New Trends and Issues Proceedings on Advances in Pure and Applied Sciences

Volume 15, Issue 1, (2022) 41-52

www.propaas.eu

Selected paper of 10th Global Congress on Renewable Energy and Environment (ESWAE- 2021) 13-15 October 2021, Lara-Antalya, Turkey

ONLINE and FACE-TO-FACE INTERNATIONAL CONFERENCE

# Exploring the most appropriate materials and methods for expanding the use of wood poles in electricity distribution networks

**Fatma Avli Firiş** [a1], Akedas Electricity Distribution Corporation, Turkey

**Suggested Citation:**

Firiş, F. A. (2022). Exploring the most appropriate materials and methods for expanding the use of wood poles in electricity distribution networks. *New Trends and Issues Proceedings on Advances in Pure and Applied Sciences*. *15*(1), 41-52. https://doi.org/10.18844/gjpaas.v15i1.7721

Received from February 22, 2022; revised from March 11, 2022; accepted from April 10, 2022.

Selection and peer review under the responsibility of Prof. Dr. Haluk Soran, Near East University, Cyprus.



**Abstract**

Considering the increasing demand for electricity in Turkey, electricity distribution companies in Turkey have been using concrete and iron poles in recent years due to operational problems, and this situation also increases the investment costs. In this study, the cycle of wooden poles from the manufacturing stage to their destruction has been examined, and suggestions for tree pole processes have been given, to develop and spread the applications of wooden poles in Turkey. Within the scope of the study, worldwide applications were examined by conducting a literature search, and then the best tree pole applications for Turkey were determined by determining the differences between them and the applications in Turkey. With the suggestions to be made, it is foreseen that the use of tree poles will become widespread in the new overhead line networks by increasing the service period of the tree poles and reviewing the processes.

**Keywords:** Electricity, investment, network, pole, wood;

* ADDRESS FOR CORRESPONDENCE: Fatma Avli Firiş, Akedas Electricity Distribution Corporation, Turkey. *E-mail address*: email: fatma.avlifiris@akedasdagitim.com.tr

## 1. Introduction

There are various applications for wooden poles, which have been used in both telecom and energy fields for a long time in the world [1]. Relevant methods have changed shape over the years due to the change in technology and needs, and it has been tried to provide suitable conditions for today's conditions. It is expected that the wood pole applications made with the development of technology will change and develop over the years.

Since wooden pole applications are cheaper than concrete and iron poles and they are easier in field applications, the development of the relevant method will be beneficial for both the distribution system operation and the economy. Since the widespread use of wooden poles will affect the developments in the market positively, it will pave the way for new applications to be made in this field [2].

### *1.1. Purpose of the study*

This study focuses on wood pole applications around the world. For the wooden pole, it is related to the compatibility with the environmental conditions and how effective it is in the geography, rather than how effective the application is. For example, the good results of the impregnation material and application method applied in arid climates do not guarantee that the same methods will work in the same way in other humid climates. For this reason, it would be appropriate to examine worldwide applications as a whole and to synthesise them by evaluating them in terms of geography, economy and expectations for the application that is open to development.

## 2. Materials and Methods

When we look at the world in terms of impregnation material selection and application methods, it is seen that different countries have different approaches. When the related methods are evaluated as a whole, it has been determined that the impregnation material has negative effects on the environment and human health, as well as on the benefits it provides. For this reason, it is necessary to decide which ones are appropriate as a whole by determining the relevant methods in line with each region's policy and strategy.

### *2.1. Forest assets for worldwide tree pole applications*

According to the World Bank data, the forest land percentages of some countries are presented in Table 1.

Table 1. Forest land percentages

| Name of country | Forest land percentage |
|---|---|
| Finland | 73 |
| Brazil | 59 |
| Latvia | 54 |

| | |
|---|---|
| Estonia | 53 |
| Angola | 46 |
| Canada | 38 |
| USA | 34 |
| Germany | 33 |
| France | 31 |
| Turkey | 15 |
| South Africa | 8 |

Projects for the creation of forested lands for industrial use are carried out throughout the world. In this context, the ownership of forested lands can be state or private sector. Forestry land ownership status worldwide is presented in Table 2.

Table 2. Ownership of forested lands

| Name of country | Ownership status of forests (%) |
|---|---|
| Turkey | 99 states |
| USA | 71.7 private sector |
| EFTA | 70.5 private sector |
| EU | 61.1 private sector |
| Japan | 56.5 private sector |
| Canada | 94 states |
| New Zealand | 79 states |
| Ireland | 77.3 state |
| Greece | 73.5 state |

## 3. Results

### *3.1. Techniques for the preparation and assembly of wooden poles*

#### *3.1.1. Preparation of wooden poles*

The main purpose of the preparation and impregnation of wood poles is to prevent fungi and insects from entering the interior parts through the cracks in the poles and reaching the unpenetrated parts of the impregnation material, thus increasing the service life of the wood poles. The penetration depth of an impregnating agent depends on the impregnation method applied, the impregnation treatment, the wood species and the ratio of sapwood to heartwood. The preparation of tree poles greatly affects the period of use. In the report they presented after the Western Wood Preservers Institute in the USA inspected and evaluated the tree poles at the place of use, they reported that the service life of the tree poles could be increased further. More precisely, they suggested the possibility that the expected lifetime of impregnated wood poles could be increased, generally from 35/45 to 50/75 years [3]. It is thought that this claim may be due to the escalation of competition in this market due to the emergence of non-wood poles (concrete, metal etc.) that have been put on the market against wood poles in recent years.

The preparation of tree poles includes several different steps such as peeling, drying, conditioning, incising, cutting and drilling [4].

**Bark peeling.** To allow the impregnation materials to penetrate the wood material, the cambium layer should be peeled off along with the bark and inner bark. At the same time, peeling off the bark is also necessary for drying, which is important for impregnation. With the peeling of the bark, the wood material dries quickly without being damaged by fungi and insects. Various methods are applied for peeling. Peeling wood by hand or with debarking tools is best done in spring and early summer because at this time the cambium layer is in a soft state. In debarking, the wood must be completely whitened. The removal of the outer bark, inner bark, cambium and outer wood layer of the last year is called bleaching. In some cases, the bark should be left in strips or pieces on the wood [4].

**Steaming.** Drying by steaming varies depending on the cross-section size of the wood material and steam at a temperature of 105°C–118°C is used for 1–20 hours. It can extract 64–80 kg of water from 1 $m^3$ of wood material during a 550 mm vacuum between 1 and 3 hours after steaming. Steam drying is mostly used in pine and European spruce.

**Drying**. In fresh wood material, the uptake of free water impregnation substances in the cell spaces is prevented. In this regard, in most impregnation methods, it is necessary to dry the wood material and remove the excess water before the impregnation process. Also, uncured material is more prone to cracking after impregnation. Through these cracks, fungi can easily penetrate the inner parts of the impregnation materials of the material that have not penetrated. For these reasons, wood material should be dried at least below LDN before impregnation [4].

### *3.2. Pressure application methods in the impregnation of wooden poles*

Pressure application methods are the most important and successful industrial methods in the impregnation of wood material. In the facilities that apply these methods, the wood material is placed in a steel boiler and the impregnation material is conveyed into the wood cells within 1–6 hours with a hydraulic pressure of approximately 10 $kp/cm^2$ [4].

Among the methods of applying pressure, two general methods are most used. These are the full cell and empty cell methods. In addition, there are oscillation and variable pressure methods, which are not as widely used as full and empty cell methods, and very high-pressure methods used in Australia [4].

### 3.3. Installation of wooden poles

Installation of distribution poles is based on planning, use of different equipment and field knowledge. The installation processes of the poles may vary based on distribution companies. It has been observed that different techniques are used because distribution companies serve different geographies and consumer groups. It is acceptable for distribution regions to follow different paths as long as certain standards are adhered to. Optimising the process by evaluating the pole type, soil type and other parameters plays an important role in reducing the CAPEX and OPEX budgets.

Figure 1. APE tree pole mounting method

Figure 1 above depicts the APE tree pole mounting method. The BMK Polcrete product, on the other hand, enables the assembly of the wooden pole with the foam material it has developed. The method has been tried and used by the Kansas energy and lighting company. In the application phase of the method in question, excavation operations are carried out as previously stated, the difference in this method is the use of foam instead of filling material. To prepare the foam filling, two different chemicals are mixed directly after sitting in the hole. Before applying the foam, the pole must also be grounded. Since chemicals must be stored at a certain temperature, it is important to use air conditioners or transport chemicals with a cooling system in the hot summer months. After the chemicals are mixed, they are applied by pouring them into the pit from the sides of the pole placed in the pit. The pouring stage of the foam and its image after drying is shown in Figure 2.

Figure 2. Foam application

After the application, the foam expands and freezes in a very short time. Afterwards, the excess foam overflowing around the pole can be shaved off and the hole can be covered with soil. Since the foam dries very quickly, it is possible to climb on the pole and connect the lines 15 minutes after the application. This application prevents or slows down the decay of the tree by protecting the base of the tree from moisture. Since the foam application dries quickly and can be applied quickly, the installation of the line can be accomplished in a short time, which reduces the time required to quickly repair the collapsed pole and re-energise the line.

### *3.4. Techniques for the disposal of wooden poles*

Various methods have been used until today to dispose of or recycle the impregnated materials that have reached the end of their useful life. These methods are classified below.

#### *3.4.1. Disposal or reduction of inert chrome, copper and arsenic (CCA) impregnated wood materials*

Applying sufficient and appropriate impregnation to the wood material during use increases the service life of the material, reduces the amount of impregnation material to be applied in places where the risk of decay is low or using less harmful preservatives, performs on-site maintenance and protects against outdoor effects, mechanical, chemical and biological deterioration. Taking design measures becomes important in using this method.

#### *3.4.2. Disposal of wood waste by burying*

The destruction of wood waste by burying it in the ground causes the impregnation material to be washed from the inactive wood and the toxic compounds to pass into the groundwater and soil. Some amount of chromium, copper and arsenic can be washed from wood impregnated with CCA. Storing inert wood is a costly option. However, inert materials are large and require sufficient capacity for burial. Measures are taken to prevent this problem. Some institutions have used wood recycling programmes to convert this material through waste collection [5,6]. In Europe, this method is not preferred because there is no benefit from the buried product, and organic wastes have not been stored since 2005 [7].

### *3.4.3. Reassessment*

The large size of the inert wood brings with it transportation and storage problems. For this reason, the impregnated wood is shredded and turned into sawdust or chips. Although re-evaluated impregnated wood products are preferred by the industry, their use in space has been restricted. The utilisation of wire poles as roofing material or building material, the use of railway sleepers as landscaping applications or fence posts on secondary railway lines and the use of impregnated end wastes as support material for construction purposes are among the waste evaluation options [6].

### *3.4.4. Recycling of inert impregnated wood*

The recycling (recycle) of the inactive wood material constitutes an important layer of the forest products industry. It is possible to turn impregnated wood waste into composite material by chipping [8]. However, problems similar to those that may occur during the re-cutting of wood (chemicals, rot and metal contamination) are also problematic in this method [9] .

### *3.4.5. Re-mowing*

Although it is an easy process to evaluate the idle wire posts or timber by sawing, their impregnation makes it difficult to find a market. The transportation, re-mowing and removal of large-sized impregnated materials that have completed their service life to the cutting site pose a problem. If there are metal connectors (accents) in the material, they can cause problems during mowing; it is considered more appropriate to remove them beforehand. Also, it does not make sense to re-cut and resize wood impregnated with CCA, which has dimensional properties. Removing the degraded pieces from the wood by planting the wood exposed to the open air reduces the cross-section of the wood material and creates wood waste. Although re-cutting of by-products does not appear to be a problem where these studies exist, it imposes additional costs [6].

### *3.4.6. Remediation of inert CCA impregnated wood material*

Remediation is the process applied to clean and remove the chromium, copper and arsenic contained in the wood material removed from the service and to reduce the damage it causes to the environment. These processes are carried out in different ways.

### *3.4.7. Bioremediation*

The harmful components in the inert wood material are removed by degrading or dissolving by micro-organisms [10], [11]. The positive side of this method is that the fibres of the wood material are not damaged; on the other hand, this technically feasible method is not efficient. In order for the procedure to give the best results, double remediation is applied. However, the cost of the nutrient culture medium is shown as a negative feature of the method [7].

### *3.4.8. Chemical remediation*

Chemical remediation with the help of chemical acids and oxide substances increases the solubility of metals and ensures that toxic metals are removed from the impregnated wood material. In order to remove CCA from wood, gradual remediation is required. With this method, metals are removed from the wood and re-oxidised. In this way, a pure CCA solution can be obtained [7]. Before chemical extraction, the impregnated wood material is shredded into sawdust and extracted with chemicals at different temperatures. Various chemicals such as oxalic, citric, formic, nitric, sulphuric and acetic acid are used as solvents for this process [12].

### *3.4.9. Removal by combination of microorganisms and chemical solvents*

In some studies, the removal of the impregnation material by chemical extraction from the impregnated wood taken from the service has been carried out by using it together with bacterial, fungal fermentation and steam bath. As a result of the studies, it has been shown that generally better results are obtained from small-sized pieces of wood. In extraction, wood chips are generally treated with oxalic acid and *Bacillus licheniformis* CC01 bacteria [12].

In the studies, it was concluded that the steam bath applied as a pre-treatment before extracting the wood was not effective in removing the chemical components. Steaming can remove some of the CCA from the extracted wood, making it an uneconomical method to apply. Shiau *et al*. [13] investigated the effect of chemical extraction and steam bath on CCA-impregnated wood on the leaching of copper, chromium and arsenic in wood. In this study, acetic, citric and sulphuric acid were used. Among the chemicals used in this study, it was reported that citric acid gave the best results in removing copper, chromium and arsenic from wood samples impregnated with CCA. It was determined that the steam bath was not effective in removing the chemical components.

### *3.4.10. Removal by the electrodialytic method*

After the impregnated wood material taken from the service is shredded, the CCA components are removed from the wood by the electrodialytic method. As a result of this process, if all of the arsenic, chromium, and copper can be reduced to some extent, the wood can be burned in solid waste furnaces and energy sources obtained from wood can be used. Copper, chromium and arsenic removed from wood can be used in CCA production. Although the use of CCA is limited in many parts of the world, the metals obtained have the chance to be used in various branches of industry.

### *3.4.11. Burning inert wood and generating energy*

With the combustion process, the impregnated inert wood is removed, and at the same time, electrical and steam energy is obtained with the high temperature applied [14–16]. The cost of grinding the impregnated material, the presence of arsenic in the gas emitted into the air and the metal deposited in the ash have led to debates on the feasibility of this option. With the ash tests carried out, it was possible to evaluate the destruction of inert materials [17].

The thermochemical methods applied in the recycling of inert wood impregnated with CCA are pyrolysis (slow and fast), incineration, co-incineration and gasification technologies.

### *3.4.12. Pyrolysis*

Decomposition increases as the wood material are heated above 200°C in an airless environment or under nitrogen. Hemicellulose, one of the components that make up the structure of wood, decomposes thermally at 200°C–250°C. Cellulose starts to decompose at 280°C and completely decomposes at 300°C–350°C. Lignin is the last component to decompose and can begin to decompose at 300°C–350ºC and completely degrade at 400°C–450°C. After the carbonisation is completed at 400°C–500°C and the scavenging gases are removed, charcoal remains.

### *3.4.13. Co-burning*

Co-incineration is thought to be among the best solution possibilities that should be preferred in the recycling of wood waste. Mixing with other fuels and charcoal is not recommended as it contains a higher amount of arsenic than CCA-impregnated charcoal. A higher amount of arsenic than the amount of arsenic released from the flue gas is released during the combustion of CCA-impregnated waste wood. Since the amount of arsenic dissolved in water is high, a lot of arsenic is released during the combustion process [18].

### *3.4.14. Gasification*

More electrical energy is produced during the gasification of wood and its negative effects on the environment are less compared to the burning method. The loaded amount of arsenic is removed from the CCA-impregnated wood and reduced to its metal form. The cleaning system is expressed as the place where all the arsenic is kept (imprisoned) at the critical point in the gasification units. At high temperatures (1,100°C–1,500°C), organic compounds are decomposed and the danger of PCDD/F (dioxin and furan) formulation is eliminated.

## 4. Discussion

The prominent evaluations, as a result of the research carried out within the scope of the study, are given below.

When the world practices were examined, it was seen that the excavation equipment used during the erection of the tree poles in EDAS was insufficient. This prolongs the assembly process and causes gaps in the pillar foundations. For this reason, it is necessary to diversify excavation equipment by considering different soil types and geography within the same distribution region. In this context, it is aimed to shorten the excavation period and to use the resources in more optimal conditions.

In overseas applications, it has been observed that distribution networks are divided into different regions and time-based maintenance is carried out for each region [19]. These regular maintenance practices should also be implemented in Turkish distribution networks. In addition, it has been observed that test equipment specific to distribution companies is used and marked during maintenance in overseas applications.

The number of tree poles in the electricity distribution network is relatively higher than other equipment. The high number takes time in terms of entering the static and dynamic data directly into the GIS system during the initial set-up phase. In addition, recording the activities carried out during regular maintenance becomes untraceable when done manually and again prolongs the process. It has been concluded that the use of RFID technology for the integration of installation and maintenance processes into GIS can be beneficial in terms of both the accuracy of the data and the speed of processing the data [20].

The distribution of the wood pole inventory by number, wood type and impregnation material is not kept in such a way as to cover the average service times, wire damage, rot and defects. Keeping the inventory in the relevant breakdowns will make the current situation analysis studies more comprehensive and useful. This is suitable for any situation where proper records need to be kept, as advised in [21].

## 5. Conclusion

In overseas applications, for the assembly of the equipment, the holes to be drilled in the tree are made before the impregnation. It has been determined that the drilling process in Turkey is carried out after the impregnation processes. The said application paves the way for the formation of weak spots in the impregnation protection of the tree.

After the wooden poles are procured from the manufacturer, they should be stored and installed in suitable conditions, so that the poles will not be affected by the sun, humidity or environmental factors during the waiting period. The lack of independent consultant control in the process from the cutting of the tree poles to the installation negatively affects the life of the tree poles, as it affects the quality of the tree pole protection and maintenance application.

Red pine is used for the construction of wooden poles in Scandinavian countries. These trees are suitable for pole construction and are easy to grow in the Scandinavian region. The time required for the growth of a tree suitable for pole construction varies between 20 and 30 years. This period seems to be relatively long when compared to Turkey. However, the slower growth of trees in the Scandinavian region is understandable given the sunshine duration.

The percentage of interior wood/exterior wood is high in red pines in Scandinavian countries. In this regard, the need for chemicalisation is less, but the relevant chemical applications should be planned in accordance with the tree species in Turkey.

Reviewing the maintenance periods and practices should be carried out by evaluating the environmental conditions in Turkey. It has been determined that the climate index map study used in overseas applications is not complete in Turkey tree pole operations. By working on the subject, it would be beneficial to both extend the life of the tree pole and use it as a roadmap in operational studies.

Instead of applying a standard procedure for all tree pole applications, the environmental and natural factors of the region should be investigated and application methods should be determined on a regional basis. Since there are no drying ovens, the drying process is carried out by the natural drying method before and after the impregnation process. Since the weather conditions cannot be controlled in the natural drying process (before and after the impregnation process), cracks may occur depending on the humidity of the poles.

**References**


[1] B. R. Winthereik, J. Maguire, and L. Watts, “The energy walk: Infrastructuring the imagination,” in *DigitalSTS: A Field Guide for Science & Technology Studies*. Princeton, NJ, USA: Princeton Univ. Press, May 2019, pp. 221--239.

[2] A. Iqbal, “Developments in tall wood and hybrid buildings and environmental impacts,” *Sustainability*, vol. 13, no. 21, p. 11881, Oct. 2021.

[3] R. A. Zabel, and J. J. Morrell, *Wood Microbiology: Decay and Its Prevention*. New York, NY, USA: Academic, Dec. 2012.

[4] A. Y. Bozkurt, Y. Göker, and N. Erdin, “Emprenye tekniği,” İ.Ü. Yayın No. 3878, Orman Fakültesi Yayın No. 432. İstanbul, Turkey, Tech. Rep., 1993.

[5] D. R. Alderman, Jr., and R. L. Smith, “Solid wood received and marketed by Virginia's landfill facilities,” *Forest Products J.*, vol. 50, no. 6, p. 39, 2000.

[6] J. J. Morrell, “Estimated service life of wood utility poles,” North Amer. Wood Pole Council, Tech. Bull., Vancouver, WA, USA, Tech. Rep., 2016: No. 16-U-101.

[7] L. Helsen and E. Van den Bulck, “Review of thermochemical conversion processes as disposal technologies for chromated copper arsenate (CCA) treated wood waste,” in *Environmental Impact of Preservative-treated Wood in a Wetland Boardwalk*. 2004, p. 277.

[8] P. A. Cooper, “Disposal of treated wood removed from service: The issues,” Presented at the Meeting Environ. Considerations Use Pressure-Treated Wood Products. Madison, WI, USA: Forest Products Society, 1993.

[9] C. B. Vick, “Enhanced adhesion of melamine-urea and melamine adhesives to CCA-treated southern pine lumber,” *Forest Products J.*, vol. 47, pp. 83--87, Jul. 1997.

[10] M. Dua, A. Singh, N. Sethunathan, and A. Johri, “Biotechnology and bioremediation: Successes and limitations,” *Appl. Microbiol. Biotechnol.*, vol. 59, nos. 2--3, pp. 143--152, Jul. 2002.

[11] A. N. Glazer and N. Hiroshi, *Microbial Biotechnology: Fundamentals of Applied Microbiology*. Cambridge, U.K.: Cambridge Univ. Press, 2007.

[12] C. A. Clausen, “Reusing remediated CCA-treated wood,” in *Proc. Manag. Treated Wood Resource II*. Boston, MA, USA: American Wood-Preservers’ Association, May 2003, pp. 49--56.

[13] R. J. Shiau, R. L. Smith, and B. Avellar, “Effects of steam explosion processing and organic acids on CCA removal from treated wood waste,” *Wood Sci. Technol.*, vol. 34, no. 5, pp. 377--388, Dec. 2000.

[14] P. C. Conlon, “Crosstie disposal: Problem or opportunity?” Presented at the AWPI, 1992.

[15] M. A. H. Diaz, A. Scouse, and S. S. Kelley, “Environmental full cost accounting of alternative materials used for railroad ties: treated-wood and concrete case study,” *J. Cleaner Prod.*, vol. 364, Sep. 2022, Art. no. 132536.

[16] C. C. Kempton, “Life cycle management of treated wood products: Issues and answers,” in *Proc. Treated Wood Life Cycle Manage. Workshop*. Vienna, VA, USA: AWPI, 1992, pp. 54--66.

[17] H. M. Solo-Gabriele, T. G. Townsend, and J. Schert, “Environmental impacts of CCA treated wood: A summary from seven years of study focusing on the U.S. Florida environment,” in *Proc. 34th Annu. IRG Meeting*, 2003.

[18] L. Lindroos, “Balance of arsenic and recycling,” IRG Secretariat, Brussels, Belgium, Tech. Rep., 2002.

[19] Z. A. Fuad, H. S. Eddy, Y. Badronnisa, and I. Syazwani, “Water leak detection method in water distribution network,” *IOP Conf. Ser., Earth Environ. Sci.*, vol. 357, no. 1, Nov. 2019, Art. no. 012033.

[20] E. Esekhaigbe, E. Kazan, and M. Usmen, “Integration of digital technologies into underground utility asset management,” *Open J. Civil Eng.*, vol. 10, no. 4, pp. 403--428, 2020.

[21] A. Margherita and M. Heikkilä, “Business continuity in the COVID-19 emergency: A framework of actions undertaken by world-leading companies,” *Bus. Horizons*, vol. 64, no. 5, pp. 683--695, Sep. 2021.