

IFEAT

SOCIO-ECONOMIC REPORT ON CEDARWOOD OILS

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PART 1: CHINA AND THE USA¹

INTRODUCTION

The term "cedarwood oil" can be confusing, in that the most important essential oils in this group are produced by distilling different junipers and cypresses (*Juniperus* and *Cupressus* spp.) rather than from true cedar trees (genus *Cedrus*). The *Oxford Encyclopaedia of Trees of the World* lists 34 tree species that have the common name "cedar" covering not only some of the above-mentioned species but also *Thuja* and *Pinus* spp. Cedarwood oil is commercially produced in many parts of the world and widely used. According to Milchard (2019) cedarwood oil is second in product volume only to the *Pinus* species of oils produced from the wood of essential oil-bearing plants.

The true cedar trees of the *Cedrus* spp are stately evergreen trees commonly divided into four species:

- *Cedrus atlantica* or Atlas or Atlantic cedar from North Africa
- *C. brevifolia*, the Cyprus cedar
- *C. deodara*, the Himalayan or Indian cedar
- *C. libani*, the cedar of Lebanon

Commercial "cedarwood oils" are obtained from three main genera of *Cupressaceae*:

- *Juniperus* spp. for Texas and Virginiana cedarwood oils
- *Cedrus* for Moroccan and Indian oils
- *Cupressus* for Chinese oils.

Part 1 of this socio-economic report provides an overview of cedarwood oil along with details of cedarwood oils from China and the USA. Also, in this edition of IFEATWORLD is *My Favourite: Chinese Cedarwood Oil (Cupressus funebris) and Firwood Oil (Cunninghamia lanceolata)* by Cathy Chen. This provides additional information and data on Chinese cedarwood and firwood oils. The latter oil is not discussed in detail in this report. The next edition of IFEATWORLD contains Part 2 which discusses cedarwood oils in India and Morocco and other smaller producers.

Many other cedarwoods are known, and have been distilled on a minor scale for their oil including:

- Nootka cypress (*Chamaecyparis nootkatensis* 'Glauca') sometimes called the yellow or Alaska cypress, which is a tall evergreen tree found on the west coast of Canada and the USA.
- *Chamaecyparis obtusa* (Siebold & Zucc.) Endl. – Japanese cedarwood from which "hinoki" oil is extracted from the leaves, branches and timber of the tree.
- Mulanje cedarwood *Widdrington whytei* Rendle syn. *W. nodiflora* (L.) Powrie.
- Port Oxford or Oregon cedarwood *Chamaecyparis lawsoniana*
- Weeping blue juniper *Juniperus recurva* Buch.-Ham.
- Hibawood oil *Thujopsis dolabrata* (L.f.) Siebold & Zucc. which was formerly used as a perfumery ingredient.

In addition, there is a small production of other cedar oils such as cedarleaf oil distilled from *Thuja occidentalis* from eastern white cedar (Trahan 2008). The main areas of cedarleaf oil production have traditionally been in New York, Vermont, Quebec, and Ontario, and some distillation has taken place in Michigan and British Columbia (western red cedar *Thuja plicata*).

USES, QUALITY AND COMPOSITION

Cedarwood oils each have characteristic woody odours which may change while drying out. The crude oils are often yellowish or even darker in colour if they are dry distilled in China. Some, such as Texas cedarwood oil, are quite viscous and deposit crystals on standing. They are used, sometimes after rectification, in a wide range of fragrance applications such as soap perfumes, household sprays, floor polishes and insecticides. Small quantities are used in microscope work as a cleaning oil and in the pharmaceutical industry.

Cedarwood oils have various uses in aromatherapy and as herbal remedies. Cedarwood has been known for thousands of years and is mentioned in the bible as a source of both wisdom and protection. It is claimed to have various medicinal properties including anti-inflammatory, stimulating blood circulation, protecting the scalp and skin from bacteria and environmental pollutants, lengthening sleeping time, reducing the onset of ageing, pain relief and acne treatment. Cedarwood oils are used to enhance relaxation and improve focus. For this reason the oil is being studied

for its beneficial effects on children with ADHD, with cedarwood oil found to decrease hyperactivity and evoke a calm, almost sedative quality reducing the stress and anxiety that comes along with the disorder. Also, the oil has been registered with the US EPA as a pesticide that stops moths from eating clothing.

The timber from the wide range of junipers (*Juniperus*), cypresses (*Cupressus spp.*) and true cedar trees (*Cedrus*) have a range of other non-oil uses such as timber, furniture, fencing, pencil making, ornamental trees, and railway sleepers. This is briefly discussed in the individual country sections.

All the cedarwood oils of commerce contain a group of chemically related compounds, the relative proportions of which depend on the plant species from which the oil is obtained. These compounds include cedrol and cedrene, and while they contribute something to the odour of the whole oil, they are also valuable to the chemical industry for conversion to other derivatives with fragrance applications. The oils are therefore used both directly and as sources of chemical isolates, including alpha cedrene epoxide, methyl cedryl ether and cedryl acetate.

Virginia cedarwood oil is considered by many perfumers to have a smoother and finer (but less powerful) odour than Texas oil. In addition, it is used in insecticides, polishes and cleaning products, soaps, liniments, and cedarwood still residues have been used in the manufacture of linoleum. A sizeable proportion of the oil is used as a starting material for cedrol and cedryl acetate.

Chinese oil has a lower cedrol content than American oils and is used more in its own right as a fragrance oil than as a source of chemical isolates. The oil and wood are used to prepare incense in China.

The uses of Moroccan cedarwood oil (*Cedrus atlantica*), Indian cedarwood oil (*Cedrus deodara*) also known as Himalayan cedarwood oil, Japanese hinoki oil (*Chamaecyparis obtusa*), and Canadian cedarleaf oil (*Thuja occidentalis L.*), are discussed in Part 2.

An important constituent of cedarwood oils is cedrol, which is used in flavours and fragrances as well as being used to make a range of chemical

derivatives such as cedrol methyl ether, cedryl acetate and other esters. The sesquiterpene hydrocarbon fractions are commercially chemically derivatised to make fragrance ingredients like acetyl cedrene and cedr-8-ene epoxide. These are all important high-volume ingredients for the global fragrance industry. After processing, the derivatives produced and their formulated products have a more diverse range of markets. Commercial cedarwood oils are vacuum rectified from the steam distilled crude oil, to give oils of a very pale-yellow colour. During rectifying crude oil, the fractions are water – top fraction (alpha pinene etc.) – cedrene – liquid cedrol – residue. Then cedrene and liquid cedrol are blended into commercial cedarwood oil based on customers' specifications. Liquid cedrol turns into solid cedrol at below 60°C and can be made into commercial cedrol by being centrifuged and dried and its melting point is about 80°C. Cedrene is also being used separately to make MCK (methyl cedryl ketone and cedrol into methyl cedryl ether, while there is a mixture of cedrene and cedrol in cedryl acetate.

Further processing of the crude oil takes place through rectification which produces fractions with different olfactory properties and isolates with individual constituents for derivative manufacture. This is undertaken either by producers in China or the USA, where there is large scale production and sizeable domestic consumption, or by end-users in importing countries in Europe and Japan.

QUALITY AND COMPOSITION

Both the overall olfactory properties and the chemical composition of cedarwood oils are important quality characteristics. The olfactory properties will be assessed by some purchasers since they are vital for its use in fragrances, while its chemical composition is vital for use as a raw material in derivative manufacture.

Texas cedarwood oil shares many of the same constituents as Virginia cedarwood oil detailed below: cedrol, alpha cedrene, beta cedrene, thujopsene, cuparene, various chamigrenes, widdrol, and pinenes, but Texas oil usually tends to show higher levels of cedrol, with the highest content being in the crude oil from the continuous distillation process at 40% or more. Despite having similar components to Virginia, the Texas

cedarwood tends to smell more woody and less oily, with much of the differentiation in smell occurring in the minor compounds of the oil. Because of the presence of these minor compounds and separate odour profiles, Texas cedarwood oil tends to have uses in the fragrance market that are distinct from Virginia oil. Additionally, there is a growing use for Texas cedarwood oil in natural insect repellents and pesticides, and the pesticidal properties of the oil are also considered to come from the combination of minor compounds in the natural oil, and not from one individual constituent.

The crude Texas cedarwood oil is a dark orange to brown, turbid, semi-viscous liquid from which crystals can separate on standing, particularly during winter. It has a pleasant odour, sweet woody but a little smoky and only used for further processing. The almost colourless non-smoky rectified fractions are used to make consistent "standardised oils" to meet customer specifications, dependant on applications. These are mostly in fragrance materials for use in soaps, candles, room sprays and floor polishes.

The main constituents in **Virginia cedarwood oil** include cedrol, alpha cedrene, beta cedrene, thujopsene, and minor amounts of widdrol, chamigrenes, and other pinenes. The relative amounts of these compounds can vary with distillation cook time, temperatures, and raw material conditions. It is common to do some further processing of the crude oil, with limited need for fractionation and blending, to standardise colour and specifications. Generally, a redistillation will remove around 2%-3% of wood rosins, which can account for colour variations between batches.

The rectified Virginia cedarwood oil is an almost colourless oil, sweetly balsamic, non-smoky smelling and is considered by many perfumers as the finest of the cedarwood oils. This is reflected in its main application in fragrances intended for use in furniture polish (rather than floor polish), cosmetics, shampoos, aftershaves, incense, and aromatherapy. It has a premium price in the marketplace, and as a result is used as produced rather than made into derivatives.

International (ISO) standards exist for Texas and Virginia cedarwood oils. For Texas oil an alcohol content

(expressed as cedrol) in the range 35-48% is specified, with a minimum cedrol content of 20%. For Virginia oil, a maximum cedrol content of 14% is stipulated. Various physico-chemical data are also defined. Both these standards need revision. This is particularly the case with the Texas specification which no longer reflects the typical oil produced by the three existing factories.

Chinese cedarwood oil has a lower cedrol content than the American oils and is used as a fragrance oil as well as a source of isolates and chemical derivatives, which include cedrol, cedralone, MCK, cedryl acetate, and cedryl methyl ether. The oil's woody odour has a sharp, fresh, camphoraceous - sometimes smoky - character, and is not as sweet as oil from other origins. Appropriately, the fragrance uses of this oil are mostly in functional and industrial products except in China where it is preferred for most cedarwood oil product applications.

Cedarwood Atlas oil is a viscous pale-yellow oil with a sweet, woody odour with floral characteristics, and as such is different from the other main origins but resembling the Himalayan oil in having a high level of himachalanes rather than cedrenes.

Himalayan cedarwood oil's main constituents are:

- p-methyl acetophenyl acetate
- 4-methyl Δ3-tetrahydroacetophenone
- α-himachalene
- Iso-himachalene
- β-himachalene
- Cis- and trans-atlantone
- Himachalol
- Allo-himachalol
- Longborneol and deodarone



SAWDUST

Estimates of cedarwood production in 1985 by Brian Lawrence:

Texas	<i>Juniperus ashei</i> Buchh.	1,400 MT
Virginia	<i>Juniperus virginiana</i> L.	240 MT
China	<i>Cupressus Funebri</i> EndL	450 MT
India	<i>Cedrus deodara</i>	20 MT
Morocco	<i>Cedrus atlantica</i>	7 MT
Kenya	<i>Juniperus procera</i> Endl.	no production

Current estimates of annual cedarwood oil production are:

China	1,800 – 2,000 MT
Texas	700 – 800 MT
Virginia	250 – 300 MT
India	600 – 700 MT
Morocco	100 MT

PRODUCTION AND MARKETS

Production

Production data on cedarwood oil are limited and annual variations in output do not help. Export data are also an inadequate guide because it is often aggregated with other oils and because of high domestic consumption levels in some producing countries. It is not possible, therefore, to be precise about the scale of global production or trade. Brian Lawrence in 1985 reviewed world production of cedarwood oil and his estimates of annual production data are shown in the above table.

Markets

Major markets for cedarwood oils are the USA, China, Western Europe, India, and Japan. The USA utilises much of its domestically produced Texas and Virginia cedarwood oils as well as importing sizeable quantities of Chinese oil.

Chinese oil is more powerful than US cedarwood oils. The USA and Europe import large quantities of the Chinese

oil - as it is lower priced than Texas and Virginia cedarwood oils and has been widely used as an adulterant of these oils.

CHINA²

Chinese cedarwood oil is obtained from the large evergreen tree or shrub *Chamaecyparis funebris* (Endl.) Franco [EFO] synonym *Cupressus funebris* Endl. [ISO 4720] – known as the Chinese weeping cypress. It has a wide distribution in Guizhou, Gansu, Sichuan, Kweichow, Zhejiang, Jiangxi, Fujian, Shangdong, and Shanxi provinces. One Chinese source indicates that *Juniperus chinensis*, *J. formosana* and *J. vulgaris* are also sources of Chinese cedarwood oil but cypress dominates. Timber from the tall, hard trunk of the cypress tree has a variety of uses such as furniture, construction, shipbuilding, and bridge building. Sawdust from cypress wood processing factories is distilled into cedarwood oil but the dominant source is abandoned tree roots. Each year large quantities of trees are felled and the roots left in the ground.



DISTILLATION EQUIPMENT for crude oil from sawdust



RECEIVERS AFTER DISTILLATION



SEPARATING CEDRENE AND CEDROL FROM THE CRUDE OIL

After a number of years, the roots are extracted from the ground, cut into pieces, and ground into sawdust, which is then steam-distilled or dry-distilled into cedarwood oil. This contrasts with Texas and Virginia cedarwood oils from the USA where no oils are obtained from root extraction.

The abandoned tree stumps and roots are collected by farmers and each year there are an estimated 1.3 million abandoned cedar and firwood stumps. There is no particular harvesting season, farmers go and extract the abandoned tree stumps and roots when they are free except during the rainy season. There is a preference for wild tree stumps and roots because the oil yield is higher than replanted trees, even if the latter are many decades old.

The older the tree stumps the higher the oil yield. The wild abandoned tree stumps are now usually deep in the mountains and to dig and transport them is not only hard physical work but also increasingly expensive as living costs increase in China. The willingness to undertake this work is mainly dependent on the price of cedarwood oil and its derivatives, and low prices prior to the COVID pandemic led to farmers and processors becoming less interested in this business and switching to other economic activities.

The stumps are either sold to oil processors or are stored outside farmers' houses waiting for a better price. Oil manufacturers chop the stumps and roots into pieces using machines and then steam or dry distill

the pieces to obtain crude oil. If the oil is made by dry distillation it has a burnt odour, which was a typical odour of Chinese cedarwood oil. The dry-distillation process has been gradually disappearing because of the oil's burnt odour and it was not good for the environment leading to government prohibition. During the last five years or so, no dry distillation has taken place in China. Steam-distillation makes a good odour and customers can use this oil directly in fragrances. As discussed earlier, the crude oil can then be further processed using distillation, rectification, and chemical synthesis technologies into a range of aroma chemical derivatives. After distillation and processing, further products can be produced from the remaining waste products.

It was in the 1950s and 1960s that production of cedarwood oil began in Hangzhou, Zhejiang province, predominantly for export. In the 1970s production expanded to Guizhou province and then in the 1980s to Sichuan province, where substantial quantities of abandoned tree roots were available. Sichuan, with almost two million hectares of cypress forest areas, including large quantities of tree roots, now dominates cedarwood oil production for both domestic and export consumption. In the 1990s Sichuan cedarwood oil processing reached a peak, with annual production exceeding 2,000 MT of crude oil. Increasingly cypress roots from cultivated trees are now being processed which usually have a lower yield of approximately 3%. The oil is used both directly as a fragrance ingredient and as a raw material for aroma chemicals, production of which began in the 1980s. Since then, China has been increasingly exporting the value-added aroma chemical products rather than the oil. As Chen (2022) points out, firwood oil, which is processed in the same way as cedarwood oil, has become a more important raw material for aroma chemicals than cedarwood oil, with an estimated usage ratio of 1:4. Over the past two decades the price of cedarwood oil has increased substantially leading to increased production of lower cost firwood oil, which contains similar components.

Annual cedarwood oil output in China was given as 1,000 – 1,500 MT in the mid 1990s (Zhaobang 1995). In 2006, the output of cedarwood oil was about 1,800 MT and firwood oil was 3,000 MT. Their exported quantity totalled around 1,600 MT. Recently, annual production of crude cedarwood oil was estimated at 1,800 – 2,000 MT compared with 6,000 – 7,500 MT of crude firwood oil.

Initially the processing technology was relatively simple resulting in low yields. Continuing improvement in technology has been made, with wooden barrels and bamboo pipes being replaced by steel equipment leading to improved quality and yields. This in turn has facilitated a growth in demand.

Socio-Economic and Environmental Benefits

The use of abandoned cedar tree stumps and roots increases the value and utilisation of forestry waste, thus supporting local farmers' incomes as well as assisting in meeting the requirements of social development

in China. An estimated 4,000 to 5,000 farmers and oil processing workers are directly involved in the oil production and processing business in Sichuan, Fujian, Jiangxi, Hunan, and Anhui. Additional employment is created in a range of supporting ancillary industries.

Alongside the economic and social benefits arising from cedarwood and firwood oil production, they also have substantial environmental benefits. Increasingly initiatives are being undertaken in the sector facilitating greater sustainability and assisting in combating climate change. Two of the main environmental issues associated with cedarwood oil are soil erosion if no trees are planted following the removal of tree stumps and roots as well as the environmental pollution created if the cedarwood and firwood oils are obtained by dry distillation. To overcome these problems the government developed a standard management system including the prohibition of dry distillation. Processing operations must strictly implement the management system to avoid any pollution. The government also requires farmers to replant a tree after digging out the stump and roots to ensure sustainability and protect the forests from deforestation and soil erosion. This meets the Government's requirements on environmental protection and maintaining a green landscape. The whole process of producing and processing cedarwood oil is encouraged by local government and is seen as an environmentally friendly circular process with minimal pollution. The process starts with the removal of aged tree roots left in the ground, which are then crushed into sawdust. The sawdust is heated with steam in a still and the oil and water filtered out, cooled, and separated. The water is recycled into another round of production, while the remaining sawdust and waste materials can be further processed into granular fuel, mechanism carbon, activated carbon as well as other products including pencil materials and bonding laminate. As such the resources of cypress and fir trees in China are sustainable because replanting must take place.

USA³ TEXAS CEDARWOOD OIL

Raw Material Source

The small tree *Juniperus ashei* J. Buchholz [ISO 4720] syn, *Juniperus mexicana* Schiede, is an abundant scrubby looking cypress type of tree, growing in the southwestern parts

of Texas up to six metres tall. Even though two species exist, they are virtually indistinguishable in the field, and for the sake of consistency, most of the references to origin in the essential oil industry refer to *Juniperus mexicana*. The tree is commonly known as Texas cedar or mountain cedar and the Edwards Plateau in Texas is home to this species. It covers approximately 80% of the terrain and regenerates by aerial seeding. The tree is unpopular with Texas ranchers since it impedes the growth of other plants, leaving the surrounding soil barren. Its high water use limits water supplies from the underground aquifer to nearby farms and urban settlements. Moreover, it is unable to decay due to its high oil content of between 2% – 3%. The locals consider it an invasive species even if it is not officially designated as such. To address the problem, responsible land stewards have regularly cleared the cedar to allow for better agricultural use, and during the clearing process, any part of the cedar tree that is not usable as fence posts, was burned. However, this wild, prolifically growing "waste" can be recycled by distilleries to make steam-distilled cedarwood oil, thus making this by-product an excellent sustainable source of raw material for the essential oil industry.

Cedarwood's ability to naturally resist insects and decomposition, has made it a staple of the fencing industry for centuries. However, much of the cedarwood grown in Texas is unusable in fencing because it is not of the necessary length and diameter. The leftover can be either burnt or delivered to a cedar mill for cash. Alongside the dual use of cedarwood, the rancher often has the added benefit of not having to pay to clear and clean up the land.

Because of the availability of cheap wood, this oil is produced in relatively large quantities compared with other cedarwood oils, with annual production of 700 – 800 MT, and is one of the most widely used oils in the fragrance industry. A favourite among perfumers, it is said that some small amounts of cedarwood or its derivatives (particularly cedryl acetate and MCK) are used in 80% of all household products, fragrances, and cosmetics.

Harvesting and Transport

Land clearing of Texas cedarwood is invariably performed by hand, using chain saws and small trucks to cover



TEXAS CEDARWOOD FELLING



CEDARWOOD VIRGINIANA cross section



TEXAS CEDARWOOD TRUNK



CEDARWOOD waiting to be processed

the dangerous terrain on which the trees grow. In some cases, tractors and larger semi-trucks are needed for the longer distance hauls inside a ranch, or to the distillation plant, but this represents a smaller proportion of supply. On average, wood that is delivered to the processing plants is harvested within a 60 – 80-mile radius. Because the Texas cedar tree tends to be more shrub-like and typically lacks a primary central trunk, mechanised harvesting equipment is not ideal for processing and loading the trees. Similar to the Virginia cedar, there is a well-developed market for fence posts that are produced from the limited number of straight limbs that can be harvested from the branches, and the value of these posts is high compared with the remainder of the wood and branches the tree contains, and once the fence posts are removed, ranchers have typically burnt the remainder of the tree. With the presence of a distillery, some value can be added to the rest

of the tree that can justify classifying and loading the additional wood and hauling it to the factory. Because the remaining pieces of the tree are more like large branches than logs, they are not ideal for hauling on a large semi-truck, and most loads are loaded on mid-size trucks carrying 12 tonnes or less and are hauled over shorter distances. This also means that there is a wider network of small hauliers that can supply locally with less investment in equipment and fuel.

Preparation and Distillation
Once the wood is at the facility, it is ground in two successive processes until it is suitable for distillation. The exact grind size has to do with the plant design, and the best raw material is wood that is large, old, and as dry as possible. Drier wood tends to grind and flow more easily through the equipment, and older wood tends to offer more yields.

Three distillation methods are used to produce Texas cedarwood oil:

- Continuous distillation that produces yields up to 3%.
- Traditional batch distillation with pressure up to 50 psi which gives average yields of around 1.5% – 2%.
- Batch distillation with atmospheric pressure that also gives yields of 1.5% – 2%.

The composition and yield of the oil produced can vary according to the tree's age, its moisture content, and where it is harvested. The composition of the oil from these different processes can vary in composition depending on the pressure and residence time of the wood during extraction. The colour of the oil produced ranges from pale yellow to red, with the redness increasing with longer cook times and temperatures. Because of the red colour, Texas

cedarwood oil is often redistilled before being compounded into fine or household fragrance, and this further processing is done both at the source in Texas, as well as downstream in the supply chain where many specialty fractions and derivatives are produced for the broader market.

Texarome is one of the three Texas cedarwood oil production sites and its operations include a diverse and versatile range of processing equipment able to provide a variety of specialist cedarwood oil products on a large scale, alongside offering toll processing operations. The processes include continuous distillation, conventional batch distillation, fractional vacuum distillation, catalytic reactions, and molecular distillation. In 2016 Texarome's proprietary continuous distillation technology was able to process 24 MT of cedarwood oil per day. In addition, the two batch distillation plants permitted greater production versatility with 10 – 20 MT per day capacity for Texas and Virginia cedarwood. In addition, there are two vacuum fractionation units used for processing up to 5 MT per day of high quality rectified cedarwood oil (Greenhalgh 2017).

VIRGINIAN CEDARWOOD OIL

Raw Material Source
Virginia cedarwood oil is obtained from a small slow-growing tree *Juniperus virginiana* L. which can grow up to 18 metres tall. It grows all over the Eastern USA in areas including the east coast, through to the south, and into Texas, Oklahoma, and Arkansas. It is commonly referred to as red cedar, eastern red cedar, or aromatic red cedar. It is now principally found in the Carolinas, Alabama, and Virginia and is mainly used for timber in furniture manufacture but the branches, off-cuts, sawdust, and stumps are used for steam distillation of the oil. Most of the production comes from North Carolina. The volumes produced are now smaller and declining, compared

to the more cost competitive Texas oil. There is a well-established industry around using the aromatic red cedar in the furniture and housing industry to make closet linings, chests, and even structural lumber, and the wood can be recognised by its signature cedar smell that is alleged to keep away moths and other bugs. It has been commonly used in the production of #2 pencils, which is where the concept of the "pencil note" comes from in odour evaluations.

In making these various products there is inevitably some waste by-product coming from these industries. In addition, the way in which the cedar tree propagates naturally, makes it a wild crop that grows back aggressively on land that has been cleared for other purposes, frustrating those landowners trying to maintain clean pastures and reduce underbrush. So, in the process of land clearing or harvesting there is always some wood that is of value in the lumber and furniture market as well as other cedarwood that is considered waste and is often burned during the land clearing operations. It is this unwanted wood that provides a good feedstock for essential oil production, since the distillation process requires that the wood be ground up anyway, and the quality and geometry of the log is less of a consideration. For the purposes of distillation, the tree only needs to be large enough to contain a significant amount of red heartwood which is where the oil is produced and stored within the tree.

Distillation
The heartwood and tree stumps contain most of the oil but the latter are not widely processed. Oil yields and quality can vary widely between 1% – 3% depending on such factors as the type and age of the tree, the form in which the wood is distilled (e.g., sawdust or chips, heartwood or sapwood). Older and slower growing

trees with a strong central axis provide higher yields.

The harvesting and primary processing of cedarwood oils, in part depends on how the cedarwood is used. When the trees are primarily utilised to produce timber, then the waste wood materials, shavings and sawdust from the sawmills are taken to the distillery for steam distillation and essential oil extracted as a secondary product. Nevertheless, these raw materials need to be handled relatively carefully to try to maximise yields and oil quality.

Technologies are in place for either continuous or batch distillation but the more common method currently used for Virginia cedarwood oil is the low-pressure batch process. Using this method, the wood is loaded into stills of various sizes using various methods of material handling. In this process the stills are filled with ground material and cooked for a period ranging between 8 – 48 hours, depending on steam pressure and raw material conditions. In a typical extraction, a yield of between 1.3% – 1.7% can be anticipated on a wet basis with the wood moisture content ranging between 20% – 35%. The crude oil produced usually comes out as a pale yellow liquid with a soft and almost oily note, and the Virginia oil is more often used directly in fine fragrance without much additional processing. After distillation, the spent wood is removed from the system and subsequently burned in a biomass boiler to provide a good source of renewable energy for the steam production.

Production and Markets
The markets for both Texas and Virginia cedarwood oils are mature and stable over long periods of time, but there are definitely trends that are contributing to change. For Virginia the estimated production capacity that is in place among the



CEDARWOOD VIRGINIANA STORAGE PILE, TEXAS



TEXAS CEDARWOOD VENDOR



TEXAS CEDARWOOD RAW MATERIAL STORAGE



CONTINUOUS DISTILLATION UNIT INTERIOR, Texas



VACUUM FRACTIONATION PLANT Texas



450 HP WOOD GRINDING SYSTEM Texas



CEDARWOOD MILLING



TEXAROME WASTE WOOD BURNING FURNACE for steam production



TEXAROME PLANT



CEDARWOOD DISTILLATION at Texarome



BATCH DISTILLATION PLANT WITH PRESSURE TANKS Texas

primary producers continues to grow and currently stands around 30 MT per month (360 per year) and is expected to level off at around 40 – 45 MT per month (480 – 540 per year) in the next few years. Even though the capacity is in place for this level of production, irregularities in the wood supply and competition from the Texas cedarwood oil within some facilities can change the actual output from month to month. In addition, changes in fuel pricing, labour trends, equipment costs, and other competing industries such as home construction and petroleum exploration, that are present in the wood harvesting areas, can offer outside uncertainties to costs and supplies of raw material.

Texas cedarwood oil has a larger installed capacity of around 70 MT

per month (840 MT per year), which is expected to grow to around 85 MT (1,020 MT) in the next five years. Actual production is also less than installed capacity because of the availability of raw material, which is influenced by high labour requirements, fuel prices, and local trends such as prolonged rain spells, and the hunting season. Labour shortages around the distillation facilities are also becoming a problem since the main operators are in very small towns with limited skilled resources and drastically increasing costs. Despite some of the ongoing challenges with raw material procurement, the production of Texas and Virginia oils continues throughout the year. Of the oil produced, it is used primarily in four major industries: fine fragrance, household fragrance, natural pesticides, and aromatherapy.

SOCIO-ECONOMIC IMPACT

To begin the discussion on social impact it is important to try and quantify the number of people that are involved in an endeavour. In this case we are analysing the supply chain of two major essential oils in the trade, that have evolved deep roots in their local regions over the past 40 – 50 years. This type of longevity in an economy in itself represents a general acceptance of the business and, hopefully, this acceptance is positive and sustainable in the long term for all the hard-working people involved. In the case of cedarwood, some assumptions can be made: a person harvesting Texas cedarwood, which is often done by hand, can reasonably harvest, load, and deliver about 3 MT per day, whether working alone, or in a

larger crew. With Virginia, a person can probably deliver closer to 6 MT per day. So, working weekdays within a month, one can expect the help of at least 22 people in the Virginia supply and 83 people in the Texas cedarwood supply of materials. In the town where Texarome operates, the population is 425 people, so if each one of the people delivering wood each day, is supporting a family, one can imagine the local impact, in an area where not many other jobs are available. To add to the supplier network, each facility employs up to 30 more people, so between the suppliers and distillers at the source, more than 250 people would be directly involved in the crude production, and there are many more ancillary industries and services involved that benefit as well. In addition, many of the Texas workforce are originally from Mexico and Central or South America. These are areas where employment can be scarce and cedarwood oil production is helping lift people that are either at or close to the poverty line.

ENVIRONMENTAL AND SUSTAINABILITY ISSUES

Alongside the direct economic and social benefits generated by the sector there are also important environmental and sustainability contributions. Clearing cedar is an environmentally friendly activity that is promoted and even subsidised by local governments. It is well known that the overgrowth of cedar can kill native grasses, stifle wildlife, prevent water from reaching the aquifer, and prevent proper land management as prescribed by local agricultural authorities. So, the ongoing transformation of an invasive plant into a valuable worldwide commodity is an activity and service that strongly serves the local communities.

In the USA the rate at which cedar is being consumed by the local cedar mills is overwhelmingly sustainable. Based on the total production of cedarwood oils with an average yield of around 1.7% by mass, the total quantity of wood required to maintain these levels would be around 8,600 MT per month, or 100,000 MT per year. To know if this is sustainable over long periods of time, one must assume the total coverage of both Texas and Virginia cedarwood as well as the rate that the trees grow back based on a buying radius from the facilities of around 100 miles. Within that area, Texas cedarwood can have up to 10 MT per acre and Virginia can have

up to 5 MT per acre coverage, which would represent 50,000,000 MT in the Texas cedar harvesting region, and 25,000,000 MT of inventory in the two major harvesting areas of the USA. A tree needs to have a maturity of about 15 years for it to be harvested for oil. This represents 100,000 MT per year used in production over 15 years, or 1,500,000 MT. When you compare 1,500,000 MT used and regrown over 15 years, to an estimated 100,000,000 MT that is readily accessible, it illustrates that not only is the raw material sustainable, but there is plenty of room to expand. After oil has been extracted from the wood, the waste product is re-cycled into biomass boilers to generate steam to be used in the distillation process. In addition, some of the waste is used as an additive in the local petroleum industry drilling process.

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FOOTNOTES

- ¹ IFEAT would like to acknowledge the contributions of Cathy Chen, Rick Boucard, Surender Mohan and Amine Bennani, who provided much of the information on China, USA, Indian and Moroccan cedarwood oils respectively.
- ² Much of the information on Chinese cedarwood and firwood oils is from Cathy Chen of Hangzhou Grascent Co.Ltd., China's largest cedarwood derivatives producer, see Chen (2022) and personal communication with Winnie Yeung.
- ³ Much of the information on US cedarwood oils is from Rick Boucard of Texarome Inc. the USA's largest cedarwood oil producer.