CHAPTER-1

INTRODUCTION

Forests play a vital role in our lives, it is known for wood and wood products, protection of wildlife, conservation of soil and water and outdoor recreation and all have been studied and well documented. The chief economic product of forest is wood, but the other benefits, such as climate control, pollution abatement and wildlife maintenance have rarely been calculated. The economic importance of non-wood forest products is also increasing. In addition, forest provides shelter for wildlife, recreation and aesthetic renewal for people and irreplaceable supplies of oxygen and soil nutrients. In order to have a sustainable benefit from forest it is necessary to protect the forest from adverse factors.

With industrialization the forest covers have decreased from 5.9 billion hectares to currently about 4 billion hectares i.e. 31 % of the earth’s land surface (FAO, 2010), which corresponds to an average of 0.6 ha per capita. The five most forest-rich countries (The Russian Federation, Brazil, Canada, The United States of America and China) account for more than half of the total forest area. The deforestation rates were highest in 1990s, when each year the world lost an average of 16 million hectares of forest. Moreover, relative rate of tropical deforestation have been about twice as high in Asia (0.8-0.9% per year) than in either Latin America or Africa (0.4-0.5% per year). Total forest covers have decreased drastically in tropical Asian nations. Bangladesh just has a tenth (10.2%) of its estimated original cover, whereas the Philippines (19.4%) and India (24.01%) each have just two tenths of its forest cover. Thailand (28.9%), Sri Lanka (30%) and Vietnam (30.2%) each have about three tenths of their original cover (Laurance, 2007)

Wood in the form of timber and fuel wood are the most important product derived from the forest. At present total forest cover and tree cover of India is 78.92 million ha constitute 24.01% of its total geographical area (328.73 m. ha) which is far below the national goal i.e. 33% as per National Forest Policy, 1988 (FSI, 2013). The total growing stock of India’s forest is estimated as 5658.046 million cum (which comprises 4173.362 million cum inside the forest and 1484.68 million cum outsides
the forests) i.e. with only 0.7 m³/hectare/year productivity against the world average of 2.1 m³/hectare/year. The per capita forest area is only 0.064 ha against the world average of 0.64 ha. (FAO, 2010) i.e. only one-tenth of the world's average this is mainly due to non-recycling of biomass in forest soil, forest fire, grazing, over-exploitation, etc.

India is currently facing an acute shortage of timber. India's round wood production is estimated to be about 240 million m³, of which 75% is the estimated share of fuel wood and 15-20 million m³ industrial round wood, including poles and small lumber for rural households (NFC Report 2006). Supply from natural forests is about 12 million m³ (about half coming from tropical forest areas). The estimated share of industrial round wood for industry coming from farm forestry and other trees outside forests is 31 million m³. Official imports of timber accounted for just over 3 million m³ in 2006, mostly in the form of logs. Hence, there is a gap between consumption and supply of timber of about 25 million m³. Import of wood and raising plantations of fast growing wood species are unlikely to meet the increasing demand of wood, emphasizing more towards the use of non-durable wood species. Wood importing countries will wish to preserve non-durable wood in order to conserve foreign currency by reducing wood imports, while wood-exporting countries will adopt preservation in order to reduce the home demand for replacement wood. The most obvious advantage of preserved wood is that it can be used with impunity in situations where normal untreated species would inevitably decay (Richardson, 1993).

Plantations of fast growing species are one of the options to reduce the gap between demand and supply of wood and wood products. National forest policy (1988) give instructions to industries to grow own plantation for supplement of raw material as per their requirement without affecting the natural forest and maintain ecological balance. Plantations are being established to supply in the least possible time the required wood for the industries. In countries with good environmental conditions a particular fast grown plantation is being developed with diverse genus: *Acacia, Eucalyptus, Pinus, Populus, Salix* etc. Currently, about 50% of the wood supply in the country is from non-forest sources, that is, outside government forests. The rest of the industrial wood consumption is accounted for partly by imports and supply from public forests, mainly plantations.
There are many plantation species in India; few are exploited for commercial purposes; *Eucalyptus* is one of them. *Eucalyptus* has more than 600 species and varieties, those planted on commercial scale. Among them *E. grandis*, *E. globulus*, *E. camaldulensis*, *E. tereticornis*, *E. viminalis*, *E. nitens*, *E. saligna* and *E. urophylla* are the predominant in fast grown plantations.

*Eucalyptus tereticornis* is evergreen, large tree up to 50 m tall; bole relatively short, straight, up to 200 cm in diameter; bark surface white, grey or grey-blue, decorticating over the whole trunk in large plates or flakes to leave a smooth or mat, mottled surface and crown fairly open. *Eucalyptus tereticornis* is one of the most important fast grown plantation species in India and it is the first eucalypts exported from Australia and is now cultivated throughout the tropics, on a large scale in India and Brazil. For the year 1995, it was estimated that worldwide *Eucalyptus* plantations amounted to 14.6 million ha, of which over 500,000 ha have been planted in India. The wood is used for construction, railway sleepers, bridges, poles, piles, posts, boats, hardboard, particle board etc (Brink, 2008).

The heartwood is pale to dark red, and fairly well demarcated from the grey to cream-coloured sapwood. The grain is wavy or interlocked, texture even and fairly fine. The wood has a density ranges between 660–1060 kg/m³, and modulus of rupture is 118–181 N/mm², modulus of elasticity 8400–15,200 N/mm², compression parallel to grain 49–72 N/mm², shear 6–11 N/mm², cleavage 26–27 N/mm and Chalais-Meudon side hardness 2.7–8.7 at 12% moisture content. The rates of shrinkage from green to oven dry are high: 4.2–10.6% radial and 7.4–13.5% tangential. The wood has a strong tendency to warp during drying and it is not stable in service. The average chemical composition of the oven-dry wood is: cellulose 45–48%, pentosans 11–23%, lignin 22–30%, ash 0.5–1.3%.

The wood is moderately durable in exterior condition and has good weathering and wearing properties. In Australia the wood is one of the most resistant to marine borer attack, but it failed after 2.5–10 years at the Pacific coast of the United States. The sapwood is susceptible to *Lyctus* borers. The heartwood is resistant to impregnation with preservatives, the sapwood is permeable. The energy value of the wood is 17,750–22,000 kJ/kg. The wood yields a very good-quality pulp. The wood fibres in material are approximately 0.80 mm long, with a diameter of 14.2 μm, a cell wall thickness of 4.5 μm and a lumen diameter of 5.2 μm. Pulping of material...
with various chemical processes gave yields of 43–46% of pulp with good mechanical properties. The wood contains 0.5% essential oil and 6–12% tannin; the bark contains 3–15% tannin.

*Pinus roxburghii* Sarg. (Pinaceae), commonly known as chir pine, is a large tree reaching 30–50 m (98–164 ft) with a trunk diameter of up to 2 m (6.6 ft), exceptionally 3 m (10 ft). The bark is red-brown, thick and deeply fissured at the base of the trunk, thinner and flaky in the upper crown. The leaves are needle-like, in fascicles of three, cylindrical, 20–35 cm (7.9–13.8 in) long and distinctly yellowish green. It is found throughout in the Himalayan region and in hills of southern India. It generally occurs at lower altitudes than other pines in the Himalaya, from 500–2,000 m (1,600–6,600 ft), occasionally up to 2,300 m (7,500 ft). It is also planted in the garden for ornamental purpose (Luna, 2005).

The tapping of the stem produces a clear, transparent oleo-resin with the pungent and bitter taste. Distillation of the turpentine oil from the oleo-resin leaves faintly aromatic and transparent rosin (colophony). It is utilized in the manufacturing of fireworks, insecticides and disinfectants and enters into certain lubricating compositions, hair fixing and nail polishing preparations (Anonymous, 2003). Pitch can be obtained from the resin and is used for waterproofing, wood preservative etc. The wood is very resinous and can be splintered and used as a torch. Wood is moderately hard, used for construction, shingles, boxes etc. The wood used as a railway sleepers after treatment with preservative, for construction, manufacture of packing cases, crates, shutters, door and window frame, carpentry and joinery; and pulped in paper industry.

For local building purposes, the chir pine wood is the least preferred, as it is the weakest and most prone to decay when compared with other conifers. On the basis of MOE and MOR in green condition, chir pine has been classified as group “C” timber for structural uses.

Sapwood distinct from heartwood, white to creamy white. Heartwood light yellowish- brown turning to light reddish- brown on exposure, with characteristic resinous odour when fresh. Wood moderately hard, moderately heavy, average weight 575 kg/m$^3$ at 12% mc, medium and uneven textured with straight to markedly spiral or twisted grain. The studies on variation of strength properties within the tree indicate that specific gravity and strength properties consistently increase from pith to
periphery. The wood has a density of 469kg/m³, and MOE 110.8 1000kg/cm², MOR 494-744 kg/cm², compression parallel to grain 317kg/cm² and shear 88.9kg/cm² at 12% moisture content. The rates of shrinkage from green to oven dry are high: 4.9% radial, 7.1% tangential and volumetric 11.7% (Rajput et al., 1996).

Chir pine wood is liable to excessive splitting, cracking and warping. Green conversion and careful staking are therefore suggested to overcome these defects. The timber seasons well in kiln though resin is liable to exude on the surface during seasoning process. The heartwood of chir pine is easily treatable. The treated wood of chir is better than most of the naturally durable timber for many uses like cooling towers and under marine conditions.

When this species of pine tree reaches a large girth, the bark forms flat patches which can be broken off in chunks. It has a layered structure like plywood, but the individual layers have no grain. The locals use the bark to make useful items like lids for vessels. Blacksmiths use this bark exclusively as the fuel for the furnaces. The improvement of the aforesaid properties of Eucalyptus tereticornis and Pinus roxburghii in an eco-friendly way are the biggest challenges but also an opportunity for wood technologists.

Trees that generate wood are divided into two broad classes. These two classes are known botanically as the Gymnosperms and the Angiosperms. Conifers are the most important members of the Gymnosperms division and are known by the term Softwood. Botanically, the seeds of softwood trees are naked and not enclosed in the ovary of the flower. Anatomically, softwoods are nonporous and do not contain vessels.

Angiosperms are subdivided into Monocotyledons and Dicotyledons. Palms and bamboos are Monocotyledons while dicotyledons are generally known by the term Hardwood (Bootle, 1971). Botanically, the seeds of hardwood trees are enclosed in the ovary of the flower. Anatomically, hardwoods contain vessel elements which are a wood cell with open ends. When vessel elements are set one above another, they form a continuous tube which forms the vessel (Miller, 1999b). Hardwoods, such as eucalyptus species, are broad leaf plants and they lose their leaves in autumn or winter and normally favour the warmer climates (Miller, 1999a).

Softwoods are mainly conifers and usually cone-bearing plants with needle or scale-like evergreen which commonly grow in temperate and cool climates. There are

Wood is a secondary xylem, primarily composed of hollow, elongate, spindle-shaped cells that are arranged parallel to each other along the trunk of a tree. When lumber and other products are cut from the tree, the characteristics of these fibrous cells and their arrangement affect such properties as strength and shrinkage as well as the grain pattern of the wood. Wood, which in merchantable are clearly differentiated into sapwood and heartwood and pith, a small core of tissue located at the centre of tree. Sapwood contains both living and dead tissue which is adjacent to the inner side of the cambium layer and is pale in colour and carries sap from the roots to the leaves. Heartwood is formed by a gradual change in the sapwood and is inactive.

The wood consists of two parts, the sapwood which is adjacent to the inner side of the cambium layer and is pale in colour (Plate-1.1). The other part called heartwood, forms the inner part towards the pith, and is mostly darker in colour (Bamber, 1987). The sapwood may vary in thickness and number of growth rings. In general, heartwood consists of inactive cells that do not function in either water conduction or food storage. The transition from sapwood to heartwood is accompanied by an increase in extractive content and which darkens the heartwood.

Heartwood extractives may affect wood by (a) reducing permeability, making the heartwood slower to dry and more difficult to impregnate with chemical preservatives, (b) increasing stability in changing moisture conditions and (c) increasing weight (slightly).

Wood cells are known as tracheids in softwood and in hardwoods as fibres and vessels. A taper tube with close ends is the approximate form of a tracheid, and the connections between them in the wood structure are small holes or pits. The vessels, on the other hand, have the form of continuous pipelines in an end-to-end arrangement. The cells are hollow and extend parallel to each other along the trunk of the tree (Bootle, 1971; Miller, 1999b). The individual wood cells are held together by a bonding material called lignin. The lignin is often called the cement agent that binds individual cells together (Fig-1.1).
Fig 1.1 - The basic elements of softwood and hardwood structure (Bootle, 1971).

Wood is susceptible to deterioration by wood decaying fungi and insect because of its lignocellulosic structure. But some wood species have natural resistance to degradation by micro-organisms which are known as natural durability. Natural durability (Kumar, 1971) has a reference only to heartwood, since sapwood as a rule is vulnerable to attack both by fungi and insects. This natural resistance or durability is a function of the type of extractives the tree stores in its heartwood. Sapwood of most species comparatively low durability because there are little extractives contained in the sapwood and it is full of starches and carbohydrates. The resistance of a particular species to attack from fungi, termites and insects is determined by the type of extractives stored in the heartwood. The compounds responsible for natural durability are phenolic and polyphenolic compounds like hydroxystilbenes, coumarins, flavonoids, iso flavonoids, neoflavonoids, tannins, hydroxyl aldehydes, hydroxyketones, tropolones, quinines, xan thones etc (Rao, 1982). But no wood is completely and permanently resistant to all forms of decay due to its organic origin, and falls an easy prey to various organisms, which consumes wood as source of food.

In India, forest produces nearly 30 million m³ of industrial wood against an annual country requirement of over 54 million m³ (Pandey et al., 2011). Shortage of wood raw material is being experienced in the country due to various reasons. The gap between demand and supply of various raw materials is likely to further widen.
due to rise in population and standard of living. In view of this government efforts to substitute wood by steel, plastics and other alternate materials, it may not be possible to reverse this increasing trend because, wood still works out to be cheaper for many applications apart from other technological advantages. Demands for woody raw material are bound to increase especially in situations where the available wood substitutes are either expensive or pose environmental risks in production. Wood being renewable can meet such demands if used intelligently. The major portion of demand will be used for replacement of old deteriorated wood. Such demand for replacement can be significantly reduced by adopting the available wood preservation technology. Even in the most hazardous situations, treated wood is expected to give at least 5 times more life than untreated wood and thus shift the wood replacement cycle. Import of wood and raising plantations of fast growing species are mainly non durable wood species. Wood importing countries would prefer to preserve non durable wood in order to conserve foreign currency by reducing wood import, while wood exporting countries will adopt preservation in order to reduce the home demand for replacement wood. Thus wood preservation can eliminate or at least decrease the replacement of wood components (Kumar and Dev, 1993).

Wood has hygroscopic nature, it has some undesirable properties such as poor resistance against biological attack of fungi and insects, and swelling and shrinkage caused by water adsorption and desorption. Seasoning and wood preservation are two distinct processes, developed primarily to increase the service life of wood.

Wood seasoning involves removal of extra moisture from wood in a scientific way to prevent degradation in service due to checking, cracking, warping etc. caused by uncontrolled drying. The activity of the biodegrading organisms are reduced as they require a certain minimum amount of moisture in the wood as their biological need but it is not a substitute for chemical preservation, which is a must for nondurable wood species. Some species like teak, sissoo, sal etc. have naturally durable heartwood and may not require any chemical preservation but such species do require to be dried adequately before putting in use.

Wood preservation is also one of option to increase the service life of wood or to reduce the pressure on natural forest. Wood preservation is the pressure or thermal impregnation of chemicals into wood to provide effective long-term resistance to attack by fungi, bacteria, insects, and marine borers. By extending the service life of
timber products, wood preservation reduces the need for harvest of already stressed forestry resources, reduces operating costs in industries such as utilities and railroads, and ensures safe working conditions where timbers are used as support structures. Experience has shown conclusively that, with suitable chemical treatment, the life of timber can be increased to 5 to 10 times than its normal life.

An important aspect of timber preservation is the means of checking to ensure that timber has been adequately treated to the required retention. This means that the operator must ensure that firstly, the chemicals have been mixed to the correct strength, and secondly, that the preservative has been impregnated appropriately into the wood. The degree of protection achieved depends on the preservative used and the proper penetration and retention of the chemicals. Some preservatives are more effective than others, and some are more adaptable to certain requirements. Treatability varies among wood species—particularly their heartwood, which generally resists preservative treatment more than does sapwood. To obtain long-term effectiveness, adequate penetration and retention are needed for each wood species, chemical preservative, and treatment method.

Wood preservatives that are applied at recommended retention levels and achieve satisfactory penetration can greatly increase the life of wood structures. Thus, the annual replacement cost of treated wood in service is much less than that of wood without treatment. In considering preservative treatment processes and wood species, the combination provides the required protection for the conditions of exposure and life of the structure.

There are three general classes of wood preservatives: oils, such as creosote; organic solvent, such as pentachlorophenol; and waterborne salts that are applied as water solutions. The effectiveness of the preservatives varies greatly and can depend not only upon its composition, but also upon the quantity injected into the wood, the depth of penetration, and the conditions to which the treated material is exposed in service.

**Conventional Processes**

The most widely recognized methods of preservative application are by brushing or spraying, dipping, soaking, steeping, or the hot and cold bath. These methods are conveniently performed need not much machinery. The uniformity of treatment throughout the specimens is sometime need to be inspected.
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Pressure treatments are commonly done in closed cylinders. In general, such processes have a number of definite advantages over non-pressure methods. As it helps in deeper and more uniform penetration and higher absorption of preservative can be secured, thus providing more effective protection to the timber. Furthermore, the treating conditions may usually be so controlled that the retention and penetration can be varied to meet the requirements of service, thus resulting in more economical use of preservative. It is further categorized into two processes 1) Full Cell Process, This process is used when high absorptions of the preservative are desired. This is achieved by filling the cells and saturating the cell walls with the preservative and 2) Empty Cell Process (Lowry and Rueping). These processes aim at a maximum penetration of the preservative with minimum of net absorptions. The operations are carried out as per the requirement of users. However, it is not always possible to get the wood treatment uniformly in a wood section. The treatment depend on many factors and one of them treatability of wood. It is essential to study the treatability class of all wood species to ascertain the treatment procedure.

Most of the commercially available indigenous wood species have been tested and categorized into five treatability classes ‘a’ to ‘e’ according to the ease of preservative impregnation. The class ‘a’: heartwood easily treatable, class ‘b’: heartwood treatable but complete penetration not always obtained in dimensions of over 6cm, class ‘c’: heartwood only partially treatable, class ‘d’: heartwood refractory to treatment, and class ‘e’: heartwood very refractory to treatment, penetration of preservative being practically nil from the ends (Kumar and Dev, 1993).

Non-conventional wood treatment process

Thermal treatment

Wood modification represents a process that is used to improve the properties of wood and this modified material can be disposed off at the end of a product’s life without presenting an environmental hazard. Modification of wood can involve active modifications, which results in a change of the chemical nature of the wood substrate or passive modifications where a change in properties is affected but without an alteration in the chemistry of the material (Hill, 2006). Thermal wood modification though mainly used for dimensional stability had shown some good results in wood protection. Tiemann (1920) used higher temperatures to decrease wood EMC. Thermal wood modification was not considered important because plenty of durable
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high quality wood species were available and research in this field remained in passive state for nearly half century. With the decrease in durable wood species and environmental pressure, this field is being explored extensively for nearly last twenty years. Many attempts were made in this direction and mainly five methods of thermal wood modification got recognition. These methods differ in use of medium of heat transfer, temperature and time of treatment. Finnish ThermoWood® uses water vapour to create protective atmosphere to prevent the wood from burning and cracking (Jamsa and Viitaniemi, 2001). German Menz Holz process uses hot vegetable oil bath for heating (Rapp and Sailer, 2001). Plato process developed in Netherland principally consists of two stage Hydro-thermolysis and dry curing, with an intermediate drying operation (Militz and Tjeerdsma, 2001). WTT Thermo treatment process developed in Denmark treat wood in a pressurized atmosphere at 3-19 bars and uses pre-dried wood (WTT, 2011). In Le Bois Perdue fresh wood is dried and further treated in a heated steam which is generated during drying, while in retification process seasoned wood is heated under nitrogenous atmosphere (Vernois, 2001). The success of treatment depends upon the treatment time, temperature and wood species. Some species require very high treatment temperature and time while other give good results with milder treatments. The average range of temperature is 150°C to 260°C. Below 150°C there is only drying and slight changes and above 260°C pyrolysis of wood takes place.

Microwave (MW) treatment

A number of wood species, particularly hardwoods, have a very low permeability causing problems during timber processing. These include, very long drying times, large material losses after drying, expensive drying processes and an extreme difficulty in impregnating the timber with preservatives and resins.

Methods to increase wood permeability include steaming, biological treatments, and incising. Steaming timber alone at 127°C or using vacuum to accelerate moisture loss after steaming has been reported extensively (McQuire, 1962; Bergervoet, 1983). Once the timber has been cooled (usually 24 h after steaming), it can be treated using the Alternating Pressure Method (Vinden and McQuire, 1978). Alternatively, the wood can be left for 7 to 21 days to allow further moisture loss, redistribution and fixation of preservative then treated with the Bethell or “Full Cell” process (McQuire, 1974).
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Steaming improves timber permeability and treatability but also reduces timber strength. Usually, a 25% loss in modulus of rupture and an 18% loss in modulus of elasticity as well as timber discoloration occur (Bellmann, 1968). Biological treatments using specific bacteria have improved wood permeability before treatment (Archer, 1983). Biological methods have not been used commercially, because of the lack of uniformity in results, poor improvement in heartwood permeability, and difficulty in optimizing the bacterial combinations used.

Incising, boring holes, piercing, and slitting have been in use since mid-1800s (Bellmann, 1968). Timber permeability has been enhanced on the wood surfaces by inserting small holes (0.7 mm in diameter and 10 mm in depth) in a regular pattern at approximately 14,000 incisions per m² (Ruddick, 1991). A problem associated with incising relates to the lack of standards that regulate its use in different species, products, and specific conditions (Morris, et al. 1994).

Over the past 30 years, considerable investment has been made in developing technologies to produce more eco-friendly wood-based products. Many of these technologies add value through the modification and/or enhancement of various wood properties.

Microwave technology has been developed for improving wood permeability (Torgovnikov and Vinden, 2009). Wood exposed to intense microwave energy generates steam pressure within the wood cells. Under high internal pressure, the weak ray cells in Pinus radiata are ruptured to form pathways for easy transportation of liquids and vapours in the radial direction (Vinden et al., 2004). An increase in the intensity of microwave energy applied to wood increases the internal pressure, forming narrow voids in the radial and longitudinal planes. A several thousand-fold increase in wood permeability in the radial and longitudinal directions can be achieved in wood species previously considered to be impermeable (Vinden and Torgovnikov, 2000). Microwave treatments are very useful for treating the wood which is difficult to treat by conventional methods. Similarly, it is also very useful where the impregnation of preservative is very difficult.

Most of the wood treating methods, a significant amounts of free water in the wood cell cavities may slow or prevent the entrance of the preservative chemical. Wood moisture also plays a very important role in the treatment. The concentration of preservative treatment and dry salt retention depends on amount of moisture content.
in wood. Thus, to obtain an optimum amount of preservative it is essential to reduce moisture content at least up to 15%. Moisture reduction can be accomplished by using artificial conditioning treatments or by air-seasoning. Unseasoned wood exposed to the open air generally dries slowly until it comes into approximate equilibrium with the relative humidity of the air. Wood is artificially conditioned by one of the three primary methods: (1) steaming-and-vacuum, (2) boiling-under vacuum (commonly referred to as the Boulton process) and (3) kiln drying. In the cases were the moisture content in wood is very high the microwave treatment may be very useful especially in freshly felled logs where moisture content ranges from 40% up to 250%. Green wood readily absorbs microwave (MW) energy. This results in a very high release of energy from within the material. Wood exposed to intense MW power generates steam pressure within the wood cells. Under high internal pressure, the weak ray cells are ruptured to form pathways for easy transportation of liquids and vapours in the radial direction.

Microwave energy is better option for wood processing such as drying as large amounts of microwave energy can be absorbed and more energy applied to a given amount of wood compared to conventional heating and drying methods. Microwave treatment enhances the rate of evaporation of water from wood and the energy generated is absorbed throughout the wood volume (Metaxas and Meredith, 1983).

Wood is a dielectric material. The dipolar components of its molecules couple electro-statically to the microwave electric field and tend to align themselves with it mechanically (Meredith, 1998). The two positively charged hydrogen ions and double negatively charged single oxygen ion of water molecule rotates and aligns with the electrical field direction. Since the microwave field is alternating, a reversal of the field causes the molecules to realign 180° causing a vibration. The dipoles therefore attempt to realign as the field reverses, and so are in a constant state of mechanical oscillation at the microwave frequency. This process manifests itself as heat (McAlister and Resch, 1971; Barnes et al., 1976), and causes the temperatures inside the wood to rise.

The energy is directly transferred into the wood, absorbed by water molecules and changed into heat (Zielonka and Gierlik, 1999). The microwave has the ability to maintain an adequate moisture flow to the evaporating surface and therefore helps in
extending the constant drying rate beyond the critical moisture content for wood (Zielonka and Gierlik, 1999).

An increase in the intensity of MW energy applied to wood increases the internal pressure, resulting in the formation of narrow voids in the radial-longitudinal planes. A several thousand-fold increase in wood permeability in radial and longitudinal directions can be achieved in species previously found to be impermeable to liquids and gases. Other physical properties and technological attributes are also improved (Vinden and Torgovnikov, 2000), these include: improved permeability, reduced density, reduced heat conductivity (better heat insulation), reduced shrinkage and swelling, improved acoustic properties (better sound insulation), improved impregnation/liquid uptake, improved sawing and improved drying.

Microwave modification of wood establishes opportunities for developing a number of new industrial applications including rapid preservative treatment of heartwood of softwoods, the treatment of refractory wood species with preservatives, rapid drying of hardwoods and new wood-based material production.

Generally, the wood, whether it is large or small has moisture. Such wood, when placed in microwave oven, gets the electric wave, through the vibration of the molecule consisting frequency two billion four hundred and fifty million times per second. The friction among molecules of wood occurs repeatedly. It then causes the frictional heat, and the temperature of the wood rises. Thus, the material containing water heat up when placed in a microwave field.

Wood cell-wall consists of heavy-walled structural cells (tracheids, libriform vessels and fibres) and thinner walled ray cells, which transport nutrients throughout the tree. Microwave heating affects the thin walled ray cells most. As the microwave-induced steam pressure, the cell wall begins to rupture, creating micro-voids within the wood structure and increasing the permeability of the wood. These micro-voids form pathways for easy transportation of liquids and vapours.

Increased applied MW intensity further increases internal steam pressure, resulting in the formation of narrow voids in the radial-longitudinal planes. The number of cavities, their dimensions and distribution varies with the species and which is affected through variation of MW intensity. A several thousand-fold increase
in wood permeability in the radial and longitudinal directions can be achieved in species previously found to be impermeable to liquids and gases (Vinden, et al. 2004)

The commercial applications of microwave (MW) have been developed in Australia. Their four frequencies are allowed for industrial applications 5.8, 2.45, 0.922 and 0.434 GHz. However, economic limitations reduce the number of commercial frequencies to just 2.45 and 0.922 GHz. The frequency 2.45 GHz can be used for timber cross section up to 50x100 mm or for modification of shell layers of timber with larger dimensions. The frequency 0.922 GHz can be used for log diameters up to 350 mm (Torgovnikov and Vinden, 2005).

To achieve the required degree of wood modification the applied MW power must be high enough to boil water within the wood to create high steam pressure in the cells to rupture the required elements of the wood structure. However, the MW power level must be below that required to initiate wood burning. The 60 kW power and 2.45 GHz frequency MW generator can supply an intensity of 5.3 kW/cm² to the wood, while 0.922 GHz (frequency) the 60kW (power) MW generator supplies levels up to 0.8 kW/cm². Such MW intensity provides opportunities for wood modification according to the application. Higher intensity provides better control of modification.

It is possible to classify (tentatively) three degrees of the wood modification which depend on the MW processing conditions. Which are (1) Low Degree - rupturing wooden cell pore membranes, resin melting replacement in channels, partly rupturing tyloses (in hardwood species). (2) Moderate Degree - rupturing wooden cell pore membranes, resin boiling and replacement, destroying tyloses (in hardwood species) and rupturing ray cells. (3) High Degree - rupturing wooden cell pore membranes, resin boiling and replacement, destroying tyloses (in hardwood species), rupturing ray cells, rupturing main cell (traheids, libriform, parenchyma) walls and walls of vessels, and formation of cavities being primarily in radial-longitudinal planes.
OBJECTIVES
The present work has been conducted to investigate the potential of MW heating in improving the treatability, permeability, pH and durability characteristics of *Pinus roxburghii* as softwood and *Eucalyptus tereticornis* as hard wood species. Following are the main objectives:

- To study the effect of Microwave on permeability, absorption of preservative and retention with dipping time.
- To study the treatability improvement in wood.
- To study the effect of microwave on pH of wood.
- To study resistance of treated wood against termite in mound.