FORMALDEHYDE EMISSION FROM WOOD BASED PANELS

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ABSTRACT

Concern about possible health effects from formaldehyde emitted from wood based panel products manufactured with formaldehyde based binding resins has led to the development and increasing use of low emission products. To control the emissions a range of tests has been developed which the wood-based panel industry can use to determine the potential of products to release formaldehyde. These research objectives are to measure the emission of formaldehyde from wood based panels, to study the effect of thickness on formaldehyde emission from wood based panels and to study the effect of different resin ratio on formaldehyde emission from wood based panels. As World Health Organization reclassified formaldehyde from "probably carcinogenic to humans" to "carcinogenic to humans", this research is more motivated. Medium density fibreboard (MDF), one of the most used wood based panels is used in this research. Urea-Formaldehyde (UF) is the type of resin that is studied here. In this research, soxhlet extraction method is used instead of perforator method along with acetylacetone method, photometrically to calculate formaldehyde content. It is expected that formaldehyde emission is decreased with time. Thicker medium density fibreboard will emit more formaldehyde. During board production, high level of resin used cause higher emission of formaldehyde on product board. Data obtain in this research can be used to control formaldehyde emission in Malaysia specifically. This will come out with safer and cleaner environment for us to live in.

ABSTRAK

Kebimbangan tentang kesan kesihatan yang mungkin berlaku dari formaldehid yang dibebaskan dari produk panel berasaskan kayu yang dihasilkan dengan pelekat berasaskan formaldehid telah menyebabkan pembangunan dan peningkatan penggunaan produk rendah pencemaran. Untuk mengawal pembebasan, pelbagai ujian telah dibangunkan yang mana industri panel berasaskan kayu boleh menggunakannya bagi menentukan potensi produk untuk membebaskan formaldehid. Penyelidikan ini adalah bertujuan untuk mengukur pembebasan formaldehid dari panel berasaskan kayu, untuk mempelajari pengaruh ketebalan terhadap pembebasan formaldehid dari panel berasaskan kayu dan untuk mengetahui pengaruh nisbah pelekatn yang berbeza pada pembebasan formaldehid dari panel berasaskan kayu. Pertubuhan Kesihatan Dunia mengklasifikasikan semula formaldehid daripada "mungkin karsinogenik bagi manusia" kepada "karsinogenik kepada manusia", kajian ini lebih termotivasi. Papan serat kepadatan sederhana (MDF), salah satu panel kayu yang paling kerap digunakan digunapakai dalam kajian ini. Urea-Formaldehyde (UF) adalah jenis pelekat yang dipelajari disini. Dalam kajian ini, kaedah ekstraksi soxhlet digunakan sebagai pengganti kaedah perforator bersama dengan kaedah asetilaseton, photometrically untuk mengira kadar formaldehid. Diharapkan bahawa pembebasan formaldehid menurun dengan masa. Papan serat kepadatan sederhana yang lebih tebal akan memancarkan lebih formaldehid. Semasa pengeluaran papan, pelekat yang banyak digunakan menyebabkan pembebasan formaldehid yang lebih tinggi daripada papan produk. Data yang diperolehi dalam kajian ini boleh digunakan untuk mengawal pembebasan formaldehid di Malaysia khususnya. Dengan itu, ia akan menghasilkan persekitaran yang lebih selamat dan bersih untuk kita hidup.

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LIST OF ABBREVIATION

ADH	-	Aldehyde Dehydrogenase
CCD	-	Charge Coupled Device
CSDS	-	Chemical Safety Data Sheet
DDL	-	Diacetyldihydrolutidine
DI	-	Distilled
IARC	-	International Agency for Research on Cancer
LED	-	Light Emitting Diode
MDF	-	Medium Density Fibreboard
MUF	-	Melamine-Urea-Formaldehyde
MUPF	-	Melamine-Urea-Phenol-Formaldehyde
OSB	-	Oriented Strand Board
OSHA	-	Occupational Safety & Health Association
PELs	-	Permissible Exposure Limits
PF	-	Phenol-Formaldehyde
PUF	-	Phenol-Urea-Formaldehyde
RW	-	Rubber Wood
STEL	-	Short Term Exposure Limit
THW	-	Mix Tropical Hard Wood
TWA	-	Time weight average
UF	-	Urea-Formaldehyde
UV-Vis	-	Ultraviolet-visible
WHO	-	World Health Organization

LIST OF NOMENCLATURE

A_S	-	Absorbance of analysed extraction solution (%)
A_B	-	Absorbance of an analysis with distilled water (%)
C(HCHO)	-	Formaldehyde concentration (mg/L)
$C(Na_2S_2O_3)$	-	Sodium thiosulfate concentration (mol/L)
f	-	Slope of standard curve (mg/ml)
H	-	Moisture content in sample (%)
M	-	Molarity (mol/l)
M_1	-	Molarity of initial solution (mol/l)
M_2	-	Molarity of desired solution (mol/l)
m_1	-	Mass of test pieces before drying (g)
m_0	-	Mass of test pieces before drying (g)
m_H	-	Mass of sample (g)
M_W	-	Molecular weight (mass/number of moles)
NOM	-	Number of moles (moles)
ρ	-	Density (mass/volume)
PV	-	Perforator Value (mg formaldehyde/100g dry board)
V	-	Volume (ml)
v	-	Volume of sodium thiosulfate titration solution for the test (ml)
v_0	-	Volume of sodium thiosulfate for the blank test (ml)
V_1	-	Volume of initial solution (ml)
V_2	-	Volume of desired solution (ml)

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Formaldehyde based resin is most commonly used adhesive in industry. This adhesive is emitting formaldehyde during production and also after finish product. As formaldehyde is polluting and dangerous to life form, it needs to be control. Wood based panels industry were the most user of formaldehyde based resin.

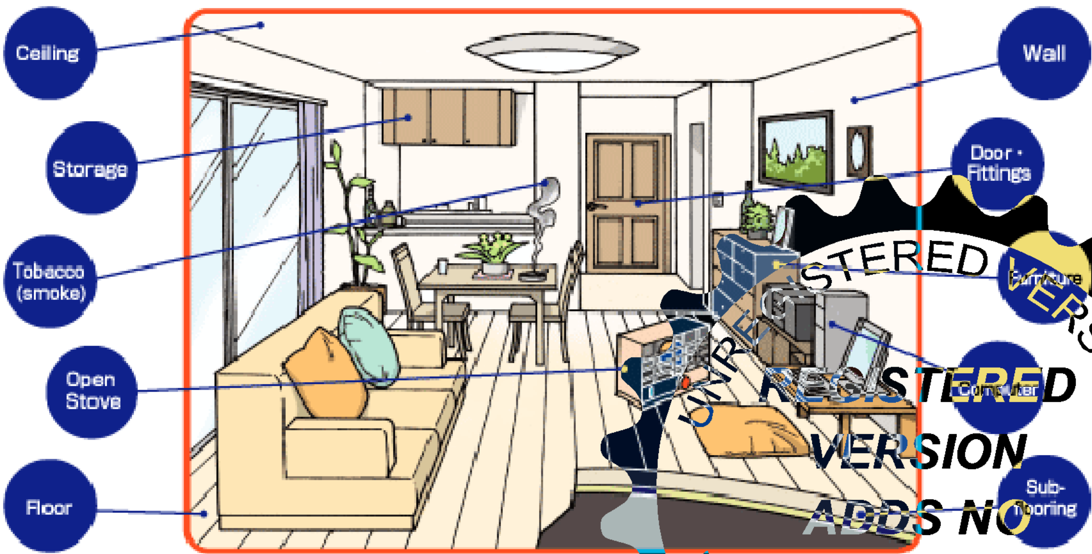

Figure 1.0 Formaldehyde Emission Sources in Home

The term 'greenhouse effect' refers to the way infrared radiation from the Earth is trapped, heating up the atmosphere. The most important greenhouse gas is carbon dioxide (CO_2), but others include steam (H_2O), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs) and sulphur hexafluoride (SF6). CO2 concentrations in the atmosphere have increased by 30% since the middle of the 19th century (Swedish Forest Industries Federation, Forests and the Climate, 2003)

There are two ways to reduce carbon dioxide in the atmosphere: either by reducing emissions, or by removing carbon dioxide and storing it: reducing 'carbon sources' and increasing 'carbon sinks'. Every cubic metre of wood used as a substitute for other building materials reduces carbon dioxide emissions to the atmosphere by an average of 1.1 tonne carbon dioxide. If this is added to the 0.9 tonne of carbon dioxide stored in wood, each cubic metre of wood saves a total of 2 tonne carbon dioxide.

Using wood also helps to save energy over the life of a building, as its cellular structure provides outstanding thermal insulation: 15 times better than concrete, 400 times better than steel and 1770 times better than aluminium. A 2.5 cm timber board has better thermal resistance than an 11.4 cm brick wall (Timber Research and Development Association UK, 2006). As a result, wood is becoming an ever more competitive solution to the increasing thermal demands of European building regulations.

Wood products are carbon stores, rather than carbon sinks, as they do not themselves capture carbon dioxide from the atmosphere. But they take an important part in enhancing the effectiveness of the forest sinks, both by extending the period that the carbon dioxide captured by the forests is kept out of the atmosphere and by encouraging increased forest growth. However long the carbon dioxide remains stored in the wood, any increase in the global volume of 'wood storage' will reduce the carbon dioxide in the atmosphere. So increasing the use of wood is one simple way of reducing climate change.

1.2 Problem Statement

On 14 June 2004 the International Agency for Research on Cancer (IARC), an advisory body of the World Health Organization (WHO) reclassify formaldehyde from “probably carcinogenic to humans” to “carcinogenic to humans”. (WHO, 2004)

Formaldehyde is a sensitizing agent that can cause an immune system response upon initial exposure. It is also a suspected human carcinogen that is linked to nasal cancer and lung cancer. Acute exposure is highly irritating to the eyes, nose, and throat and can make you cough and wheeze. Subsequent exposure may cause severe allergic reactions of the skin, eyes, and respiratory tract. Ingestion of formaldehyde can be fatal, and long-term exposure to low levels in the air or on the skin can cause asthma-like respiratory problems and skin irritation such as dermatitis and itching. Concentrations of 100 ppm are immediately dangerous to health or life.

Human can inhale formaldehyde as a gas or vapour or absorb it through the skin as a liquid. They can be exposed during the treatment of textiles and the production of resins. Besides health care professionals and medical lab technicians, groups at potentially high risk include mortuary employees as well as teachers and students who handle biological specimens preserved with formaldehyde or formalin.

In homes, the most significant sources of formaldehyde are likely to be pressed wood products made using adhesives that contain urea-formaldehyde (UF) resin or other types of formaldehyde based resins. Pressed wood products made for indoor use include particleboard, hardwood plywood panelling and medium density fibreboard (MDF).

1.3 Research Objectives

Based on the aforementioned research background and problem statement, the objectives of this study are:

1. To measure emission of formaldehyde from wood based panels.
2. Study the effect of thickness on formaldehyde emission from wood based panels.
3. Study the effect of different resin ratio on formaldehyde emission from wood based panels.
4. Study the effect of time on formaldehyde emission from wood based panels.

1.4 Research Scope

This research has wide range of scope. To make it simpler and easy to carry and understand, I would focus on certain things. First, thickness of wood based panels that I would use in this research. Second, ratio of resin used in production of wood based panels. To state this scope is very important because it would narrow this research on more specific field.

Wood panels have variety of types. The most commonly used wood panels are MDF and particle board. Here in Malaysia, MDF is the main product produced. Thus, it is important to focus more on MDF.

Adhesives are important in wood panels industry. Almost all types of adhesives contain formaldehyde. These include phenol-urea-formaldehyde resins (PUF), phenol-formaldehyde resins (PF), melamine-urea-phenol-formaldehyde resins (MUPF), melamine-urea-formaldehyde resins (MUF), and urea-formaldehyde resins. All this adhesives will release an amount of formaldehyde at a time in processing wood panels and also after finish product is produced. Such condition makes this research more important. Mostly in industry, UF resin is used.

1.5 Rational and Significance

Currently, Malaysia is one of the main producers of MDF in the Asia Pacific region. The adhesives used are mainly formaldehyde based. Wood based panels have future potential in furniture industry in Malaysia.

In European country, such experiment to measure the emission of formaldehyde had already done. Their main focus is on indoor air quality. As a result, level of formaldehyde in home is typically one third of the WHO guideline value. This is also the same as result obtains by Japan.

As Malaysia grown as the main producers of MDF, such research is essential. This is to make sure that formaldehyde emission didn't exceed the guideline value by WHO. Even there is no evidence good enough to say that formaldehyde can cause cancer, but as WHO classified formaldehyde as carcinogenic to human, we must take serious of this mater.

This research is also to make sure the safety of individual that have direct or indirect contact with wood panels that emits formaldehyde in the making or when using it. Nowadays, there are many research conducted to find a resin that didn't or less emit formaldehyde. This kind of research is also essential and can collaborate with research to measure the emission of formaldehyde.

For the time being, formaldehyde based resins are the best resin available in market. This is because of the properties of formaldehyde. These items are extremely economical due to the superior bonding properties and efficient production of formaldehyde-based glues. There are some applications where other materials could replace formaldehyde. But, it would entail significant cost increases or performance losses.

CHAPTER 2

LITERATURE REVIEW

2.1 Formaldehyde

Formaldehyde is a colourless, strong-smelling gas. Commonly known as a preservative in medical laboratories and mortuaries, formaldehyde is also found in other products such as chemicals, particle board, household products, glues, permanent press fabrics, paper product coatings, fibreboard and plywood. It is also widely used as an industrial fungicide, germicide and disinfectant.

When released into the soil, formaldehyde is expected to leach into groundwater. When released into water, formaldehyde is expected to readily biodegrade and not expected to evaporate significantly. Formaldehyde is not expected to significantly bioaccumulate. When released into the air, formaldehyde is expected to be readily degraded by reaction with photochemically produced hydroxyl radicals, readily degraded by photolysis, readily removed from the atmosphere by dry and wet deposition and expected to have a half-life of less than 1 day.

Formaldehyde is a simple but essential organic chemical that occurs in most forms of life, including humans. At the biological level, all normally functioning cells (human, animal and vegetable) produce and use or metabolize formaldehyde. It is an important substance in the manufacture of numerous products.

Formaldehyde exposure is stated in Occupational Safety and Health Association (OSHA.) The permissible exposure limits (PELs) for formaldehyde in the workplace covered by the standard are 0.75 parts formaldehyde per million parts of air (0.75 ppm) measured as an 8 hour time weighted average (TWA). The standard includes a second PEL in the form of a short-term exposure limit (STEL) of 2 ppm that is the maximum exposure allowed during a 15 minute period. The action level which is the threshold for increased industrial hygiene monitoring and initiation of employee medical surveillance is 0.5 ppm when calculated as an 8 hour TWA. (OSHA, 2002)

All organic life forms such as bacteria, plants, animals and humans produce formaldehyde. The air we breathe contains 1 to 68 parts-per-billion (ppb) of formaldehyde. Humans inhale it, exhale it and eat it in fruits and vegetables. In fact, the average person produces about 1.5 ounces of formaldehyde each day as part of normal metabolic processes. Formaldehyde is normally present in human blood at a low steady-state concentration of approximately 1 to 2 parts-per-million (ppm). Formaldehyde exists all around us naturally. It degrades in the presence of sunlight to CO_2 and H_2O. (R. P. Wayne, 1994) Animals readily metabolize formaldehyde using an enzyme called aldehyde dehydrogenase (ADH). (EPF, 2004)

Table 1.0 Physical and Chemical Properties of Formaldehyde

Property	Information	Reference
Molecular weight	30.03	Lide and Frederikse 1996
Colour	Colourless	Budavari et al. 1989
Physical state	Gas	Budavari et al. 1989
Melting point	-92 °C	Budavari et al. 1989
Boiling point	-21 °C	ASTER 1996
Density at -20 °C	0.815 g/mL	Lide and Frederikse 1996
Odour	Pungent, suffocating odour; highly irritating odour	Budavari et al. 1989; NFPA 1994

Odour threshold: Water Air	 50 ppm 0.5–1.0 ppm	 HSDB 1999 Klaassen 1996
Taste	50 ppm	HSDB 1999
Solubility: Freshwater at 20 °C Saltwater at 25 °C Organic solvent(s)	 Very soluble; up to 55% No data Ether, alcohol, acetone, benzene	 Budavari et al. 1989 Lide and Frederikse 1996; Budavari et al. 1989
Partition coefficients: Log K_{OW} Log K_{OC}	 0.350 1.567 No data, negligible	 SRC 1995b Calculated from Lyman 1982 HSDB 1999
Vapour pressure at 25 °C	Gas: vapour pressure>bp; 3,883 mm Hg	HSDB 1999; Howard 1989
Polymerization	Polymerizes; polymerizes readily in water	Budavari et al. 1989
Photolysis	Half-life (in sunlight) 1.6–19 hours producing H_2 and CO or H^+ and HCO	Lewis 1993
Henry’s law constant at 25 °C	3.27x10-7 atm-m3/mol	Howard 1989
Auto ignition temperature	300 °C	NFPA 1994
Flashpoint	60 °C	Budavari et al. 1989
Flammability limits at 25 °C	7–73%	NFPA 1994
Incompatibilities	Reacts with alkalies, acids, and oxidizers	NFPA 1994
Conversion factors (25 °C)	1 ppb (v/v) = 1.23 µg/m3 1 µg/m3 = 0.813 ppb (v/v)	Calculated
Explosive limits	7–73%	Lewis 1993

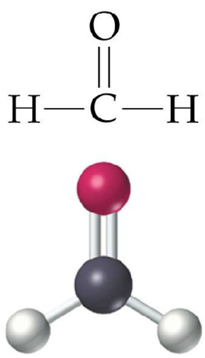

Figure 2.0 Formaldehyde Structure

2.3 Wood Based Panels

There are many wood based panel types, this include softwood plywood, oriented strand board (OSB), particle board and MDF. Composite wood panels have expanded into hybrid products which combine two or more panels, or panels with other materials, into a single product.

Wood based panels is an important sector, accounting for 9%, or €13 000 million, of total industry production, employing around 80 000 people in the Europe. In 2004, production totalled 45.6 million m^3. The construction market is the most important end-user for plywood, followed by packaging. Plywood also enjoys specific niche markets, such as transport, boat-building and musical instruments. The furniture industry is the most important user of particleboard, about 41% in 2004. Laminate flooring is a booming market for MDF and now accounts for nearly more than 40% of all applications. The industry is increasingly dominated by major groups, typically covering a wide range of wood based panel products, as well as other woodworking products. (European Panels Federation, 2004)

Formaldehyde's use as a component of the resin binder is strictly controlled within the board manufacturing process, and for the most part is handled in closed systems. In board forming and pressing areas extraction systems are used and climate controlled cabins are provided for operators.

Composite wood panel products are made from wood-based materials bonded together with a synthetic adhesive using heat and pressure. The materials include veneer, strands, particles and fibres. The nature of the wood raw material and the adhesive essentially determine the differentiated characteristics of the products. These include mechanical properties, water resistance, dimensional stability, surface quality and machinability.

Wood-based panel products have become increasingly specialized in recent years and are used in wide ranging applications. The demand for panels is forecast to increase well into the next century as quality logs for traditional products become increasingly scarce and as designers and consumers gain experience with positive product attributes and new applications. Composite panels will also substitute for metals and plastics.

The panel industry is environmentally responsible. Nonetheless, regulations have become increasingly stringent and the industry has responded with the application of appropriate technologies. New environmental technologies developed for other industries will have to be adapted to the panel industry, but with minimal cost impact.

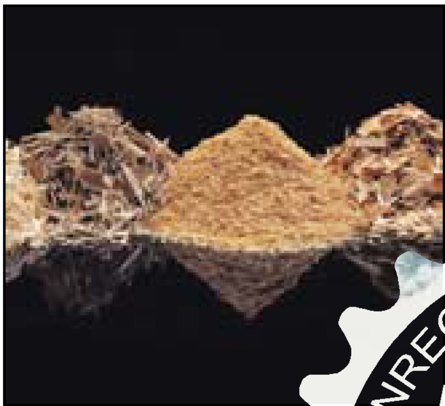

Figure 2.1 Wood Fibres, Particle and Saw Dust

2.3.1 Medium Density Fibreboard

Medium density fibreboard is a versatile wood-based panel with good machinability. MDF has a consistent structure and density and a very smooth surface. This makes it suitable for routed, lacquered and painted finishes. The MDF production process involves grinding wood chips into fibres and binding them with synthetic resin under heat and pressure. MDF is used mainly for the furniture industry, skirting boards, architraves, packaging material, in the door industry and in everything from book covers to shoes.

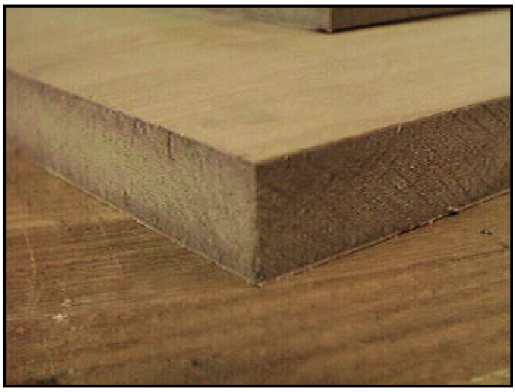

Figure 2.2 Medium Density Fibreboard

MDF has a substantially homogeneous consistency resulting from the uniform distribution of the wood fibres throughout the board. Different characteristics can be produced to meet end use requirements. Smooth and solid edges can be easily machined and finished, and the uniform surface provides an excellent substrate for painting or applying decorative overlays. This advantage has secured MDF's solid position in the furniture market. It has been successfully used in shelves, flush doors, television cabinets, wrapped mouldings, cupboards, drawer fronts, table tops, pool tables, office furniture, plaques and shields, game boards, toys, picture frames, mirror surroundings, pedestals for tables, bedroom furniture and bathroom accessories. Thick MDF is penetrating markets for millwork applications such as door frames, window frames, window sills, stiles, casings and turnings, as a substitute for solid wood.

The MDF industry currently has 14 plants with a total annual installed capacity of 2.9 million. For 2008, the export of MDF totalled at RM1.2 billion. The industry has started utilising acacia mangium and THW to produce MDF as alternatives to RW. Currently, Malaysia is the world's third largest exporter of MDF, after Germany and France. MDF from Malaysia has attained international standards such as BS, Asia-Pacific: Japan Australia and New Zealand (JANS), and EN standards. A number of companies have also ventured into the production of laminated/printed MDF.

MDF building material similar in application to plywood but made up of separated fibres, not wood veneers. It is denser than normal particleboard. MDF typically has a density of 600-800 kg/m^3, in contrast to particle board (160-450 kg/m^3) and to high-density fibreboard (500-1450 kg/m^3). Similar manufacturing processes are used in making all types of fibreboard.

Hardboard is used for exterior cladding (outer walls of buildings), panelling and furniture. Insulation boards are used for cladding in buildings for thermal insulation. Some boards are produced with a coating of sealant to help protect from water. MDF is primarily used in the joinery and furniture industry. It has several key advantages over other products:

Surface Finish: smoothness allows patterns (e.g wood grain) to be printed directly without the need for any underlay.

Fine Particles: form a smooth profiled edge when machined or cut. The edges of other boards, like particleboard, require filling or joining with products to give a good finish.

Uniform Density: delivers superior working qualities such as screw withdrawal.

The manufacturing processes of MDF start when trees are debarked after being cut. The bark can be sold for use in landscaping, or burned in on-site furnaces. The debarked logs are sent to the MDF plant where they go though the chipping process. A typical disk chipper contains 4-16 blades. Any resulting chips that are too large may be re-chipped; undersized chips may be used as fuel. All chips are then washed and checked for defects.

The chips are then compacted using a screw feeder, and will be heated for 30-120 seconds to soften the wood; they are then fed into a defibrator which maintains high pressure and temperature. The pulp that exits from the defibrator is fine, fluffy, and light in weight and in colour.

From the defibrator the pulp enters a blow line where it is joined with wax to improve moisture resistance and resin to stop the pulp from forming bundles. The material expands in size and is then heated by heating coils. When it comes out it may be stored in bins for an indefinite length of time.

After this drying period the board goes through a conforming process which creates 230-610 mm thick boards. Then it is cut and continues to the press. Here it is pressed for a few minutes, to make a stronger and denser board. After pressing, MDF is cooled in a star cooler, trimmed and sanded. In certain applications boards are also laminated for extra strength.

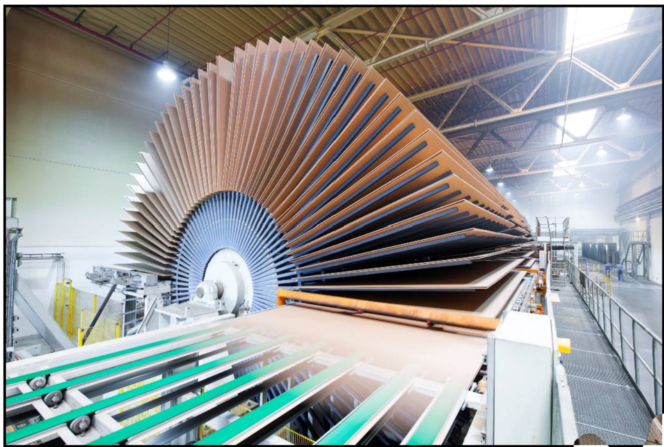

Figure 2.3 Star Cooler

2.3.2 Particle Board

Particleboard also known as chipboard is a multi-purpose material and one of the most widely-used wood-based panels. Particleboard is an engineered wood-based product manufactured from wood chip of various sizes particles and a synthetic binding resin. Raw material currently used in the manufacture of particle board comprises primarily sawdust, planer shavings, edgings, and other wood residues. The board is form in a press using a hot platen mat-formed process with larger particles concentrated in the core and smaller sized furnishes on both faces.

Particle board can be manufactured in different sizes, thicknesses, densities and grades for a variety of end uses. It has relatively homogenous properties making it an excellent core material for furniture manufacturing. Over the years, the industry has concentrated its effort on improving board surface smoothness for improved finishing and laminating purposes.

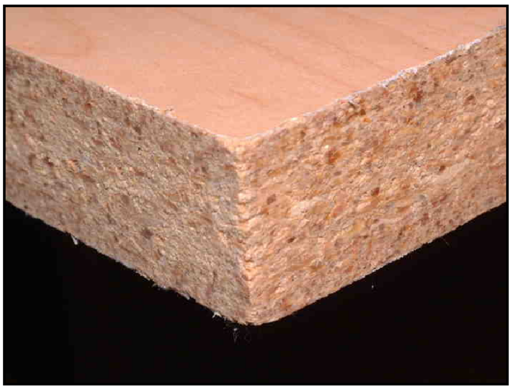

Figure 2.4 Particle Board

Particle board applications include furniture, cabinets, floor underlayment, sub-flooring in manufactured housing, door cores, and many other non-structural industrial applications. The main customers for particleboard are the furniture manufacturing and refurbishment sectors. Ideal for internal components, the product can also be coated with a decorative surface for applications such as kitchen, bathroom, bedroom and office furniture and shelving.

2.3.3 Plywood

Softwood plywood is manufactured to meet stringent requirements for exterior applications. Exterior plywood is an engineered panel built up of veneer plies. The thickness and orientation of the plies determine the performance of the panel. The veneer sheets are united under high temperature and pressure with PF adhesive, a waterproof adhesive, making the plywood suitable for exposed conditions.

Softwood plywood uses logs, preferably of good quality, as its raw material. These are put on a lathe and peeled into veneer. A range of coniferous species is used in manufacture, and each has special characteristics that may affect the performance level of the final product. Veneer of different species can be combined. Douglas-fir plywood, for example, must be faced with Douglas-fir veneer but 12 other species may be used as inner plies. Canadian softwood plywood allows 13 species for face veneer and 20 species for the inner plies.

Panels are manufactured in standard and modified constructions. Modified construction varies from standard lay-up in regard to the grain direction of the plies, the number of plies or the thickness of the individual plies. Plywood is also manufactured with adhesive-fibre overlays and specialty plywood may be textured with decorative patterns for display purposes.

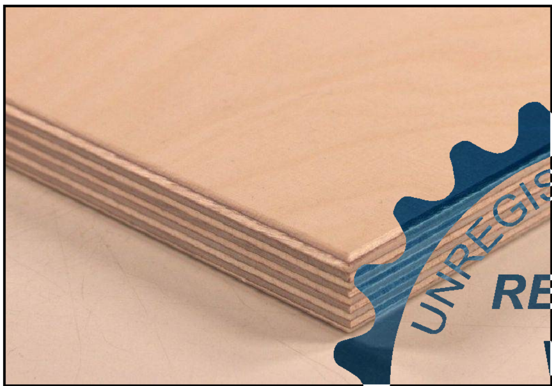

Figure 2.5 Plywood

Because of plywood's combination of mechanical and physical properties, including dimensional stability, it is a material of choice for a wide range of applications, such as roof and floor sheathing for residential and commercial construction, underlay for vinyl flooring and for concrete forms.

Plywood is used extensively in the fabrication of engineered building components such as wood I-beams, preserved wood foundations, concrete forms and stress skin panels. Industrial applications include crating, pallets, bins, furniture, display racks, store fixtures and exterior signs.

The hardwood veneer and plywood sector shares many features with its softwood counterpart, but it is very different from it. Panel properties are quite different. Hardwood panels are generally used for decorative rather than structural purposes. There are also differences in equipment settings and requirements for adhesives. Because they are used mostly in protected applications, hardwood plywood traditionally uses urea-formaldehyde adhesives. The industry is extremely fragmented. On the other hand, of all the panel sectors studied in this report, it is the most experienced in value-added products.

In the hardwood sector, there is a major emphasis on the appearance and value of the final product, and the quality of the face veneer. The hardwood sector manufactures veneer which is often thinner than for softwood. Veneer slicing may used as an alternative to rotary peeling, and peeling speeds are typically lower than in the softwood sector.

Hardwood veneer and plywood operations are generally smaller and located in separate plants. Log availability and quality are problems for both sectors, but this issue is perhaps more serious in the case of hardwoods. The industry also imports significant volumes of wood as logs, flitches and veneer.