of Onion waste is tossed away every year all around the world, and specifically around 500,000 tons in the European Union, Spain, Holland and the United Kingdom on the top in which it becomes an environmental problem. The outer brown skin is rich in fiber and flavonoids, which are beneficial to health. As the growing demand for this type of bulbs increased over the years, the generation of its waste also increased as studied by (ScienceDaily, 2011)

According to a research paper published in the *International Journal of Environment and Pollution*, it has been found that all the hazardous heavy metals, such as arsenic, iron, lead, cadmium, tin and mercury in contaminated materials, can be removed by using the onion and garlic waste which comes from the food industry.

The process of using waste from processing and canning of garlic and onion as new and alternative remediation materials to rid the contaminated materials like industrial effluent from all the toxic elements, has been explained by Biotechnologists Rahul Negi, Gouri Satpathy, Yogesh Tyagi and Rajinder Gupta of the GGS Indraprastha University in Delhi, India. This respective team has studied the factors including the influence of alkalinity or acidity, temperature, contact time and concentration of different materials in order to find the optimum conditions required to create a biological heavy metal filter that could be used for decontamination on an industrial scale as mentioned by (Negi et al., 2012)

Fig 2:3 The first application of the Onion's Dry Skin on a table top as a decorative element before 8 years.

2.5.2 Onion Waste into Energy

A project was established to investigate the characteristic of the produced liquid from the rotten onions, and also the possibilities of using onion waste accompanied with dairy waste to generate methane gas in anaerobic digesters.

Looking at food waste becomes an alternative for the conventional sources of energy. The disposed culled onions or any vegetable or fruit are either fed to animals or to be thrown on

fields and plow with the soil. Piling onions will make them ready to decay in place, in which a liquid would be produced during the process, this liquid has a high chemical oxygen demand (COD) which could be a pollution source if run into water bodies or leaked to water bodies driven by underground movement (Hawkins, 2013).

2.6 Adhesive

Adhesive is a material which can be used to bond two surfaces together by attachment as explained by (Green Building Regulations & Specifications, 2015)

Resin is a thick sticky flammable organic substance, unsolvable in water and produced by some trees and other plants especially pine and fir. It becomes yellow and hard after it is collected. Originally, resin is a natural substance but it can also be made from human-made element that is used in the industry as stated by (Anon, 2015).

Giroux, Freel and Graham, (2001) stated that the term "Resin" is a general word or phrase that used to define both natural and synthetic glues. The gluey characteristics of the resin are derived from the implicit capability to polymerize in a certain steady manner. The conventional resins used in the industry are normally made up of petroleum feedstock, such as phenol formaldehyde (P/F) and urea formaldehyde (U/F) resins, which is considered the most substantial types of synthetic resins in terms of quantity of production and overall sales. They are both used as binders for artificial wood products.

2.6.1 Human- made Resins vs. Natural Resins

For decades, Urea-formaldehyde (UF) resins and many other formaldehyde-condensed resins, have been used as wood adhesives. These types of wood adhesives are oil–based and they are poisonous. With respect to indoor environment, the law is strictly regulating the levels of gas emissions produced from UF-bonded goods. Furthermore, most formaldehyde-condensed resins are expensive and the UF resins show insignificant moisture resistance properties. For these reasons, different alternative of wood adhesives were produced. The need of developing new

types of adhesives from renewable materials or substances was inevitable. On the one hand, it is to reduce the reliance on the conventional types in the market which contains chemicals made of oil. And on the other hand, it is to increase the use of non-food agricultural merchandise and agriculture waste. The regulations became very strict against the use of building materials, when bonded with petroleum-derived chemicals or synthetic resins, because of the emissions associated with these types of synthetic materials that affect the human comfort and health. Consequently, the use of wood adhesive from natural sources was considered developed during the time in which the agriculture industry was keen to expand their market by investing in non-food products to reduce the cost with the same performance. Protein glues, such as casein, blood, and soy glues, were commonly used in the 1960s but they have faded out in the 1970s which were replaced by the synthetic ones. Formulating wood adhesives researches from protein sources mostly took place before 1960's as pointed out by (Kuo, MYERS and HEEMSTRA, 2001)

Vezzoli and Manzini, (2008) stated that in interior spaces material selection, non- toxic and harmless resources materials should be considered. Designers have to avoid working with aldehyde-based adhesives because they produce high of free aldehyde. Designers should go for alternative adhesives as new types are being investigated, for instance the ones that are based on poly-propylene and cellulose.

For centuries, natural resins were used by people for different purposes. For instance, pine pitch has been used in boats sealing, mummies, food containers etc. It is also used as a component in some substances and objects such as varnish, lacquer, inks, perfumes, and jewelry. With the technology development during the industry revolution, the human-made resin was discovered after it has been formulated into polymers.

Largely, polymers which are made from resins are the synthetic ranges of resins which in turn are firm and predictable, identically cheaper and easier to refine in comparison with the natural ones because they are made under measured and controlled environments with less probability of impurities insertion. The formulation of the resinous composite is as a result of some chemicals combinations' reaction. The resulted substance can be used in the industry to produce plastics,

paints and other similar substances that have natural resin in their components as explained by (Wise GEEK, 2015).

2.6.2 Dubai Municipality

Green Building Regulations & Specifications

Dubai Municipality (DM) put a considerable amount of effort towards standards for construction contractors and consultants. Consequently, its initiatives and objectives are fundamental in the thorough strategy. Dubai Municipality also introduced e-publishing in order to support the development and progress of any construction. The e-publishing comprised of the following regulations and rules regarding: specifications, green buildings, and a consultative notes on safety practices and building material specifications. In order to incorporate insulation materials into the buildings, the following points must be obtained:

1. The insulation materials must be fabricated and manufactured without the use of Chlorofluorocarbons (CFC's).
2. During the combustion the production of toxic fumes should be avoided, hence the insulation materials should not be toxic.
3. The added formaldehyde should be 0.05 parts per million (ppm) or less in the materials.
4. The Threshold Limit Value (TLV) in these insulation materials should have 0.1 or less of Individual Volatile Organic Compounds.
5. As Dubai Civil Defense requires, the materials should be fire resistant.
6. The Dubai Central Lab has to certify and approve these materials.
7. The requirements by Dubai Municipality of the specifications they have agreed to must be achieved and met. After the consent of Dubai Municipality, all thermal and acoustical insulation must be installed according to the manufacturer's instructions.
8. Low Emission Material in Coatings and Paints: The rules and regulations regarding the limits of Volatile Organic Compound (VOC) must be followed by all buildings, including the new applications of paints and coatings applied in buildings, which means these rules do not only apply to current buildings. Furthermore, the Dubai Central Lab must assent and certify these paints and coatings, or they can be approved by Dubai Municipality.

9. Low Emission Materials in Sealants and Adhesives: When using building adhesives, adhesive primers, and adhesive bonding primers, sealants, and sealant primers while building, the same rules above should be applied. First of all, the Dubai Central Lab and Dubai Municipality must have consent of these materials; second of all, the usage must follow the guidelines of the Volatile Organic Compound (VOC) as explained by (Dubai Municipality, 2015).

2.6.3 Formaldehyde

Formaldehyde is the most commonly found pollutant in different house products such as furniture and furnishing in extensively high amounts. It was classified by Missia et al (2010) as the top carcinogenic indoor material, among many other researched pollutants, and was found to have a direct effect on the entire occupant's health, specifically with high amounts of exposure.

Formaldehyde sources are characterized as being neutral gases with a very distinct strong odor, which are emitted largely in the indoor environments. This pollutant is found chiefly in building products, furniture, different user products and a variety of insulating materials. In wood-based products, a major element is urea-formaldehyde (UF) resin which produces the adhesive that is used in plywood, particleboard and chipboard and is made of a combination of urea, formaldehyde, and water. The UF resin is used with each of these wood products differently: in the plywood sheets, it is used as a glue which compresses the sheets simultaneously, while in chipboard and particleboard this UF resin is applied to the wood fragments and flakes to saturate them and structure the final product mix as stated by Turiel (1985) in (Salah El Danaf, 2013). According to Mazzeo (2011), 6-8% of the particleboard is UF resin and 8-10% of its weight is Medium Density Fiberboard. There are always some non-reacted formaldehyde that remains in the material after production which are the source of the emissions from these wood products. Due to the effect of some indoor conditions like moisture and heat, it would react with the resin and cause crack-up as emphasized by Turiel (1985) in (Salah El Danaf, 2013).

Phenol formaldehyde (P/F) resin has a high resistance characteristic to moisture, hence it has specific value in outdoor or humid environments. Consequently, the foremost adhesive is used for the plywood manufacturing, oriented strand board (OSB) and wafer board. Moreover, it is

used in lamination, insulation, molding composites, foundry materials, materials for abrasives and friction in the transportation manufacturing i.e., clutch facings, disk facings and transmission components.

Essentially the finished product of P/F resins is a mixture of P/F (phenol and formaldehyde), mordant, and water. In some particular adhesive applications, assorted fillers, extenders and dispersal agents may then be added.

The formaldehyde component in P/F resin is originated from methanol, which is in turn composed of natural gas. Phenol is also used in the manufacture of other important products, such as Bisphenol A which is a main component in polycarbonates used in computer, discs, compact discs and automotive parts. Further, it is a raw material for Nylon 6 called Caprolactam which is used within stain resistant carpets according to (Giroux, Freel and Graham, 2001).

2.6.4 Nontoxic Adhesive and Its Properties

Non-toxic adhesive, such as the worldwide Weldbond® is a kind of adhesive that bonds most anything. It is an environmental-friendly product. Moreover, it is a nonflammable adhesive which is fumes free, has low VOCs, and is created without animal by-products.

There are lots of advantages of Weldbond over other products of different brands, the main advantage being is that it is not a toxic formula. A third party company called Ecologo makes it safe for use against the environment and also certifies that it is manufactured without the use of formaldehyde. The certification code is CCD 046 – General Adhesives. Further, this adhesive becomes dry with flexible and clear finish and is therefore very fit for applications with fabrics and woods because it has no glue lines and the glue will adjust with the movement. It will not stain and will not be brittle over long period of time.

The above Universal adhesive is a bonding composite for many applications such as wood, glass, plaster, different types of metals, tiles, building panels blocks and boards, concrete, bricks, linoleum, foam, leather, fabrics and much more. This composite can be used as a bonding agent, glue, sealer or primer. It has high solid content which makes it easy to dilute, and therefore it has

been considered a very practical choice over customary products used for very particular application. It is soluble in water and within 20 minutes of usage, it can be removed and cleaned using water when drips appear. To remove this, use a warm wet cloth and put on the area to remove the drips. It will eventually become resistant to water but will not become waterproof.
Additionally, this type of adhesive does not require heavy clamping while it is being dried because it will produce a solid bond when it cures. Weldbond can also be painted over after it is cured. When it is cured, it is dry and be absolutely painted over which makes it suitable for repairing and craft projects because the glue lines are not visible.
It can act as a primer for bare drywalls or other absorbent surfaces because it can be diluted. Moreover, Weldbond aids in sealing the drywall and makes sure that the paint will not be absorbed by the drywall, instead it stays on top for an attractive finish, i.e., any kind of paint can be used on top of the Weldbond. This will result to savings on time and money.

Finally Weldbond is free from any animal by-products. It is produced in North America.

It can be applied in outdoor projects because it is weatherproof. However, Weldbond is permeable and not waterproof, hence Weldbond should not be used when there is standing water, which will make the adhesive to freeze as explained by (Weldbond.com, 2015).

According to (EPA 2012), the communal organic chemicals which can be found universally in the outdoors environment are Volatile organic compounds. VOCs are produced as gases in different interior spaces at certain temperatures and conditions.

VOC emissions are formed in interior places from the use of different materials with the presence of related conditions inside the place. These conditions such as room temperature and humidity levels and the rates of ventilation augment those building materials to produce gases. Occasionally, when the level of relative humidity increased in the indoor spaces, the emissions from VOCs become higher in concentration as explained by Mazzeo (2011) in (Salah El Danaf, 2013).

Not very long time ago, it was a common situation where people have to leave their house because of the fumes when repainting is done. Almost all traditional paints are having high intensity of volatile organic compounds that generates gas which is breathable when used. These compounds reduce the quality of the air, and may be dangerous to the health of the people.

Presently, optional techniques of manufacturing have given way to the production of less or nothing at all VOC paints that emits minimum or no VOC contaminants and are effectively odor free.

Adhesives, paints, and other protective finishing products are most of the time formulated with volatile organic compounds or solvents for the improvement of durability and performance. Moreover, cleaning up the paint always require harmful solvents that emits another VOC contaminants. However, the need for awareness of possible health hazards and overall quality issues has resulted to a requirement for products which has less emission of VOCs. This prompt manufacturers to rise to the challenge through the development of high-quality adhesives and coating which are latex-based and can be used for wide applications. Water is used as the carrier and solvent for latex paints which allows easier cleaning-up and mostly having lesser toxicity as compared to oil-based paints. At present, latex paints have the same or much better durability and quality than the traditional oil-based paints. There are also generally available stain and clear finish applicable for cabinets and floors.

It is important to note that not all latex-based coating have low VOCs. Products are described having low-VOC if they emit gas, which are significantly lower than other products. Few oil-based paints are considered having low-VOC because improvement has been made on their formulas. VOC levels are measured in grams per liter (g/l) or pounds per gallon (lbs/gal). Interior paint is granted a Green seal if the content of the VOC is less than 150 g/l (non-flat sheen) or 50 g/l (for flat sheen).

Many major manufacturers are now offering special paints that are completely free from VOCs and odorless for people who are specifically sensitive or who are very concern regarding quality of the air as stated by (Toolbase.org, 2001).

Nowadays, the building and construction sectors are using exclusively traditional building materials and adhesives which are chemically-based. These adhesives have undergone approvals from health organizations to be non-harmful to the tenants living inside the building. However,

there were no further actions taken regarding the handling of the chemicals after applying it on the building.

Chemical binders which are normally used as adhesives in the building materials are supposed to be safe for the tenants of the building. Many countries imposed their own rules and regulations regarding the chemicals to be used or not. If not prohibited, the usage of toxic binders in the building materials undergoes very stringent regulations. Chemical binders are usually hazardous also during its production if they are not properly handled. A chemically based binder would catch fire if it emits harmful gases. One of the significant problems about chemicals is the process of our mother nature in taking care of them and breaking them down which takes very long time. Some hazardous chemicals could not completely be broken down. Binders which are produced using organic materials and minerals are more appropriate for our environment because our nature can handle them after their practical application.

The development of building materials would need knowledge about the full life span of the building material and its effect on our environment. Usage of a non-hazardous eco-friendly binder in a panel would become user friendly for both the people living inside the building as well as to our mother nature. The plywood industry is expected to find adhesives which are environmentally friendly and uses renewable resources that will replace traditional adhesives coming from limited petroleum resources as emphasized by (Bäcklund, 2011)

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Overview of Research Methodology

Essentially, research methodology pertains to the processes or techniques that the researchers used which covers the process of the description, explanation, and prediction of an event or occurrence. A research method always considers the design or the development of a methodology regarding the problem or subject topic that is to be discussed. Same way, it is significant that the researchers must design an appropriate research methodology and research methods, which are required and suitable for the research report. Frequently, the terms research methodology and research methods are used interchangeably, however they are different from each other. Research methods are defined as the various processes, structures, and systems used in the research, on the other hand research methodology is the rational way of solving the problem. There are several factors to be considered in the development of the research methodology. Few of these are the following:

- Appropriate method for the selected problem.
- The degree of accuracy of the output of the method.
- The proficiency of the method (Rajasekar, et al, 2006).

3.1.1 Laboratory Methodology

The Laboratory-based methodology is characterized as an experimental research method that is controlled and makes use of a laboratory to execute the experimental study from which the measurements are collected. It is a fitting technique in testing particular parameters such as the performance of certain materials. Through this technique, absolute conditions can be controlled and managed such as the variables to be tested, and the sample materials can be exposed to various environmental conditions like sunlight, wind, and moisture. This approach will have its limitations to analyze the complete situation that will happen during its natural condition. Moreover, the setting-up of a test laboratory including all the required test equipment, and all accessories like the test probes and sensors for measurement purposes, will require considerably

high cost over an inadequate time schedule allocated to complete the research report as stressed out by (Kothari, 2004).

3.1.2 Case Study Methodology

There are various types of research methodology or technique. One type is called case study method. Essentially, the description of case study method is focused on the deeper complete understanding of a multi-faceted problem in the real-life situation. It is a combined research design that is adaptable to a broad range of industries, particularly with social science discipline. Case studies should be used for the purpose of explanation, description, and exploration of phenomena or events on a daily situation from which they occurred or emerged. They could be utilized to comprehend and study the causes and pathways as a result of phenomena or an event. In contrast with the experimental design method in which the objective is to analyze and test known hypotheses over an intentional manipulation of environment, case study methods are more designed on collecting data on a more understandable way. This simply means it is in-depth on the 'what', 'how', and 'why' of the problems according to (Crowe, Cresswell, Roberson, Huby, Avery, & Sheikh, 2011).

The case study methodology can be approached in several ways, which depends on the knowledge perception of the researcher. These comprise the following:

- Critical – emphasizes on questioning a person's own assumptions as well as other people's assumptions.
- Interpret visit – attempts to comprehend any inquiry related to social science and other disciplines.
- Positivist – familiarizing the factors of natural sciences as pointed out by (Crowe, Cresswell, Roberson, Huby, Avery, & Sheick, 2011).

The benefits of implementing the case study methodology are revealed from its features of being very adaptable. With this, case study research methodology assists examining investigation to be able to reach an improved understanding of particular events or to produce concepts and ideas to be used for the follow-up activity. It can also be utilized to accomplish a deeper account of particular experiences while maintaining the analysis of the 'what', 'how', and 'why' exploratory

questions, hence this supports the analytic assessment using the cross-case analysis approach. Further, it is very adaptable in such a way that it can be utilized as a study technique in carrying out emancipator work, for example: participatory inquiry, action research, etc as highlighted by (Gilson, 2006).

3.1.3 Field Monitoring Method

The field monitoring method will be applied in the advanced studies and it requires few sample specimen materials, which will be used in a specific interior space. The materials will either be used as a coating material of a wall and furniture or interior spaces partitions. Clear characteristics have to be considered like the changes in the climactic condition and temperature to investigate more the response of the occupants as well as the impact on their comfort and finally collect evidence-based data and information.

(Humphreys and Weinstein, 2009) explained that field experiments are so named to be able to arrive at a comparison with the laboratory experiments, which imposes scientific measures through testing of a hypothesis in a highly controlled and artificial setting of an experiment laboratory. One of the benefits of the field experiments is that the results are observed in the natural environment rather than in an unnatural laboratory setting. With this advantage, field experiments are considered to be more valid than laboratory experiments. However, field experiments also experience the chance of being contaminated unlike the laboratory experiments; this is why experimental conditions inside the laboratory are controlled with better precision and accuracy. But some events like the voter's presence in an election will not be easily analyzed inside a laboratory.

Field experimental approach is the appropriate method to be used in later studies. One benefit from this method is that it is quite precise. It is a database of sensible and scientific data, which is an outcome of a fully controlled, carefully planned and supervised tests and researches. This was evident on the mentioned reports with the specimen material being collected and tested on a careful manner.

One more benefit from the field experiment methods is experimental tests can be done many times based on the researcher's requirements till they have arrived at the most accurate and appropriate results. The use of exceptional instruments and computerized parameters provide

results that are not subjected by personal views and opinions. Field experimental method gives the opportunity to researchers to completely understand the characteristics of any material under investigation.

More so, the field experimental method makes sure the independent variables are managed properly and unwanted dependent variables are reduced. Managing the dependent variables is more beneficial than any other research methods.

3.1.4 Survey Methodology

This research methodology is selected as one of the methods to be used in latter stages of the research study in parallel with the field monitoring method, in order to have a feedback from the users of the interior space in which the new material is applied. Several types of question are usually used in the survey questionnaire. The first type is a true or false type of questions is to identify the understanding level of the respondents about the research topic. The second type, from which the respondents simply choose their answer based on their consciousness, is the choice questions. The rating type of question is the third type, such as the 5-point Likert-type scale, in which the respondents answers by rating it. The fourth type uses a 1-7 scale so the respondents can rate accordingly. A multiple-choice type group of questions related to the fourth group is the fifth type where the respondents are allowed to tick on a tick box for the appropriate answer. Finally, the respondents are allowed to answer a question in a phrase format.

There are several ways to send the survey questionnaire – either by personal interview, over the telephone interview, mail or email, and online or internet. Any of the ways mentioned can aim for specific responses from the respondents based on the type of questions asked. Time will not be wasted in acquiring results or outcomes because it is a direct to the point approach. This research methodology will be useful for researchers to get as much information as they would like to have as mentioned in the survey questionnaires. Another advantage is it allows focusing on a smaller group of people among a huge number of individuals.

One of the shortcomings of this approach is that some survey questionnaires could not effectively generate data as others do. There is a tendency of having partial results if the respondents were not properly chosen. Survey questionnaires which are not conducted personally

may have different results if they are done in person. Some answers may also be false information as they may not take the survey seriously.

However, this approach will be important in the future when the new material is applied in the interior space, because during that stage, survey questionnaires can be conducted with the occupants of the building regarding the impact of renewable natural materials used in the interior of their building.

3.2 Selected Research Methods

The proceeding discussion provides analysis of methodologies used by other papers having a similar subject, which will help in selecting the best applicable methodology for this dissertation.

3.2.1 Experimental Study Method

Several studies were made using this research methodology which made it as the right choice to be used in our research. Several parameters were measured during the experiment which confirmed its accuracy and reliability. The most promising benefit of this research method is that it is the only approach that can generate cause and effect relationships.
One advantage of this method over other research methodologies is its accuracy. This method encompasses sensible and scientific data based on monitored, carefully planned and fully controlled testing and research. Another benefit is the ability to perform experiments or tests on unlimited basis until the desired results are achieved. One strong point is the application of test instruments and program logics in the experiment which avoid the influence of personal views on the results or outcomes.

There are also some disadvantages in this research method, like its being artificial which does not conform to real life scenarios or situations. Sometimes, each variable is hard to control due to certain limitations of the laboratory. Another drawback is that this research method approach takes more time to perform and the test instruments may cost a lot.

An experimental method will be conducted by using a manufactured aluminum chamber to perform a test on three specimens to determine the Indoor Air Quality issue that might affect the

occupants, also different mock up boxes will be fabricated representing real rooms, to test the sound insulation and absorption, will be illustrated in Chapter 4.

3.2.2 Literature Review Approach

Literature review approach is another appropriate method to be used as a supportive method in this study.

A literature review is an evaluative report of studies found in the literature related to the selected study area according to (Boote and Beile, 2005). One advantage of this technique is that it uses substantial quantity of references to reach at a particular conclusion, which allows a broader list of information regarding any subject in hand. The research papers discussed earlier used review of literature methodology and have presented several references which contained relevant ideas and knowledge about the research topic.

A literature review can be a fast and efficient approach for earliest benchmarking, and to collect a large volume of information inexpensively and further, literature reviews have a practical value if the components are useful to the research as emphasized by (Marrelli, 2005).

A literature review goes beyond the search for evidence and includes coherent speech relationships between the literature and the field of study in hand.

In this research the literature has been reviewed, described, summarized, evaluated, and clarified in order to give theoretical basis for the study and help define the nature of the research.

3.2.3 Interview Method

An efficient research technique is following an inclusive interviewing method that involves contriving thorough individual interviews and gaining responses, in order to find out the perspectives of the interviewed people on certain situations and ideas (Boyce and Neale, 2006, p.3). These interviews are divided into three types: structured, unstructured and semi-structured.

The Structured interviews method is considered to be the most quick and straightforward one compared to the other two forms. Simply put, it is a series of questions previously determined

and set by the interviewer for the individuals to answer consecutively. Afterwards, the researcher is free to compare and contrast between each answer by different individuals in an easy way.

On the other hand, Unstructured interviews are the least reliable of all forms since the interviewer does not have a prepared list of questions. This way it is quite hard for the interviewer to compare and contrast between the answers since the questioning process is rather in formal and it is based on asking each person different questions.

The Semi-structured interviews combine the two previous forms together. In other words, the interviewer prepares a list of questions to be answered by all individuals, but he/she might be forced to ask additional questions to some individuals for clarification and further explanation.

The interviewing method has advantageous and disadvantageous. The advantageous include the ability of collecting the needed information and details regarding the research, and the ability of the interviewer to control the interviewing process directly by being able to clarify any misunderstanding or explaining any point. The advantages include the requirement of time and effort in comparison with other data-collection methods, and the fact that the researcher has to arrange the interviews based on the free time of the individuals and their ability to be around for questioning.

The interviewer should not be biased to a certain opinion while interviewing the individuals. Disagreement and displeasure should not be apparent on the interviewer's features if the person interviewed expressed ideas that do not go along with the interviewer's. One other thing is that the interviewing process, as mentioned above, needs time, effort and a suitable, relaxed environment so the interviewee does not feel pressured and annoyed while answering, this way the answers should be more effective as stated by (Connaway and Powell, 2010, p.170).

Engel and Schutt (2005) illustrate that some scholars say that a friendly environment is much needed while the interviewing process is held. The interviewer should not ask the questions in a threatening manner and should give an introduction to the topic, make the interviewee feel that his/her answers are important to the research, and assure the interviewee of the confidentiality of the process. Some scholars also note that some individuals can be biased while being interviewed, and the best way to avoid that is not to give them any freedom by not showing any expression that can make them alter their answers or ideas. Surely, if the interview is held in a

private and a formal setting where the interviewee does not feel pressured and judged, the bias can be reduced if not entirely avoided.

In this research the interviewing process was conducted as a supportive method with the experimental study, and it varied between the Semi-structured and the Unstructured. During the interview, questions were asked and each answer led to a different question, which made the process fall mostly into the Semi-structured pattern.

3.3 Advantages of Mixed-Method Approach

The combination of both quantitative and qualitative research methodologies have been a standard design selected by many researchers in carrying out their research studies. The mixed method research approach allows several perceptive outcome and conclusions, given the fact that text-based and numeric resources are integrated together. From its fundamental definition, mixed-method style entails the use of a minimum one qualitative method and one quantitative method, wherein these two forms of technique are both not essentially related to any particular investigative hypotheses as pointed out by (Creswell & Clark, 2011).

The benefits of using mixed-method technique or the combination of the two methods (e.g. quantitative and qualitative) are quite obvious. One of the benefits is that mixed-methods technique will allow the researcher to collect more proof to analyze a research problem than either a qualitative or quantitative method alone could deliver. Moreover, it also provides the researcher the window to focus on the weak points of utilizing qualitative or quantitative approach alone. This point out that the combination of both research methods provides advantages that counters the disadvantages of both the techniques. In the same way, mixed methods approach allows the opportunity to researchers in resolving the research questions that qualitative or quantitative methods alone could not be answered or addressed as argued by (Creswell & Clark, 2011). In an overview, mixed methods offer the benefits regarding the capability of the researcher to analyze completely a research problem by integrating test-based and numeric sources. Complete investigation is achieved in a sense that the research is directed towards the utilization of quantitative and qualitative approaches which supports each other's acquired results and assessments.

3.4 Research Design Diagram

The research design diagram below illustrates the stages of the experimental studies and the steps that have been used to get the results, which will be analyzed later.

The experimental study consists of two parts as shown below and will be discussed in details in chapter 5

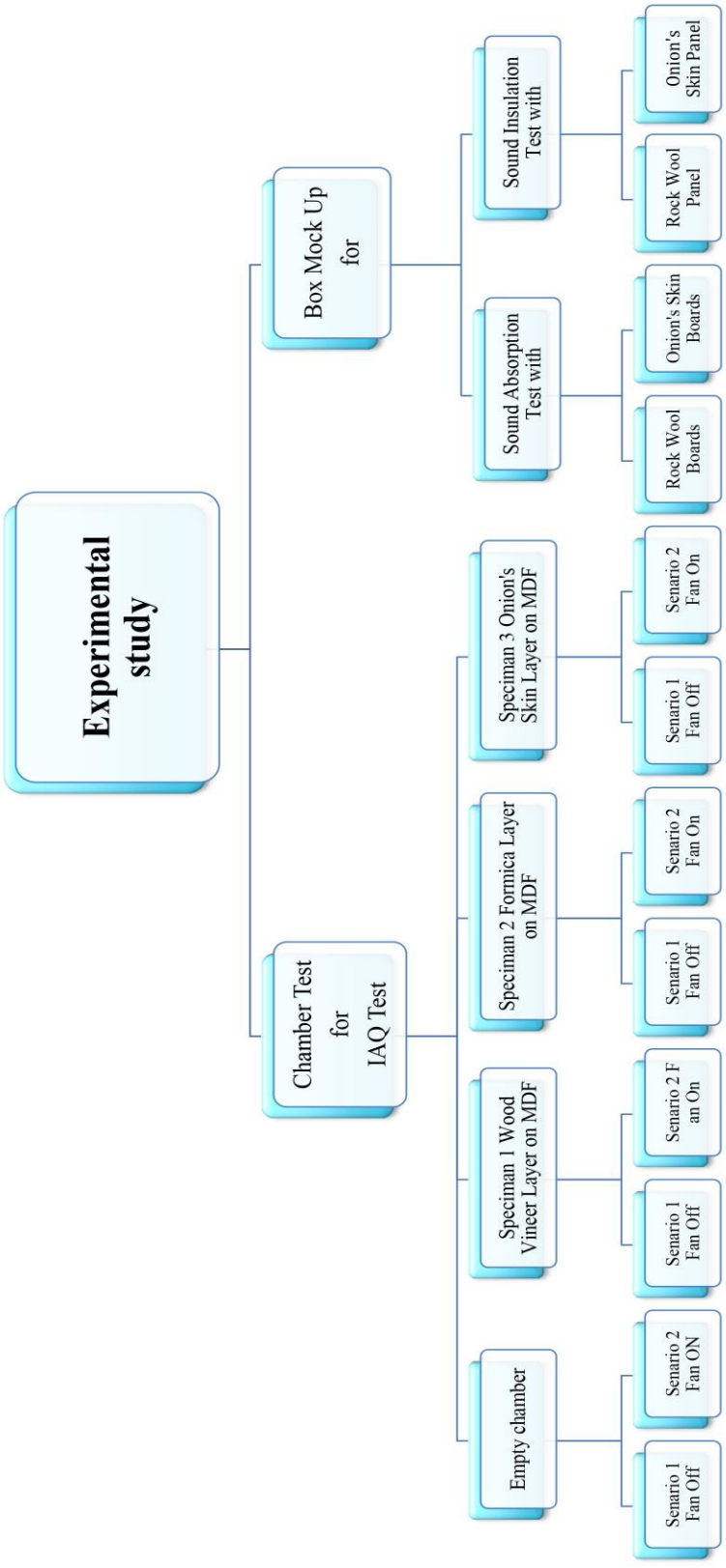


Figure 3.1 Research design diagram

CHAPTER 4 DATA COLLECTION

4.1 Introduction

This chapter of the dissertation presents the results of the data collected and analyzed relative to the Indoor Air Quality and sound insulation.

This chapter gives an overview of how the onion dry outer peels were used, manufactured and tested. It also classifies the methodology used in this research. The procedure of manufacturing the materials is explained and the appliances used in manufacturing the panel are presented. This chapter also identifies the features of the experimental study, subjects, and the appropriate requirements needed to apply chamber test, in addition to the system used for analyzing the data. The materials used in this research are described. Testing equipment is also described, and the three different test methods are explained.

4.2 Objective Study

To collect data with regard to the indoor air quality indicators, the research study used an instrument, which monitors the indicators, called Direct Sense – IAQ. This permits the researcher to quantify and determine any Indoor Air Quality IAQ issue that could affect the tenants. The Direct Sense – IAQ is an advanced and a user-friendly measuring instrument, which allows the researcher to use it conveniently. Moreover, this instrument (figure 4.1) is portable, allowing the researcher to execute any required measurement for any given area at any time. It is very suitable not only for the walk-through exploration, but even for the constant measurement over long periods of time because it measures the absolute ratio or amount of the required air components in a way that it shows the real condition of the IAQ status. Table 4.1 as shown below, explains few of the features of the instrument which provides the justification of applying it in this research report.

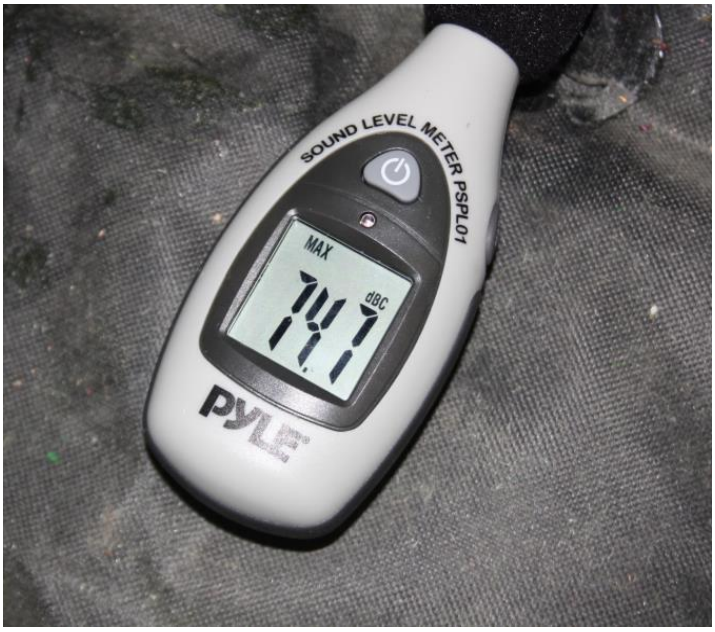
Feature	Description
Logging of Data	When the device is used manually, snapshots can be taken
Back-lit colored display	This feature provides the user accurate display of figures with visuals and various graphics.
Intelligent user Interface	The interface is very user-friendly coming with drop down menus.
Report Generation	The user will just simply download the information and the notes through a PC software called WolfSense, and the results can be used directly to produce reports.
Accessories	Security case using hard-shell is applicable in saving the device when transported and used for long-term measurements. More options like camera, or some other software and devices can be taken as extras with the main device to conduct large measurements.

Table 4.1: Multi-functional features of Direct Sense-IAQ.

Figure 4.1: The Direct Sense – IAQ measuring instrument.

The research study utilized a Sound Level Meter called PYLE PSPL01. By using this instrument the researcher can measure and identify the sound levels.

PYLE PSPL01 sound level meter measures from 40 to 130 dB with accuracy of 3.5 dB. For more accurate sound measuring, it has a 0.5' electret condenser microphone. As for the digital display, it offers 0.1 dB sound resolutions with rapid weighting, and it uses C-type frequency weighting. After 15 minutes of inaction, PYLE PSPL01 sound level meter powers off automatically. Furthermore, the microphone is protected by a wind screen, and it also includes a 9 Volts battery for up to 50 hours of battery life (Figure 4.2).



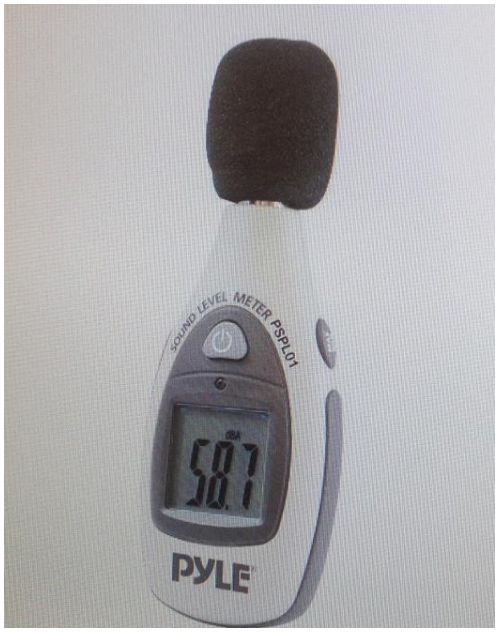


Figure 4.2: PYLE PSPL01 sound level meter.

4.3 Subjective Study

Some experts and contractors in the interior design field and market were interviewed, as well as acoustic experts in the market and acoustic teachers at Ajman University of Science and Technology. The experts were selected according to their long-time expertise in the field of interior design, working as well as teaching.

Data were gathered from these experts, all relating to their perception and knowledge on the matter of sound insulation, as well as the conventional sound insulation materials used in interior design.

Building material supplying companies were visited in order to collect some conventional materials, which were used in the experimental study to compare their properties versus the new material.

4.4 Experimental Study

4.4.1 Onion Peels Collection

As discussed earlier, many advantages arise from the use of onion's dry outer skin. Firstly, this raw material is largely available all over the world, specifically in the Countries of Origin, as for

the UAE and the surrounding region it is considered a waste material which can be easily found and processed. Secondly, onionskin as an agricultural onion-waste product is a competent source for producing environmentally friendly panels. Using this raw material in composites is environmentally safe and it is a clean alternative to the conventional materials in the market.

The type of onion abundantly available in the market and mostly used in the UAE is the Red onion or the Indian onion. It appears in a purple colour. This kind of red onion is available the entire year and there is no specific season for it.

The onion papery peels were collected from many different sources and locations. A large quantity of them was required, which needed quite a long time to acquire and collect. The onion peels are generally considered as litter by the public and the onion sellers, which meant that it was usually discarded as garbage and not given any thought. Thus, we had to ask for them to collect it for us which was considered odd, and the merchants found that it was a rather surprising request.

The vegetable markets in the UAE (specifically Dubai, Sharjah and Ajman) were the target of collection as they are wholesale markets. Supermarkets, minimarkets and the daily home kitchens were additional sources of collection.
The onion waste, which was collected from the markets, was either for free as people considered it waste, or for sale for a very small amount of money as a gratuity for the person who collected it.

4.4.2 Preparation of Dry Onion Peels

The process of onion peels for fabrication is similar to other composites fabrication such as chopped wood or sugar cane bagasse composite. First, the bagasse is prepared for the cleaning from organic residues, then it is cut, filtered and dried to be ready for mixing with adhesive resin as mentioned by (Putra et. al, 2012).
Consequently, after the collection of onion's dry peels, it is necessary for another initial operation to be done which is the process of cleaning (cleaning from organic residues, filtering and sieving the peels from the leftovers and dirt, rot or decayed parts).

Washing the peels under running water and drying them either by spreading them outdoor exposed to the sun, or for a faster result, a normal hairdryer is used in order to get rid of the moist and any odor to be ready to apply the adhesive. The above process has been done manually at home, as there were no factories or labs to provide these services (Figures 4.3 and 4.4).

Figure 4.3: the cleaning, sifting and washing of onion skins.

Figure 4.4: Leave the cleaned outer onion skin to dry.

4.4.3 Fabricating of Onion Sheet and Board

A proficient in the interior design field, manager and owner of an interior design company and wood working factory, has been reached and contacted. The issue and the possibilities of constructing sheets of the onion's dry skin that can be used as a sound insulation panel and/ or as a decorative element in the interior design projects has been discussed.

Another wood working factory for customizing wooden doors has been recommended by the proficient, to have the raw material pressed and bonded by a press machine.

First trial was pressing a thick layer of the raw material with a chemical adhesive that comes in a powder form and dissolves with water. The result was not persuasive in terms of the content or the appearance, as the adhesive's white colour was dominant (Figure 4.5).

Figure 4.5: First unsuccessful trial: onion layers bonded with chemical water base adhesive.

Second trial was pressing a thin layer of the raw material with a PVA adhesive, which is an environmentally friendly product. Weldbond PVA is a universal adhesive. It is non-toxic, nonflammable, free of fumes, has low VOCs, and is made without animal by-products (figure 4.6).

It was an attempt to make a (40 x 40) cm^2 thin layer of onionskin pressed by a manual press machine, bonded with the PVA adhesive. The attempt was not successful enough due to several reasons, which include:

- The adhesive was used in thick formulation without any added water, where it should have been used in a balanced formulation to the amount of onion skin.
- The colour of the onion skin was greatly affected and appeared burnt.
- The sheet was removed from the press machine before it had dried.
- After removing the sheet from the press machine, it shrank and bent upon exposure to air.
- It turned out to be aesthetically unpleasant.

Figure 4.6: a sample of a pressed sheet of dry onion skin bonded with PVA.

The researcher did the third trial manually; it was to press a sheet of the raw material (dry onion skin) manually using homemade adhesive. The adhesive consists of 125g 13 metric tbsp of edible Gelatin Powder and 39 metric tbsp of vinegar. The glue is organic, water resistant and safe, but it did not work to bond the material strongly, thus the result was not satisfactory enough because the sheet started to break into pieces (as illustrated in figure 4.7). However, aesthetically the sample was acceptable because the colour of the finished sheet of the onion layer remained in the same natural appearance. Normal paint brush with the glue was used to fabricate this sample as shown in the figure below.

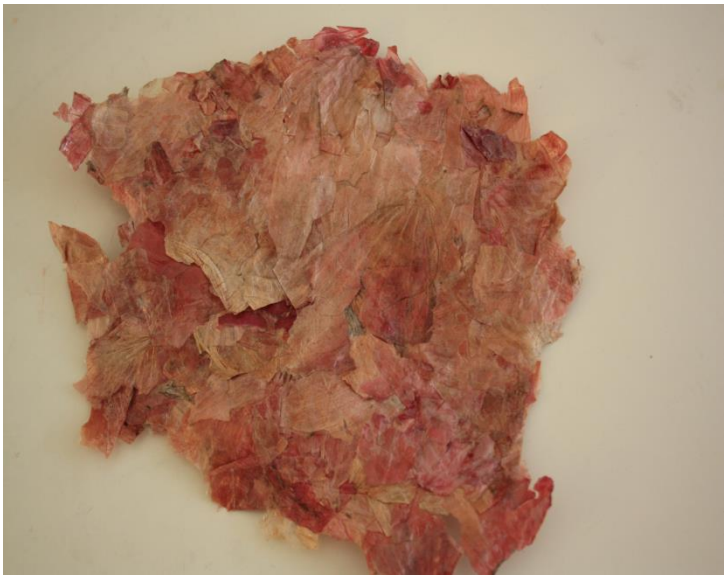


Figure 4.7: Unsuccessful attempt: pressed sheet of onion's dry peels with homemade glue.

Figure 4.8 shows the forth-unsuccessful trial, which was also pressing a sheet of the raw material with the same homemade adhesive. The required size is (40 x 40) cm^2 in 2mm thickness, but it was done in the woodwork factory and pressed with the manual press machine. The result was not successful as the sheet broke into small parts after few days of exposure to the indoor environment as shown in the figure below.

Figure 4.8: Unsuccessful attempt: pressed sheet of onion peels with homemade glue.

4.4.4 Fabrication of Specimens for IAQ Test

Three specimens were prepared in a woodwork factory with the assistance of an expert (Anonymous 2015). After discussing and explaining with illustration drawings, specimens were customized according to the required dimensions and descriptions (30 x 30 x 1) cm^3 boards of MDF. The first sample is an MDF board with Formica layer glued on one side; the second sample is an MDF board with a wood veneer layer glued on one side; while the third one is an MDF board layered with onion outer dry skin glued on one side as well. The first two layers were pressed on the MDF in the factory using chemical adhesive, whereas the onion's dry skin layer was done manually using an eco-friendly adhesive.

After completion, specimens were wrapped with plastic wrapping in order to enclose the material compositions that may produce emissions during transferring time and to submit them as new materials on an actual site to be ready for testing (figure 4.9).

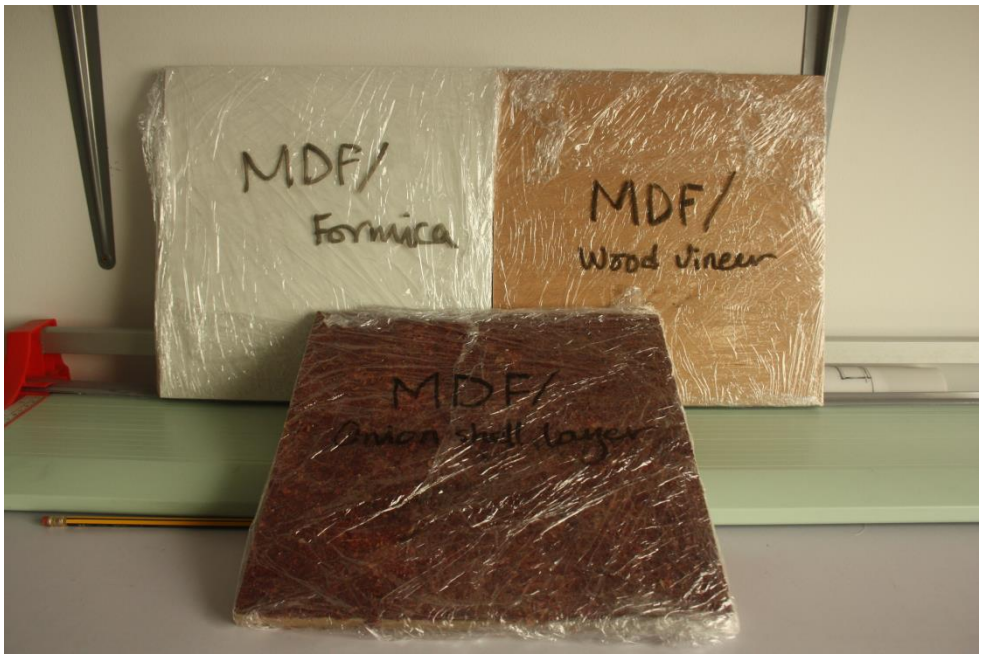


Figure 4.9: Wrapped specimens ready for testing.

4.4.5 Chamber Test / IAQ Test

The experiment study was conducted at Ajman University of Science and Technology in Ajman in one of the University's labs, specifically the Fab Lab in the engineering college in which the chamber was placed. The lab's temperature was set at 21°c and Relative Humidity 45%. The experiment duration was carried over three days.

The small chamber in which the material were placed to be tested was borrowed from the British University in Dubai, with dimensions of 60cm (L) x 60cm (W) x 60cm (H) = 0.216m^3. Made of 6mm clear glass and supported by 4.5cm aluminum frames, which hermetically sealed the chamber from the edges.

A central fan was placed and fixed at the base of the chamber in order to provide positive pressure (controlled air flow) to the sample, which is placed on a grid-like steel plate which in turn lets the air swirl inside the chamber (Figure 4.10).

The glass panels were fixed without any use of silicon or adhesives so as to lessen the impact of external emissions on the specimen and the measuring instruments (Salah El Danaf, 2013). The condition of the chamber was set as ±1.7 24°c in temperature, relative humidity ±10% 60%

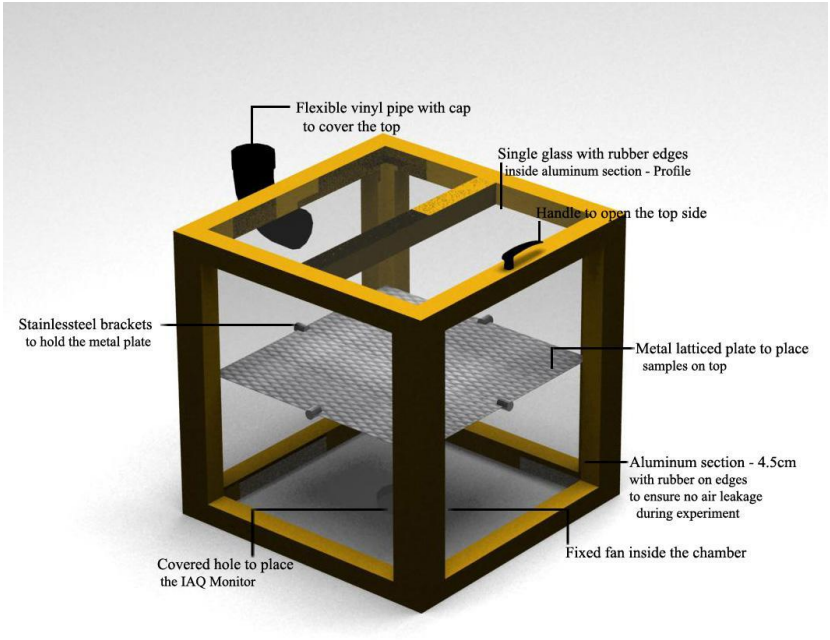


Figure 4.10: Chamber (Salah El Danaf, 2013, p. 47).

4.4.6 Fabrication of Sound Insulation Specimen

Acoustic panels are used to reduce noise and control sound in many different ways and aspects. They can be fabric-wrapped in many types and colors to meet the needed design, budget and durability of requirements. In general, most of the sound absorbing wall panels are made from a polyester, polypropylene, cotton and fiberglass which are proven for their high specialty and feature of behaving as a heavy duty sound absorber panels, to be used for walls, ceiling and other indoor and outdoor application. The onion's outer papery skin panel is likely to be added to the group above due to its acoustic properties as a sound insulator, too. And it also made up of natural resource that gives an additional advantage to it.

Figure: 4.11: An illustration of a panel fully made of dry onion layers bonded with PVA adhesive for sound insulation test, with a measurement of A (30 x 30 x 1) cm^3.

The panel fabricating process has been made during summer season between the month of April / July at a high temperature of 30-45C and a relative humidity of 45%-80%. The process of fabricating the onion layers has taken place at the interior designs project management company at the woodwork factory section.

The panel was done by using a (35 x 35) cm wooden fabricated template that has been used to press over onion peels from the inside to give it the needed shape and thickness, with the use of Polyvinyl Acetate adhesive, which is known as PVA adhesive or white glue.

The importance of the PVA usage comes with less harmful emissions and fumes when it is compared to other human-made chemicals and solvents still highly consumed in markets, besides their proven harmful impact over the environment such as the commercial resins which include urea formaldehyde and phenol as main components.

The first step of fabricating the onion panel was to prepare the bonding adhesive, and this was done by mixing the PVA adhesive with a certain amount of lukewarm water. The water adds light texture to the mixture, which allows a full penetration to the entire onion skin quantity. The pouring process of the mixture took its way inside the template and was completed by pressing the texture with the use of heavy loads. By repeating this process for several times, the required panel thickness was attained. After one week, the panel dried; it was cut and trimmed to the required size (1 x 30 x 30) cm3 (as shown above in figure 4.11). More than one panel was prepared in order to be used in the mock up boxes as required. The drying process was done in an open air and a dry place because of the extreme hot and humid weather in the UAE. Meanwhile, the mock up boxes were being customized to fill the required sizes.

4.4.7 Fabrication of Mock Up Boxes

1. The first box mock up measurement was of (30 x 30 x 30) cm^3 and to be fully lined with (1 x 30 x 30) cm^3 onion peels panels pressed and bonded with an eco-friendly adhesive as shown in (figure 4.12).
2. The second box measurement was of (30 x 30 x 60) cm^3 to be fully lined with 1 cm Rock Wool rolls or panels. This box was divided into two equal parts: once by the panel of onion peels and the other time by the panel of rock wool in order to measure the sound insulation property for both materials, and later to make a comparison between them. The box was fabricated to have a slot in the middle, which enables the onion and rock wool panels to slide easily inside it (as shown in Figures 4.13, 4.14 and 4.16).

Figure 4.12: (30 x 30 x 30) cm^3 box mock up fully lined with (1 x 30 x 30) cm^3 pressed panels made of onion peels bonded with eco-friendly adhesive.

Figure 4.13: Shows the mock up boxes with the onionskin board before covering with rock wool.

The box mock up above in (Figure 4.13) was fully lined with one type of rock wool, which comes in rolls, but the result was not successful enough due to inaccurate finishing and unpleasant appearance which made it aesthetically unacceptable, as illustrated in (Figure 4.14). Thus, there was another attempt for lining the box mock up, which is using the Rock Wool panels (Figure 4.15 and 4.16).

Figure 4.14: First unsuccessful attempt of covering the box with rock wool rolls.

Figure 4.15: Panels of Rockwool (Insultherminc.com, 2014)

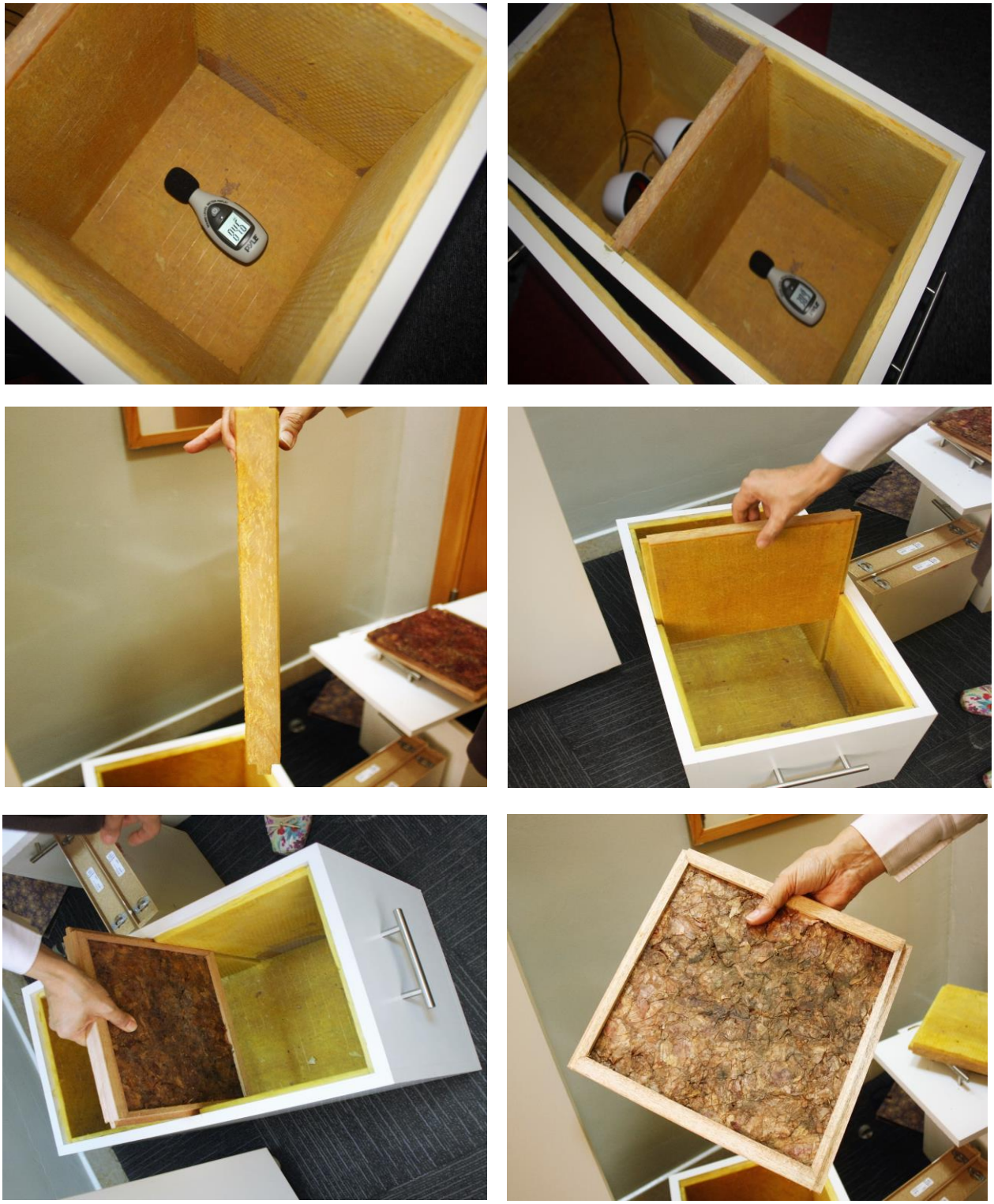


Figure 4.16: The mock up boxes after being fully covered with rock wool panels and divided by a rock wool partition in the middle.

4.4.8 Sound Insulation Test

The test took place at Ajman University of Science and Technology in Ajman in the Multimedia studio (Figure 4.17). It is a studio built as per international specifications (appendix 2-B).

Figure 4.17: Multimedia studio at Ajman University of Science and Technology in Ajman

The test has been done in two stages:

First, testing and measuring the ability of the onion skin board of sound absorption as following:

1. Entering a constant sound source of 1000 Hz onto the speakers in the insulated room in the Multimedia studio, the reading of the meter was 95.2 dBC as shown in (Figure 4.18).

Figure 4.18

2. Entering a constant sound source of 1000 Hz inside a box mock up, which is fully insulated with dry onion's skin boards (Figure 4.12), the reading was 61.2 dBC as shown in (Figure 4.19).

Figure 4.19

3. Entering a constant sound source of 1000 Hz inside a box mock up, which is fully insulated with rock wool boards (Figure 4.16), the reading was 58.5 dBC as shown in (Figure 4.20).

Figure 4.20

Second, testing and measuring the ability of this board to insulate the sound when used as a partition that separates two spaces.

In this second test, a (60 x 30 x 30) cm3 MDF box mock up was made to represent a (6 x 3 x 3) m3 room, the box mock up was fully insulated with rock wool and divided into two parts as shown in (Figure 4.16): the first time the divider was a rock wool board, the other time the divider was the onion skin board.

1. Measuring the insulation rate inside the insulated box without a divider (Figure 4.24), the reading was 93.4 dBC as shown in (Figure 4.21).

Figure 4.21

2. Using the rock wool board divider and measure the insulation rate (Figure 4.24), the reading was 84.6 dBC as shown in (Figure 4.22).

Figure 4.22

3. When using the dry onion skin board divider (Figure 4.24), the reading was 85.5 dBC as shown in (Figure 4.23).

Figure 4.23

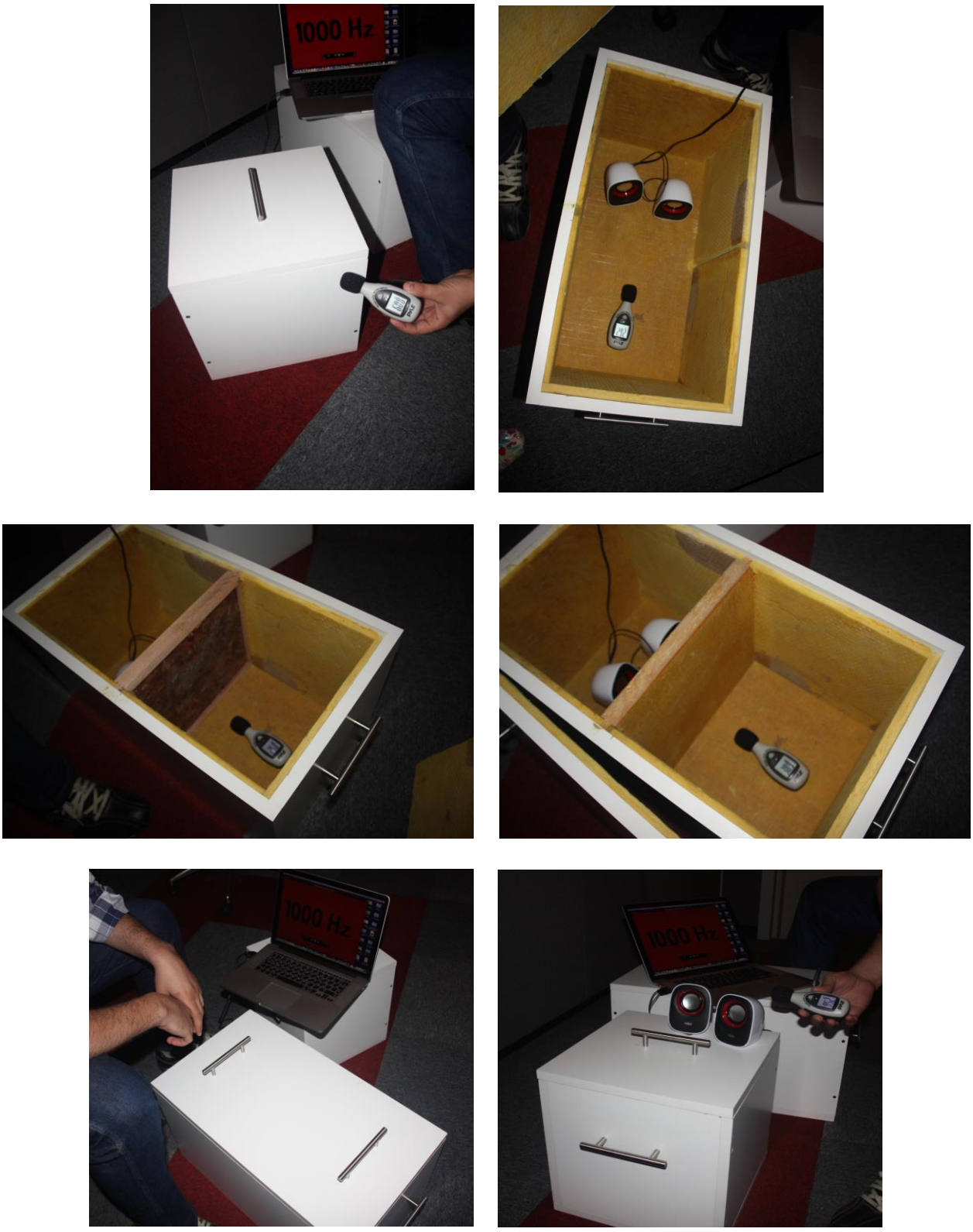


Figure 4.24: Shows mock up boxes during the test with the partitions in the middle; once a panel made of dry onion peels bonded with eco-friendly adhesive, and the other time made of rock wool.

CHAPTER 5: RESULTS AND DISCUSSION

5.1 Introduction

The aim of this research study is to explore the natural materials specifically the onion's outer skin, which is possible to be used in the interior finishing and space. This will be a replacement to existing synthetic and wooden conventional interior materials that might contribute pollutants to the indoor air and affect the comfort and health of the occupants. The study will also explore the relationship between the interior natural materials used in buildings and the human comfort, and it will focus specifically on the effects of these materials on the human's comfortable level as there are lots of factors influenced by the interior natural materials leading to opposing effects. And finally, it will identify the environmental impacts of the interior natural material in hand by determining if they emit VOCs and harmful gases.

Evidently, onion's outer skin is known to everyone as the thin, lightweight, strong outer part that provides an exceptionally powerful antioxidant, anti- inflammatory compound and treats forms of cancer under special circumstances as mentioned by (Boyles, 2015).

This dissertation study introduces another advantage of this friendly outer skin, which is the usage of bonded and squeezed sheets of onion skins treated under some mechanical properties to be used for the interior design purposes in future.

The investigation upon this study has been based on experiments along the way and there are still more practical issues regarding the manufacturing and testing which are waiting to be solved during the whole process. Basically, no previous research has been issued or has come to light yet regarding this study.

5.2 IAQ Measurements

For the experiment using test scenarios, (as illustrated in Figure 3.1) four experiments are set for testing and each experiment consists of two sub scenarios. There were three samples to be tested:

1. The first one is a (30 x 30 x 1) cm^3 of MDF board (Medium Density Fiberboard) with

Formica layer on one side glued with a chemical adhesive.

2. The second one is a (30 x 30 x 1) cm^3 of MDF board with wood veneer layer on one side glued with a chemical adhesive.
3. The third one is a (30 x 30 x 1) cm^3 of MDF board with the onion's dry skin layer on one side glued with the eco-friendly adhesive.

   In this experiment, two sub-scenarios are conducted for each sample, one is with Fan Off mode and the other one is with Fan On mode. However, before the three samples are tested, the chamber should be tested without material in the condition of the fan in On and Off modes. As shown previously, Direct Sense is the IAQ measuring instrument used for this test in all the scenarios.

Chamber flushing out is the status of operating the fan before starting the materials testing. The flush out happens in the condition of empty chamber for 30 minutes in order to allow all the trapped fumes or odors from a previous use to access out of the chamber through the PVC exhaust pipe (as shown in Figure 5.1). This operation occurs after the testing of each material and after each scenario, and it lasts for 30 minutes to get rid of all the left odors and emissions from the previous testing through the PVC exhaust pipe.

Figure 5.1: The chamber during flushing out, with open PVC exhaust pipe.

Experiment 1: Empty Chamber - Testing the level of Total Volatile Organic Compounds (TVOCs), Carbon Dioxide CO2, Ozone O3, Carbon Monoxide CO, Temperature (T), and Relative Humidity (RH), emissions in the empty chamber (as shown in Figure 5.2 (|a) and (b))

Scenario 1: When the Fan Off mode, duration of the test is 30 minutes. The readings after 30 minutes are illustrated in the Table 5.1 below.

Scenario 2: When the Fan On mode, the readings after 30 minutes are illustrated in the Table 5.1 below.

a **b**

Figure 5.2: a) Scenario 1: Empty Chamber Test with Fan On mode,

b) Scenario 2: Empty Chamber Test with Fan Off mode

Experiment 1 Empty Chamber	Fan Off	Fan On
TVOC- ppb	**722**	**535**
CO2- ppm	**368**	**364**
O3- ppm	**0.01**	**0.01**
CO- ppm	**0.4**	**0.2**
Temperature- ℃	**21.2**	**21.5**
Relative Humidity- %RH	**75.4**	**67.5**

Table 5.1: Results of emissions test in an Empty Chamber with Fan On and Fan Off modes

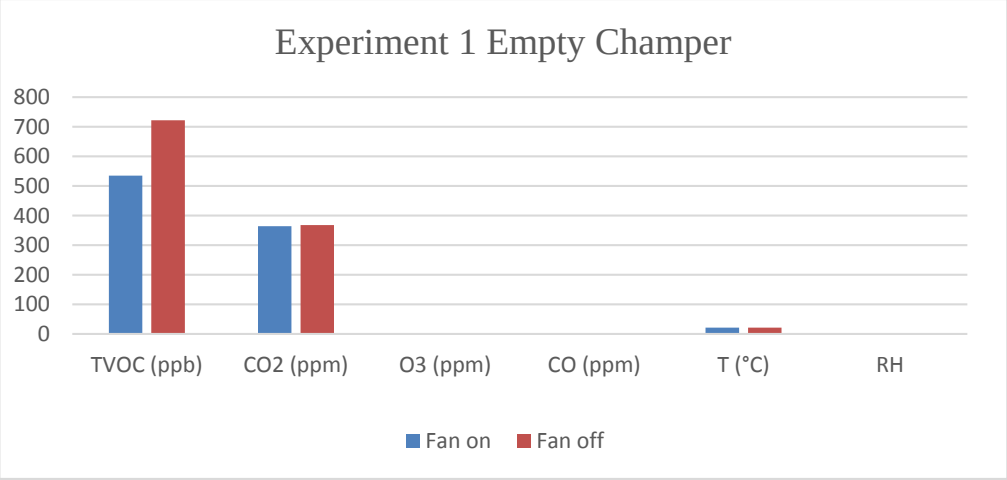
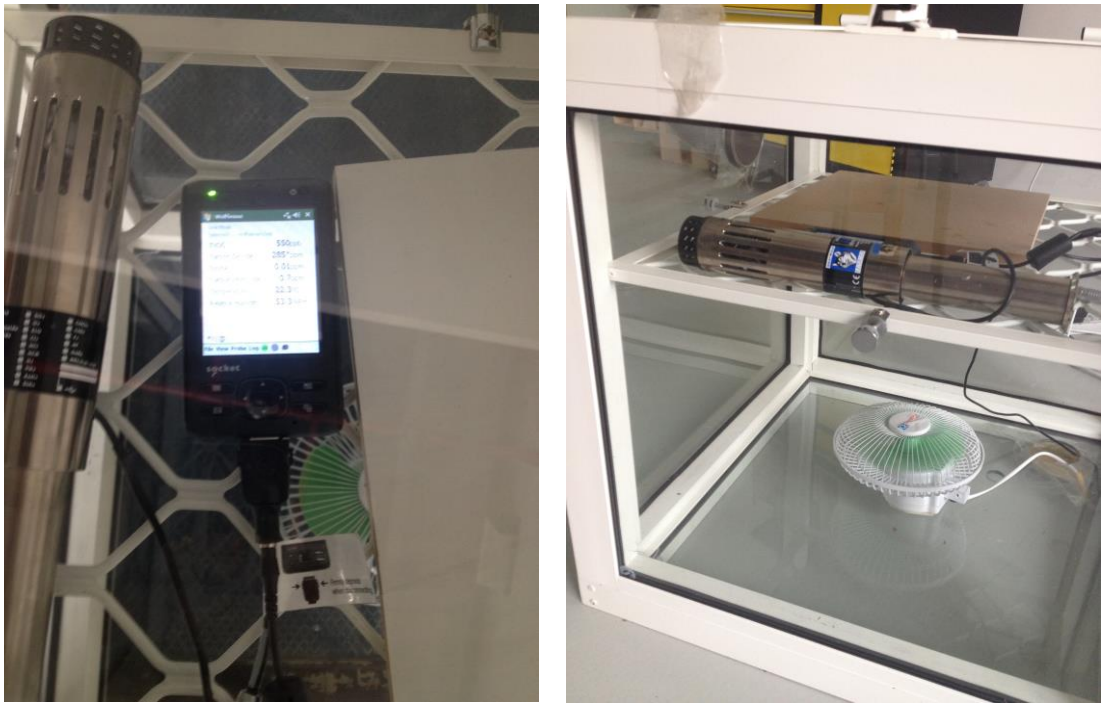


Figure 5.3: The assessment of IAQ emissions in empty chamber with Fan On and Fan Off modes.

Experiment 2: Formica layer - the level of TVOC, CO2, O3, CO, T and RH emissions on the first specimen have been tested by using the IAQ measuring instrument, which was mentioned previously a (30 x 30 x 1) cm^3 of MDF board (Medium Density Fiberboard) with Formica layer on one side glued with a chemical adhesive.

Scenario 1: With the Fan Off, duration of the testing is 30 minutes. After 30 minutes the readings were illustrated in the Table 5.4 below. After recording the readings, chamber flushing out is applied.

Scenario 2: With the Fan On, after 30 minutes the readings were illustrated in the Table 5.4 below. And chamber flushing out is applied



a b

Figure 5.4: a) Scenario 1: Formica Layer Test with Fan On mode.

b) Scenario 2: Formica Layer Test with Fan Off mode.

Experiment 2 Formica layer	Fan Off	Fan On
TVOC- ppb	**550**	**552**
CO2- ppm	**285**	**416**
O3- ppm	**0.01**	**0.01**
CO- ppm	**0.7**	**0.4**
Temperature- ℃	**22.3**	**21.5**
Relative Humidity- %RH	**53.3**	**62.2**

Table 5.2: Results of emissions test of Formica layer specimen with Fan On and Fan Off modes

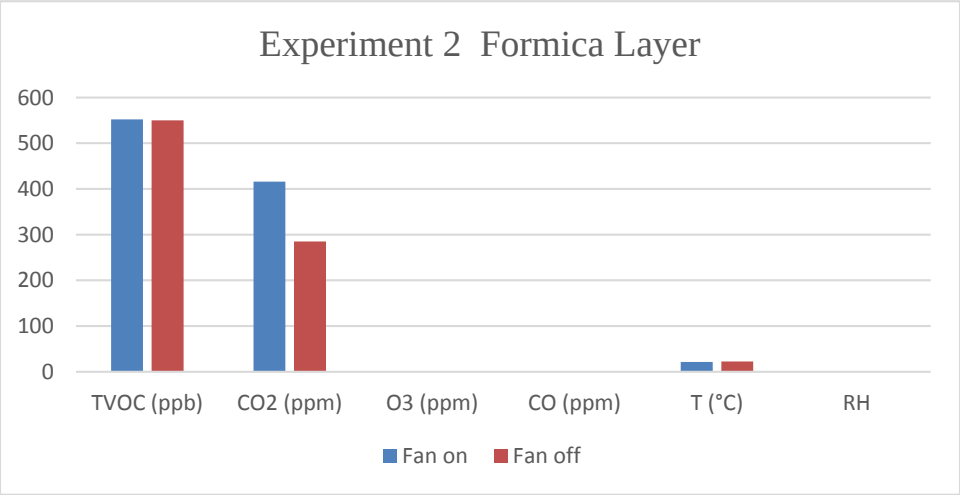


Figure 5.5: The assessment of IAQ emissions of Formica layer specimen with Fan On and Fan Off modes

Experiment 3: **Wood Veneer layer** - Testing the level of TVOC, CO2, O3, CO, T, and RH, emissions with the second specimen - (30 x 30 x 1) cm^3 of MDF board (Medium Density Fiberboard) with Wood Veneer layer on one side glued with a chemical adhesive.

Scenario 1: With the Fan Off, duration of the test was 30 min. After 30 minutes the readings were as illustrated in the Table 5.6 below.

Scenario 2: With the Fan On, after 30 minutes the readings were as illustrated in the Table 5.6 below.

a b

Figure 5.6: a) Scenario 1: Wood Veneer Layer Test with Fan On mode,

b) Scenario 2: Wood Veneer Layer Test with Fan Off mode.

Experiment 3 Wood Veneer Layer	Fan Off	Fan On
TVOC- ppb	**511**	**1187**
CO2- ppm	**578**	**277**
O3- ppm	**0.02**	**0.01**
CO- ppm	**0.7**	**2.8**
Temperature- ℃	**21.8**	**21.8**
Relative Humidity- %RH	**54.0**	**62.3**

Table 5.3: Results of emissions test using Wood Veneer Layer with Fan On and Fan Off modes

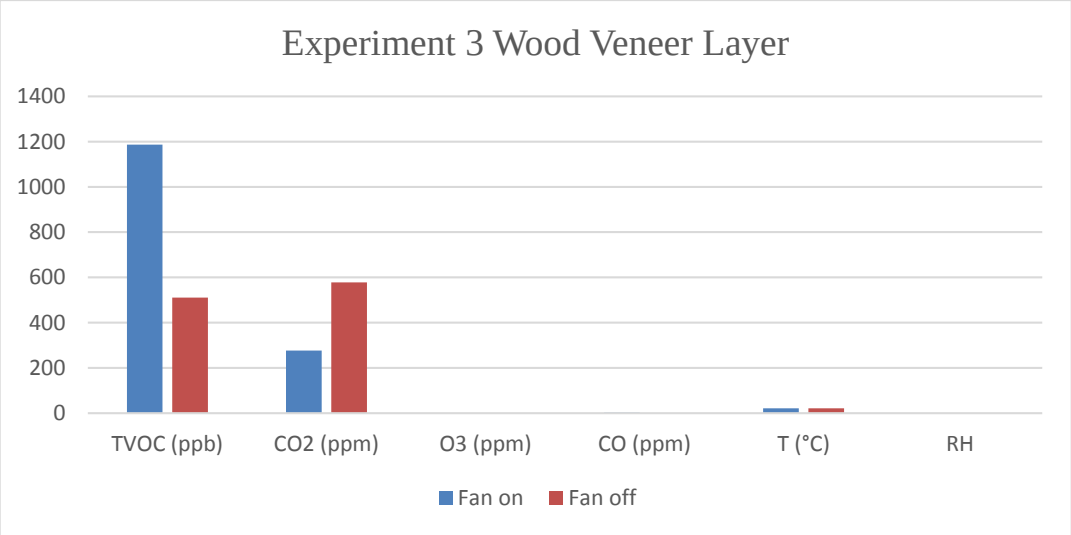


Figure 5.7: The assessment of IAQ emissions of Wood Veneer layer specimen with Fan On and Fan Off modes

Experiment 4: **Onion's Dry Skin layer** - Testing the level of TVOC, CO2, O3, CO, T, and RH, emissions with the third specimen - (30 x 30 x 1) cm^3 of MDF board (Medium Density Fiberboard) with onion skin layer on one side glued with eco-friendly adhesive.

Scenario 1: With the Fan Off, duration of the test was 30 minutes.

After 30 minutes the readings were as illustrated in the figure 5.7 below. After recording the readings chamber flushing out is applied.

Scenario 2: with the Fan On, after 30 minutes the readings were as illustrated in the figure below. And chamber flushing out is applied.

a b

Figure 5.8: a) Scenario 1: Wood Veneer Layer Test with Fan On mode.

b) Scenario 2: Wood Veneer Layer Test with Fan Off mode.

Experiment 4 Onion's Dry Skin layer	Fan Off	Fan On
TVOC- ppb	931	1390
CO2- ppm	324	406
O3- ppm	0.02	0.02
CO- ppm	1.4	1.1
Temperature- ℃	22.7	22.0
Relative Humidity- %RH	68.3	75.5

Table 5.4: Results of emissions test using Onion's Dry Skin Layer with Fan On and Fan Off modes.

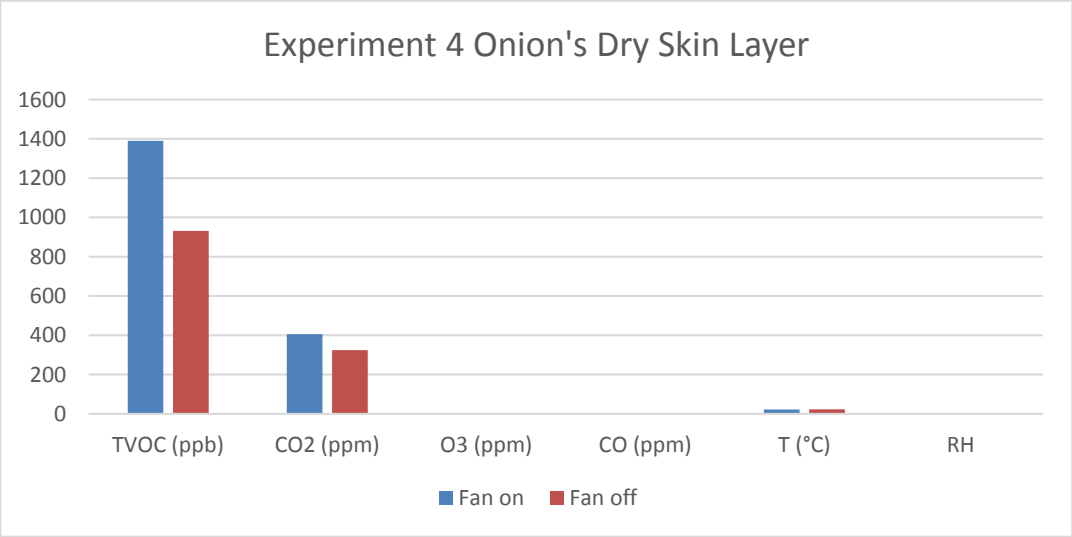


Figure 5.9: The assessment of IAQ emissions of the onion's dry skin layer specimen with Fan On and Fan Off modes**.**

5.3 Discussion of Research Findings

5.3.1 VOCs Concentration

The recommended concentration levels of Total Volatile Organic Compounds (TVOCs) according to the ASHRAE Standard 62-1989R should not be higher than 1.0 mg/m3. Essentially, the concentrations of TVOC could be controlled to be less than the no-effects level of 0.2 mg/m3.

By looking at the results of the figures above (the four experiments and eight scenarios), it can be seen that the average concentration level of TVOCs in experiments 3 & 4 is higher than the other experiments, with the concentration of 511 ppb and 931 ppb for the wood veneer layer and the onion's skin layer respectively with Fan Off mode, and it increases with the Fan On mode to reach 1187ppb and 1390 ppb in concentration for the wood veneer layer and the onion's skin layer respectively. The illustration of Experiment 4 in Table 5.4 shows the amount of VOCs emissions out of the onion skin as considered a natural source of VOC. Those two MDF board's layers - the wood veneer and the onion's skin are of natural source.

It is obvious that onion skins are made of natural porous cells, and that feature allows it to release VOCs naturally without being trapped inside, such as the materials found in furniture that are made of MDF layers.

It is important to mention that the device submitted the TVOCs measurement inside the chamber plus the VOC emissions from the onion skin, which could be affected by the MDF compounds and others. Thus, comes the need to an alternative device to detect the origin of VOCs.

As previously mentioned by Mazzeo (2011), when the level of a relative humidity increased in the inside spaces, the emissions of VOCs become higher in concentration. Emissions of VOCs are formed from the use of different types of building materials in the interior spaces. The reaction of these materials is varied due to ventilation rates, room temperature and humidity levels which lead to the production of such gases.

High temperature is another cause of high levels of VOCs emissions. As heat accelerates, the emissions of VOCs in liquids and solids also increase. Exposure to high temperature should be

no more than 30 – 60 minutes. The sample needs to be kept in a cold or normal place as mentioned by (Green Building Regulations & Specifications, 2015).

It has to be noted that water-based finishes and adhesives contain lots of water and may interact with the surface of the material. As water soaks into the surfaces, it may react with a chemical hidden beneath the surface and cause it to be released into the atmosphere. Always use small quantities at first. If there is no reaction, let it dry and then try a larger area.

Another explanation of high rates of TVOCs in Experiment 4 illustrates the reaction between the VOCs emitted by the onion skin and the formaldehyde in the MDF compound and indicates that the specimen was made manually without any chemical treatment.

As mentioned previously, that VOCs emissions are being formed in interior places under the presence of different materials such as room temperature, humidity level and the ventilation rates. When the level of relative humidity increases in the indoor spaces, the emissions from VOCs become higher in concentration as emphasized by Mazzeo (2011).

Guo et al (2002) specified that VOCs gases are mainly generated from particle boards which consist of Formaldehyde, Hexanol, Butanone, Benzene and Benzaldehyde. Furthermore, the plywood along with the particle boards emits other types of harmful gases such as formaldehyde, hydrocarbons, aromatic and trepans. Materials as bonding fibers (besides types of resins, wood fibers and coating) are considered as main source of indoor pollution.

It is known that there is an inverse proportion relationship between the emission rates of a product to the time it is exposed to air, where the emission rate reduces the more it is exposed to air. This is known as the rate of decay, the drop in emission rate over time. An example at hand, is that the emissions from wet products like paint or adhesives have high decay rates, whereas the level of formaldehyde from wooden products and radon from the concretes tend to remain the same for years as highlighted by (SBC. 2007).

5.3.2 CO_2 Concentration

One of the main products of human respiratory activity is the carbon dioxide (CO_2), which is also an essential indicator for evaluating and assessing indoor air quality and the performance levels of ventilation systems. The ASHRAE have set generally- accepted standards for CO2 levels, which is that it should be below 1000 ppm as stated by ASHRAE (2014).

The Tables (5.1, 5.2, 5.3 and 5.4) show the average concentration levels of carbon dioxide observed in the four experiments and eight scenarios. Based on the collected data in the above tables, firstly by looking at scenario 1 (Fan Off mode), it is obvious that Experiment 3 with the wood veneer layer has recorded the highest level of CO2 concentration, with an average of 578ppm. This number is reduced in the three other experiments, 1 (empty chamber), 4 (onion's skin layer) and 2 (Formica layer) with the concentration of 368ppm, 324ppm, and 285ppm respectively. Secondly, by observing scenario 2 (Fan On mode), the tables above illustrated the average rates of CO2 concentration - they are relatively high in experiment 2 (Formica layer) and 4 (onion's dry layer) with concentration level of 416 ppm and 406 ppm respectively. While this level decreases in experiments 1 and 2 to 364 ppm and 277 ppm respectively.

There are different variables and conditions that have to be taken into consideration such as exposure of the materials' specimens to different environments like the moisture, wind, heat and sunlight, especially during the work in the factory. These variables are possible to be affecting the concentration level of CO2. Further discussion and research have to be taken into consideration in the future.

5.3.3 CO Concentration

The odorless and tasteless gas, carbon monoxide CO that could have harmful health impacts if not identified in early stages. Different international standards fixed recommended and satisfactory concentration levels for carbon monoxide which are convenient for the different indoor spaces including the office buildings.

By looking above at the Tables (5.1, 5.2, 5.3 and 5.4) (the four experiments and eight scenarios), it is obvious that the average concentration level of (CO) was relatively stable in experiments 1,

2 and 3, ranging between 0.4 ppm and 0.7 ppm, and the highest recorded 1.4 ppm for the onion's dry skin specimen, when with the Fan Off mode. It decreases with the Fan On mode to record an average concentration level of 0.2 ppm, 0.4 ppm and 1.1 ppm in experiments 1, 2 and 4 respectively, whereas it increases to reach 2.8 ppm in experiment 3 (veneer layer).

5.3.4 O3 Concentration

The ozone (O3) is a naturally produced gas in our atmosphere, and is characterized as being a colourless gas but has a perceptible odor. Ozone concentrations are also subjected to regulations, as there are vast ranges of guidelines and standards that were put by organizations to control its levels in the atmosphere. Some of these organizations are the NAAQS as well as the Canadian standards, which established the accepted ozone concentration being below 0.12 ppm. On the other hand, there are OSHA, NIOSH, WHO and ACGIH, who determined the acceptable concentration levels of O3 as below 0.1 ppm as stated by (ASHRAE Standards, 2007).

While on the contrary, the Dubai government's identified standards for the maximum accepted levels of Ozone concentration is 0.06 ppm, which when compared to the rest of the international standards (like ASHRAE, OSHA and NAAQS), are quite lower levels (Dubai Government, 2015).

The Tables (5.1, 5.2, 5.3 and 5.4) show the average concentration levels of Ozone (O3) observed in the four experiments and eight scenarios. Based on the collected data in the above tables, it is clear that the average concentration levels of Ozone (O3) is relatively stable in the 8 scenarios with an average between 0.01 and 0.02 ppm.

5.4 Sound Insulation Assessment

By reading the results of the sound absorption and insulation tests:

1. In the sound absorption test, as they are illustrated earlier in the figures 4.18, 4.19 and 4.20, the readings show a small difference between the rock wool and the onion's skin, in the average of 58.5 dBC and 61.2 dBC respectively which gives an indication of good absorption properties.

2. As shown in figures 4.21 , 4.22 and 4.23 the results in the sound insulation test were almost similar for both the rock wool and the onion's skin dividers in the average of 84.6 dBC and 85.5 dBC respectively, which shows a good insulation properties for the onion's skin panel in comparison with the rock wool panel.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

Due to an increasing population all around the world, the demand for wood products has also increased. The speedy changes that our planet is passing through caused an enormous pressure and fatigue to this planet. Serious solutions need to be taken into action in order to lessen these activities so as to adapt to the environmental changes in a sustainable direction as figured out by (Bäcklund, 2011).

Using onion's outer skin as an alternative material instead of conventional wooden and synthetic building materials would be an environmentally friendly solution. Plastics are especially high in embodied carbon because they are energy intensive to produce, and they often release a significant amount of the carbon stored in their petroleum constituents in the manufacturing process according to (Newman, 2012).

Interior design professionals have been focusing on how to build a clean and fresh environment in the interior spaces to achieve an indoor comfort and healthiness. Different building materials are used with little attention to the negative impact on perceived indoor air quality.

6.2 Advantageous Utilizations of Onion's Outer Skin

To repeat, the main objectives of this dissertation was first fabricating new products from onion's outer skin as an ultimate raw material because of its low manufacturing costs, and it is a natural eco-friendly material. And second, to study the possibilities of using this material in the interior spaces as a sound insulation panels or as a finishing layer.

The fact is that this material is ideal due to its effortless attainability, since the widespread onion cultivation source is endless and stable.

The associated costs of collection, modifications and/or other pre-treatments of onion's outer skin in the transformation process to ready-to-be used materials are possibly reduced as the complex procedures are simplified by the pure usage of onion's hard outer skin.

This research examined 3 types of materials, with layered wood-based MDF boards (Medium Density Fiber) that are diffused in the UAE market, and their impact on the indoor environment.. The layers were glued with two different types of adhesive and the following experimental conditions were studied and assessed:

(i) MDF panel with Formica layer glued with chemical adhesive.

(ii) MDF panel with Wood veneer layer glued with chemical adhesive.

(iii) MDF panel with onions dry skin layer glued by eco-friendly adhesive.

(iv) Empty chamber.

The specimens were tested in a chamber (illustrated in chapter 4) which was made of glass and aluminum structured frame. Consequently, testing TVOC, CO2, O3, CO, T, and RH (mentioned in chapter 4) emitted from these layered wood products, can evaluate air quality in order to determine human comfort level. The test was conducted in two scenarios: when the Fan On and Fan Off modes.

The test duration in both modes was 30 minutes, followed by a 30 minutes of chamber flushing out, in order to get rid of the fumes and emissions left from the previous specimen.

6.3 Summary of Findings

No definite conclusions about the properties of this material have been made yet. Researches and suggestions are still on their way for further results to shed the light of the proper use of such material in future. It is important to clarify that the testing process was not an easy procedure to perform due to lack of laboratories or factories to fabricate an ideal sample with ideal standards.

With these ideas, the framework of this dissertation was to study the use of onion waste, specifically the papery dry outer layer (skin) as a sound insulation material when reinforced with an ecofriendly adhesive. Such composite has the potential to be a low cost composite, and additionally to be an alternative material to replace the common acoustical material in the market. The following attributes has been found:

- Good acoustic performance is found and is comparable against that from the conventional synthetic absorber.

- In the sound absorption test, a minor difference found between the rock wool and the onion's skin, in the average of 58.5 dBC and 61.2 dBC respectively which gives an indication of good absorption properties.

- In the sound insulation test, the results were almost similar for both the rock wool and the onion's skin dividers in the average of 84.6 dBC and 85.5 dBC respectively, which shows good insulation properties for the onion's skin panel in comparison with the rock wool panel.

- Good performance in layering MDF surfaces as a replacement of wood veneer or Formica in some places.

  After measuring the indoor air quality indicators (Total Volatile Organic Compound, Ozone, Carbon Monoxide, Carbon Dioxide, Relative Humidity, and Temperature) on three specimens, the findings showed that the average concentration level of TVOC recorded from the two natural materials (the wood veneer and the onion's outer skin when Fan On and Fan Off modes) was almost approximate and was higher than the Formica layer specimen.

  The collected data showed the average concentration levels of carbon dioxide CO_2 observed in the three specimens in both scenarios. In the Fan Off mode scenario, the wood veneer layer has recorded the highest level of CO_2 concentration, followed by the two other specimens: the onion's skin layer and the Formica layer respectively.
  In the Fan On mode scenario, the average rate of CO_2 concentrations were relatively high in the Formica layer group and the onion's dry layer, while this level decreases almost to the half in the wood veneer layer.

  It was also clear that the average concentration level of carbon monoxide (CO) was relatively stable in the Formica layer group and the wood veneer group, while the highest record was for the onion's dry skin group when the fan was in the Off mode scenario. However, during the Fan On mode scenario the average concentration level of CO_2 decreased in the experiments of the Formica layer and onion's dry skin, whereas it increased in the wood veneer layer experiment.

The average concentration levels of Ozone (O3) was also observed in the experiments during both scenarios in the Fan On and Fan Off modes. Based on the collected data, it is clear that the average concentration levels of Ozone (O3) is relatively stable in all specimens and in both scenarios.

- No embodied energy cost because of the availability of this raw material as a waste material everywhere in the world as the onion is an essential food in the houses, hotels, restaurants and all types of markets.

- Need a protocol of waste management to take into account this raw material as an important material to be collected in an organized procedure.

6.4 Recommendations for Future Studies

The research provides a comprehensive detailed report of the new product made out of natural material - onion's dry skin. And how this material is utilized in the interior spaces, firstly as a finishing layer for the furniture, and secondly as a sound insulation panel to substitute other conventional materials in the UAE market. It is important to take the data that is collected and utilize it to do the analysis using measurements, surveys, or interviews to get a clear picture of the situation.

The following factors are essentials to be taken into consideration in the future studies of this product:

1- Material properties (onion's skin) need to be tested as follows:

- Test if the raw material is a non-combustible fiber.

- Test the new fabricated material to fire resistance according to standard methods.

- Test the material if it is moisture resistant and its durability.

- Test the material's durability after pressing.

- Test the material's propensity to fracture after manufacturing the sound insulation panels.

- Test the resiliency of the fabricated material and its ability to recoil or spring back into shape after bending.

- This material needs more treatments and finishes to be protected from the indoor environment and weather changes.

2- Fabricating the specimens done in wood work company in a simple way with manual machines, not in the proper places with mechanical machines, need to have more professional places with more developed machines for fabricating the new material

3- Sound proofing: simple acoustic test has been done with a simple and limited tools and instruments, need to have more advanced places and labs for testing the new material.

4- Searching for the ideal natural base adhesive was problematic:

- The selected adhesive quality is a very important step to take in consideration for future researches. One of the recommended adhesives that should be taken in consideration is the soybean ones, as a natural source type and got a positive impact upon users and environment.
- Other various additives may be used to improve the properties of the composite, such as fire resistance and Fungi resistance.

5- In the advance stages of the research when the product was applied into the interior spaces, survey questionnaire method will be essential to be conducted, human resources as volunteers will be required to distribute the Survey Questionnaires to the target participants and collect it from them later, as this will save time and money. There is also a need for labor people to fix the new material in the suggested interior parts of the building.

6- When suitable modifications and manufacturing processes are applied, onion's hard outer skin might display an improved mechanical properties such as hardness and impact strength.

7- Further studies in natural materials should be conducted so as to utilize those materials in the interior space finishing.

6.5 Potentials for Future Applications

- In addition to the sound absorption and insulation, and the surfaces layering capabilities of this natural material, the fabrication of wallpaper from this raw material and window blinds might be another use to be developed in the future in the UAE, and especially the countries having onion cultivation. In the present time, there is no availability of wallpaper factories in the UAE.
- Molded furniture and lighting fixtures are other recommended applications to be taken into consideration for future development in the interior design field.

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Appendices

Appendix A

WELDBOND® PHYSICAL CHARACTERISTICS:

Solids Content	51 – 53 %
Viscosity	10,500 – 12,000 CPS
PH	4.5 – 5.5
Particle Size	Medium, Average 1.5u
Particle Charge	Nonionic
Specific Gravity	1.095
Residual Monomer	0.5% Maximum
Odour	Slight, Characteristic

Colour Wet	White
Colour Dry	Clear
Film:	
-Flexibility	Flexible
-Water Resistance	Good
-Appearance	Slightly Hazy
U.V. Resistance	Very Good

G.T. (Glass Transitional) Spec is 5+

Physical Characteristics of Weldbond Adhesive

Appendix B-1

تيسير و السلطي لمقاولات الديكور

Al Salti Dicor Contracting

هاتف وفاكس 065339244 – متحرك : 0506974202– امتداد شارع الوحدة –الشارقة

Sharjah – Al Wihdah Street – Mobile :050 6974202- Tel Fax: 065339244

التاريخ: 2011/ 7 / 9

السادة /جامعة عجمان للعلوم و التكنولوجيا المحترمين

السلام عليكم ورحمة الله وبركاته ’

استبيان لمواصفات عزل الصوت

- وحدات عزل الصوت (موانع الصدى) :
وحدات عبارة عن إطارات خشبية بقياس (120سم × 60سم) بسماكة 18سم مقسومة إلى إطارين الخارجي سماكة 6سم بمثابة صندوق بحيث يتكون من قاعدة من الهارد بورد المثقب بسماكة 6مم بحشوه من الصوف الصخري بضغط 100\كج يعلوه طبقة من الفنيل الأسود ومكسوة بالكامل بقماش خاص حسب اللون المطلوب .أما الطبقة الداخلية عبارة عن صندوق مفتوح من الأعلى على الطبقة الأولى بسماكة 12سم بقاعدة من الخشب والإسفنج بحيث يكون كغرفة ارتدادية للصوت النافذ من الطبقة الأولى مكسوة بالكامل بالقماش .

- الأبواب:
أبالجدران: بسماكة 10سم مسننة بحشوه كاملة من (التشيب بورد) ذات إطار خشبي مطابق للباب من أربع جهات يحتوي على عوازل مطاطية بالإضافة إلى (دور كلوسر).

- الجدران :
عبارة عن جدران مستعارة من الأرض إلى السقف الأساسي بسماكة 30سم تتكون من أربع طبقات من (الجبسم بورد) بالترتيب التالي : طبقتين من الجبسم بورد ،طبقة من الفلين ،طبقة من الصوف الصخري و بالعكس مدهونة باللون المرغوب فيه .

- النوافذ :
إطارات خشبية على عرض الجدار المستعار يتم عليه تركيب 3طبقات من الزجاج الحراري سماكة 12مم بمنافذ تفريغ ضغط الهواء بالوسط .

- الأرضية :
الأستوديو : توريد فنيل لون رمادي خاص بالاستوديوهات سماكة 3مم صناعة ألمانية بضمان 10 سنوات بالإضافة إلى تسوية مستوى الأرض والتركيب .
الكنترول : توريد وتركيب موكيت بلاط (50سم × 50سم) بقاعدة مطاطية سميكة مقاومة لصوت خطوات الأقدام .

ضمن هذه المواصفات تم تطبيقها على استوديوهات عدة داخل وخارج الدولة بضمان النتيجة المرجوة وشهادة الآخرين وأحدثها أستوديو قناة الريان التلفزيونية في قطر .

شاكري لكم حسن تعاونكم
وتفضلوا بقبول فائق الاحترام ...

تيسير السلطي
تيسير و السلطي لمقاولات الديكور

Descriptions in Arabic language of sound insulation units in the Media Studio at Ajman University

Appendix B-2

Al Salti Dicor Contracting

Specifications of Sound Insulation

Date: 7/ 9/ 2011

To/ Gentlemen of Ajman University of science and Technology

Sound Insulation Units (Full Echo Suppressor)

Wooden frames units of 120cm x 60cm and thickness of 18cm (measurement unit). Divided into two outer frames performing the following:

-An outer wooden frame of a 6cm thickness, with a perforated, hardboard base. Stuffed with 100/Kg of compressed Rockwool, topped with a layer of black Vinyl and fully covered up with fabric as required.

-The interior layer has an opening from the top with thickness of 12 cm (measurement unit) that has overlooked the first layer. And is made of sponge and wood, to act a sound absorber.

- Doors
- Comes with 10 cm thickness stuffed with chipboard with four sides of wooden frames that contain rubber insulation plus a door closer.

- Walls

  Extended partitions with the thickness of 30 cm (measurement unit) consist of four layers of gypsum board, divided as follows:
- 2 layers of gypsum board

- 1 layer of foam
- 1 layer of rock wool.

- Windows :

  Wooden frames with three layers of thermal glass with thickness of 12 mm (measurement unit). With an unloading air pressure window (in the middle).

- Floors

  Studio: imported grey Vinyl with thickness of 3mm (measurement unit), with ten years warrantee. Made in Germany.

  Control Room: tile installation with thickness of 50cm x 50 cm (measurement unit), with a thick, rubber and sound absorbent base.

  These specifications have been implemented on different studios inside and outside the UAE .

Appendix C

National Ambient Air Quality Standards (NAAQS)

National Ambient Air Quality Standards		
POLLUTANT	**STANDARD VALUE**	**STANDARD TYPE**
Carbon Monoxide (CO)		
8-hour Average[1]	9 ppm (10 mg/m^3)	Primary
1-hour Average[1]	35 ppm (40 mg/m^3)	Primary
Lead (Pb)		
Rolling 3-Month Average[2]	0.15 $\mu g/m^3$	Primary & Secondary
Nitrogen Dioxide (NO_2)		
Annual Average	0.053 ppm	Primary & Secondary
1-Hour[3]	100 ppb	Primary
Coarse Particulate (PM_{10})		
24-hour Average[4]	150 $\mu g/m^3$	Primary & Secondary
Fine Particulate ($PM_{2.5}$)		
Annual Average[11]	12.0 $\mu g/m^3$	Primary
Annual Average[5]	15.0 $\mu g/m^3$	Secondary
24-hour Average[6]	35 $\mu g/m^3$	Primary & Secondary
Ozone (O_3)		
8-hour Average (2008 Standard)[7]	0.075 ppm	Primary & Secondary
8-hour Average (1997 Standard)[8]	0.08 ppm	Primary & Secondary
1-Hour Average[9]	0.12 ppm	Primary & Secondary
Sulfur Dioxide (SO_2)		
Annual Average	0.03 ppm	Primary
24-hour Average[1]	0.14 ppm	Primary
3-hour Average[1]	0.50 ppm	Secondary
1-hour[10]	75 ppb	Primary