ONLINE ISSN 2069-7430
ISSN-L 1841-4737
PRO LIGNO
www.proligno.ro
Vol. 21 N° 1 2025
pp. 49-58

PRESERVATION PRACTICES FOR WOODEN UTILITY POLES IN MUFINDI DISTRICT, TANZANIA

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Abstract:
Mufindi District in Tanzania extensively produces wooden utility poles due to their affordability and ease of availability from local forest resources. However, the longevity of these poles depends on effective preservation techniques, involving mainly chemical treatments to protect against wood biodegraders. This study explored the wood preservation practices focusing on the types of wood chemical preservatives used, concentration levels, preservation methods, and the occupational health impacts on workers. Chromated Copper Arsenate (CCA) was found to be the main preservative employed in treating wooden poles. Analysis revealed copper (Cu) content at 9.4% and arsenic (As) at 12.8%, within TANESCO standards. The average chromium (Cr) content of 13.0% was below the TANESCO minimum standard of 13.70%. Preservation methods involved the full-cell pressure process (Bethel), to ensure deep penetration of preservatives into wood fibres and enhanced resistance to biodegradation. The average preservative concentration applied during treatment was 5.67% weight/volume (w/v), aligning with the minimum requirement of 5% w/v. However, improper storage practices, such as prolonged exposure to moisture, were observed to impact the poles' preservation negatively. Occupational health assessments indicated significant risks, with 45% of workers reporting respiratory issues and 35% experiencing skin irritations due to exposure to CCA. Inconsistent use of personal protective equipment (PPE) and insufficient safety training worsened these risks. Statistical analysis demonstrated a significant correlation between chemical exposure levels and the incidence of health problems ($p < 0.05$). Chromium levels are low, which may affect durability. Poor storage increases moisture, impacting preservation. Health risks for workers are aggravated by inadequate PPE use and training. The study recommends optimizing preservative formulations, enforcing safety protocols, and considering alternative preservatives to improve pole longevity and worker safety. The study recommends adjusting Cr levels in preservative formulations, enforcing safety protocols, and improving storage practices. Further, adopting alternative preservatives with lower health risks, expanding health monitoring programs, and implementing comprehensive safety training to mitigate occupational hazards associated with chemical exposure are suggested.

Key words: *Health; PPE; Poles; Practices; Preservation.*

INTRODUCTION

The global reliance on wooden utility poles for infrastructure, such as electricity supply and telecommunication networks, is significant. In regions where wooden poles are widely used, their durability and long-term performance are essential to maintaining reliable services (Voufo *et* al. 2022; Martín & López 2023; NAWPC 2024). However, untreated wood is inherently vulnerable to biological degradation. Klem (1984) reported untreated wood facing limitations, such as decay caused by fungi, insect infestation, and exposure to harsh environmental conditions. Wood preservation techniques are often employed to counter these threats, involving the use of chemical preservatives to extend the service life of the poles (Klem 1984; Oregon State University 2017). Proper treatment ensures the poles maintain structural integrity and

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functionality over many years, even in environments that would otherwise accelerate deterioration (Winandy & McDonald 1993; Kumar & Morrell 2010).

The preservation of wooden utility poles typically encompasses the application of various chemical preservatives, with Chromated Copper Arsenate (CCA) being the most commonly used (Schiopu & Tiruta-Barna 2012; Dos Santos *et al*. 2018; Martín & López 2023). CCA protects wood against fungal decay, insect attacks, and other forms of degradation. Due to its nature, this chemical penetrates the wood better under pressure, providing deep and long-lasting protection. Although CCA is effective, it has sparked discussions about potential environmental and health risks due to the presence of arsenic, a known toxic substance (Lebow & Tippie 2001; Stevanovic-Janezic *et al*. 2001). Lebow and Tippie (2001), along with Lebow *et al*. (2004), argue that the toxicity of arsenic makes it a subject of concern, especially for workers handling treated poles.

In Tanzania, Mufindi District is a major centre for manufacturing and treating wooden utility poles. Situated in the Southern Highlands, Mufindi has a thriving wood industry, supported by its abundance of forest resources and numerous wood treatment plants. The district's strategic importance stems from its high production capacity, with multiple large- and medium-scale industries engaged in wood preservation to meet the growing demand for durable poles required for infrastructural projects, both domestically and in neighbouring regions like Rwanda, Kenya and Uganda. According to Balama (2022), Mufindi District plays a crucial role in supporting Tanzania's electric grid and telecommunication infrastructure by providing treated wooden poles, with a production capacity of 131,560m³ per annum.

The effectiveness of the wood preservation process, particularly in terms of preservative penetration and retention, is crucial to the long-term durability of the poles. However, improper handling or storage of the treated poles can compromise their quality. Exposure to rain or storage in moisture-prone environments can lead to moisture absorption. Studies by Newman and Murphy (1981), Anderson *et al*. (1995), and the EPA (2015) highlight the risks of improper storage, which can negate the benefits of preservative treatment.

Addressing the occupational health and safety of workers in the wood preservation process is essential, given the significant exposure to chemical preservatives during tasks such as mixing chemicals, loading and unloading wood into pressure-treatment cylinders, and handling freshly treated wood. Prolonged exposure to CCA, particularly its arsenic component, poses serious health risks, including respiratory issues, skin irritations, and, in severe cases, chronic illnesses such as cancer. As noted by Adam et al. (2009) and the EPA (2024).

To emphasize the significance of this study, it's essential to highlight its practical applications and broader impacts. This research is valuable not only for generating scientific insights but also for informing industry practices, improving worker safety, and supporting sustainable resource management in the Mufindi District. By examining wood preservation practices and their occupational health implications, the study provides critical data that can guide local and regional policymakers in establishing guidelines for the safe handling and storage of chemically treated wood. This information can aid decision-makers in developing and enforcing regulations to protect worker health and ensure environmental sustainability, aligning with international standards for wood treatment and occupational safety. Additionally, the findings serve the wood preservation industry by identifying best practices that can enhance the durability of utility poles while minimizing health risks to the workers. The findings of this study are valuable to several key organizations, including Tanzania Electric Supply Company Limited (TANESCO), which could use the insights to improve utility pole standards, and the Ministry of Natural Resources and Tourism (MNRT), which oversees sustainable forestry practices in Tanzania. Additionally, the Occupational Safety and Health Authority (OSHA), Sokoine University of Agriculture (SUA), Tanzania Forestry Research Institute (TAFORI) and the National Environment Management Council (NEMC) could apply the results to strengthen regulations for worker safety and environmental protection related to wood treatment. Non-governmental organizations such as The Forest Stewardship Council (FSC), and the Tanzania Forest Conservation Group (TFCG) may benefit by using this information to advocate for sustainable wood preservation practices. Moreover, workers' rights organizations and environmental advocacy groups could leverage the findings to promote safer handling and monitoring of chemical preservatives, supporting both worker health and environmental sustainability initiatives.

OBJECTIVES

The objective of this study was to explore the wood preservation practices in Mufindi District, Tanzania, focusing on the types of wooden poles' chemical preservatives used, their concentrations, methods used in treating wooden utility poles and the occupational health impacts on workers engaged in pole preservation. The study aimed to assess the effectiveness of these preservation techniques in extending the durability of the poles, while also investigating the occupational health impacts of chemical exposure on workers. Specifically, it evaluated the use of Chromated Copper Arsenate (CCA) chemical preservative, analyzing whether its chemical components met the required standards, and identified gaps in safety practices.

MATERIALS AND METHODS

Study Area

Mufindi District is located between latitudes 8° 00′ and 9° 15′ South, and longitudes 34° 35′ and 35° 55′ East (Fig. 1). The district is bordered with Iringa Rural District to the north, Njombe Region to the south, Morogoro Region to the east, and Singida Region to the west. It has an average elevation of 1,880 metres above sea level and spans an area of 7,123 square kilometres, constituting approximately 19.9% of the total area of the Iringa Region (NBS, 2013). The district hosts a variety of wood preservation plants, ranging from small-scale to large-scale industries (Table 1) (Balama 2022).

Table 1

Various pole treatment plants in Mufindi, Iringa Region Tanzania

		Ownership	
S/No	**Name of Industry**	**Individual**	**Group**
1	Qwihaya General Enterprises Company Ltd	0	1
2	Sao Hill Industries Ltd (Poles)	0	1
3	Mufindi Wood Poles Plant and Timber Ltd	0	1
4	Shedaffa General Supplies Ltd (Poles)	1	0
5	Leshea Investment Company (Poles)	0	1
6	Mafinga Wood Treatment Plant Ltd	0	1

Source: Balama (2022)

Mufindi District experiences an overcast wet season and a dry season that is both windy and predominantly clear, with temperatures remaining warm throughout the year. The annual temperature ranges from 15°C to 32°C, rarely dropping below 10°C or exceeding 34°C. Agriculture serves as the cornerstone of the district's economy, as highlighted by the 2008 National Agriculture Sample Survey, which ranked the agriculture sector first in the sale of both annual and perennial crops (NBS 2013; Ngaga 2011).

The choice of the study area was based on the district’s distinctive status as the largest producer of utility poles in the region, with a production capacity of 131,560 m^3 and an installed capacity of 374,818m^3 (Mwamakimbullah 2016; Hawkes & Sumari 2018; Balama 2022).

Study Design

The study utilized a purposive sampling design, selecting three industries based on their installed capacities that is one large-scale industry, one medium-scale industry, and one small-scale industry.

Data Collection

To characterize the types and concentrations of wood preservatives used, the concentration of chemicals was measured before starting the treatment process, following the AWPA A9-18 standard (2018). This method was selected for its reliability and alignment with industry standards, ensuring precise measurement of preservative components. A 500cm^3 sample of preservative chemicals was collected from each of three selected treatment plants in the Mufindi District, with laboratory analyses conducted to determine the percentage composition of each constituent element, as per TBS (2021a). In addition, field observations, questionnaires, and checklists were used to assess the machinery, treatment methods, and occupational health hazards in all six treatment plants. A comprehensive mapping of the flow path of wooden poles from felling to final installation was performed, covering all stages-handling, transportation, and storage-and examining how each stage impacts pole quality and preservation.

Data Analysis

Data collection was conducted in two main stages: fieldwork and laboratory analysis. Field data were recorded in standardized field forms during fieldwork, and laboratory data were documented in corresponding laboratory forms. After collection, data were analyzed using statistical software, including R (version 4.3.1) and SPSS. This approach aligns with methods successfully applied by Ssemaganda et al. (2011), Mugabi and Thembo (2018), and Aguayo et al. (2022).

Descriptive statistics, including mean, median, and standard deviation, were calculated to summarize the concentration of wood chemical preservatives.

RESULTS AND DISCUSSION

Identification of Chemical Preservatives

The study found that Chromated Copper Arsenate (CCA) was the dominant chemical preservative applied in treating wooden utility poles in the study area, across all three industries surveyed.

Studies conducted by Feist (2004) in the United States of America and Dos Santos *et al*. (2018) in Brazil and Canada found that in the preservation process, chromium plays a role as a fixative, binding the copper and arsenic to the wood fibres, making the treatment resistant to leaching and also, protecting against degradation by ultraviolet light, copper serves as a fungicide, protecting the wood from decay-causing organisms, while arsenic is highly effective in deterring insect infestation. Together, these constituents work to provide a robust defense against the biological threats that often compromise the integrity of untreated wooden poles.

The use of CCA in the Mufindi District is consistent with global practices for treating utility poles and other outdoor wood structures that require a long service life. CCA's water-borne nature allows to penetrate deeply into the wood during the treatment process, ensuring thorough protection throughout the pole's cross-section. This is particularly important in areas where high humidity and frequent rainfall present ongoing challenges for maintaining the durability of wooden poles (Brooks 1997; AWPA 2001; JORF 2004; Nakiguli *et al*. 2018; Smith 2020).

Despite CCA being effective in preserving wood, its use is also accompanied by certain environmental and health concerns due to the presence of arsenic. Therefore, industries must adhere to strict regulatory guidelines to ensure the safe handling, application, and disposal of CCA-treated wood. Despite these concerns, the preservative remains a key component in the preservation strategy for wooden utility poles in the Mufindi District, contributing significantly to the longevity and reliability of the poles in service (Woo *et al*. 2010; Vromman *et al*. 2018).

Preservative Concentration Levels

The study found that the solution strength used for the treatment of wooden poles was not less than 5% weight/volume (w/V), which is the standard requirement for ensuring effective protection. The analysis revealed that the average solution strength applied during the treatment process was 5.67%, which aligns with the specifications set by TANESCO (Tanzania Electric Supply Company) and the TBS (Tanzania Bureau of Standards).

The study found that CCA Type C was the preservative used for treating wooden utility poles. This preservative, composed of Copper (Cu), Chromium (Cr), and Arsenic (As), is applied using a pressure treatment method to ensure deep penetration into the wood fibres. This is because CCA Type C provides effective protection against decay, fungi, and insect infestation, making it well-suited for poles used in outdoor environments as highlighted by TANESCO (2022) and EPA (2024).

Smith (2020) and AWPA (2024) showed that Cu acts as a fungicide, preventing wood rot, while Cr fixes the preservative into the wood, ensuring long-term resistance to leaching. Ar is an insecticide, that protects the poles from damage caused by termites and other pests. This treatment method enhanced the durability and longevity of the utility poles, contributing to their structural integrity over extended periods of service in the field.

This solution concentration ensures that the preservative penetrates the wood effectively, providing long-term protection against decay, termites, and other environmental hazards. The compliance with both TANESCO specifications and TBS standards confirms the adequacy of the treatment process in maintaining the required quality and durability of the treated poles.

The study showed the percentage composition of constituent elements in the samples, when compared to TANESCO standards as a main consumer of the wooden utility poles, reveals the following: The average chromium content of 13.0% is below the minimum standard of 13.70%, indicating that the chromium levels are insufficient. In contrast, the average copper content of 9.4% falls within the acceptable range set by TANESCO (8.05% to 9.95%), suggesting that the copper concentration meets the required standards. Similarly, the average arsenic content of 12.8% is within the TANESCO range of 11.60% to 14.65%, showing that the arsenic levels are acceptable. The total composition of the elements, at 35.2%, is within TANESCO's specified range of 33% to 40%. Overall, while copper and arsenic levels are satisfactory, the chromium concentration does not meet TANESCO's standards and requires adjustment (Table 2). The chromium content, with an average of 13.0%, falls short of the TANESCO minimum requirement of 13.70%. This deficit suggests that the material may not meet the durability or performance criteria expected for applications requiring higher chromium levels. Chromium is often used to enhance resistance to corrosion and wear, so its lower concentration could affect the longevity and effectiveness of the poles. It may be necessary to review the material's treatment process or source to address this shortfall and ensure it meets the required specifications.

Table 2

Percentage Composition of Constituent Elements for CCA samples

Constituent element	**Percentage Composition of Constituent Element(%)**			**Average (%)**	**Remark**
	IND01/CCA01	**IND02/CCA02**	**IND03/CCA03**		
Cr	10.0	13.0	15.9	13.0	Below
Cu	8.0	9.8	10.5	9.4	Accepted level
As	9.5	14.0	14.9	12.8	Accepted level

Assessment of Preservation Methods

The study found that the preservation method used in the treatment of wooden poles was the pressure process, specifically employing the full-cell process. According to Brooks (1997), Vromman *et al*. (2018) and McEwan (2021) suggested that this method is widely recognized for its effectiveness in maximizing the penetration of chemical preservatives into the wood fibres and cells at large. In the full-cell process, also known as the Bethell process, the wood is first placed in a vacuum chamber to remove air and moisture from the cell structure. Following this, a preservative solution is introduced under high pressure, forcing it deep into the wood cells and ensuring the good distribution of preservatives to the poles.

This method is particularly advantageous for treating poles intended for long-term outdoor use, as it ensures higher retention of preservatives and provides greater resistance to environmental factors like moisture, fungal decay, and insect infestation as per Klem (1984). The study observed that the pressure applied during the process allowed for thorough saturation of the poles, significantly improving their durability and extending their service life.

In comparison to other preservation methods, such as surface treatments or dipping, the pressure process, particularly the full-cell method, proved to be superior in terms of both preservative retention and penetration depth as shown by Muthike and Ali (2021) and Gathogo (2024). This finding underscores the importance of selecting an appropriate preservation technique, as the pressure process plays a critical role in enhancing the long-term performance and sustainability of wooden poles used in construction and infrastructure projects.

Flow Path Mapping

The findings indicated that each stage plays a critical role in maintaining the structural integrity and effectiveness of the chemical preservatives, highlighting the importance of proper management throughout the process to ensure optimal preservation outcomes as shown in Fig. 1.

The study acknowledges the crucial role of storage conditions in maintaining the quality of the wooden poles before their final installation. The study found that there is improper storage, such as prolonged exposure to rain or inadequate stacking, and lack of enough retention ditches for the logs which can influence the increased moisture content, compromising both the wood structure and the retention of chemical preservatives. Proper storage techniques were shown to significantly improve retention rates and preserve the durability of the poles over time as per the study of Adam *et al*. (2009).

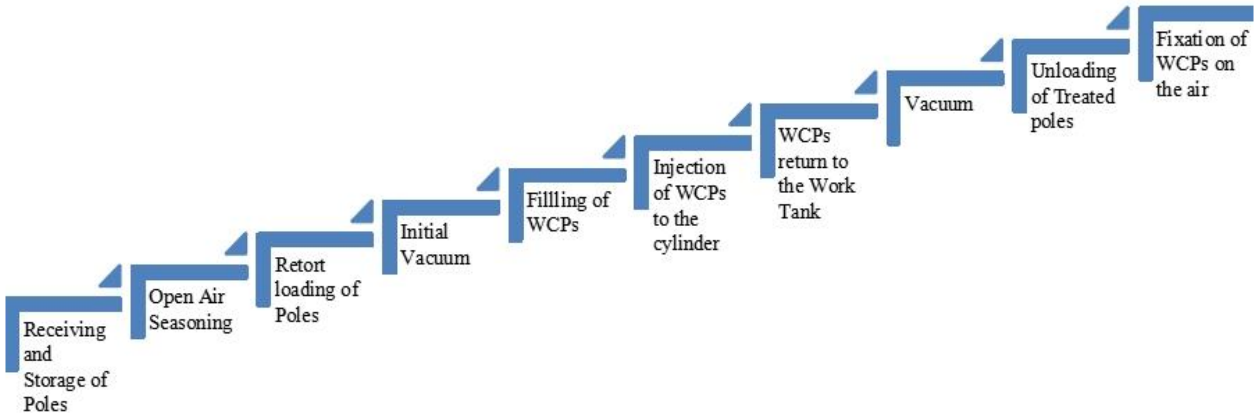

Fig. 1.
Flow diagram of the full-cell pressure treating processes used in Mufindi District.

Occupational Health Impacts

The study found a significant correlation between exposure level and health issues ($p < 0.05$) implying a strong relationship between the amount of exposure to chemical preservatives i.e. CCA and the health problems experienced by workers. The study revealed several health issues commonly encountered by workers involved in the wood preservation process, particularly those exposed to chemical preservatives CCA as shown in Table 3. The most frequently reported health problems included respiratory issues, such as coughing and shortness of breath, skin irritations and allergic reactions like rashes and itching. Workers handling treated wood or directly involved in applying chemical preservatives were more prone to these symptoms, likely due to prolonged and frequent contact with the chemicals.

Table 3
Health Problems and Exposure Levels of CCA among Workers in Pole Preservation Plants

Category	Findings	Percentage (%)
Health Problems		
Respiratory Issues	Coughing, shortness of breath, chest tightness	45
Skin Irritations	Rashes, redness, itching	35
Allergic Reactions	Swelling, itching, skin inflammation	20
Chronic Health Concerns	Recurring respiratory issues, skin sensitivities	10
Exposure Levels		
High Exposure (daily contact with CCA)	Workers involved in chemical application and pole resizing	60
Medium Exposure	Workers handling treated poles in storage	40
Low Exposure	Workers in transportation and administrative roles	15
Protective Measures		
PPE Provided	Gloves, masks and protective clothing provided	75
Inconsistent PPE Usage	Workers who did not consistently use PPE	40
Ventilation Systems Adequate	Proper ventilation in work areas	30
Health Monitoring	Facilities conducting regular health checks	25
Risk Awareness & Training		
Safety Training Received	Workers who received training in handling chemical preservatives	60
Adequacy of Training	Workers who felt that safety training was adequate	35

This study found that workers are exposed to wood preservatives in several ways, such as mixing the chemicals, loading them into pressure-treatment cylinders, working near spraying or dipping operations, handling freshly treated wood, cleaning or service equipment, or dealing with waste materials. While closed systems for handling the chemicals and using machines to move treated wood can reduce exposure, they don’t entirely remove the risk of routine or accidental exposure for workers.

In more severe cases, some workers reported experiencing chronic respiratory conditions, possibly linked to long-term exposure to arsenic compounds found in CCA. Though no immediate cases of significant chemical poisoning were recorded, there were concerns about potential long-term risks such as carcinogenic effects, particularly from the inhalation of arsenic-laden dust during the treatment or cutting of preserved wood. A report by the ATSDR (2017), showed various health effects from exposure to CCA. The ATSDR listed several possible health effects for those exposed to CCA, depending on duration and amount of exposure. Acute exposure is said to cause skin irritation, respiratory problems, and gastrointestinal problems. Long-term or chronic exposure to arsenic in particular has been associated with more serious diseases, especially an increased risk of developing certain types of cancers like skin, lung, and bladder cancer. Other health effects associated with long-term exposure include cardiovascular system complications, kidney and liver complications, and impairment of immune function.

This study underlines that whenever possible, there should be complete avoidance of direct contact with CCA-treated wood, and it especially refers to people who deal with such professions. Reasonable protection from its probably adverse effects might include measures of protection, such as proper gloves, masks, and other forms of protective equipments as recommended by Woo *et al*. (2010) and Vromman *et al*. (2018).

In terms of the use of protective measures in place in the industries surveyed, results showed that personal protective equipments (PPEs), including gloves, masks, and protective clothing, were provided to workers in most cases. However, the proper use of these PPE was inconsistent, with some workers not fully adhering to safety protocols, either due to discomfort or lack of regulations enforcement.

The study noted health monitoring programs were present in a few of the larger industries, though not uniformly applied across all facilities. Workers expressed the need for better health and safety training, along with clearer guidelines on the proper handling of chemical preservatives.

Nakiguli *et al.* 2018 and Morais *et al*. (2021) researched that CCA is a restricted chemical product in most countries, due to potential environmental health hazards associated with skin contact with the CCA residues from treated facilities and the surrounding soil, as well as soil contamination. However, large amounts of CCA-treated timbers are in service in framings, outdoor playground equipment, landscaping, building poles, jetty piles, and fencing structures around the world, thus CCA remains a source of pollutants to the environment and people's health.

The results indicated that while some protective measures were in place, gaps in their consistent application potentially exposed workers to unnecessary health risks. The findings emphasize the importance of enhancing workplace safety protocols, ensuring the consistent use of PPE, and improving health monitoring and training programs to mitigate the risks associated with workers' exposure to chemical preservatives.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study of wooden utility poles in the Mufindi District found that CCA (Chromated Copper Arsenate) is the primary preservative used, valued for its effectiveness in protecting wood from decay, insects, and fungi. However, chromium levels in the CCA were often below TANESCO standards, while copper and arsenic concentrations were within acceptable limits. The full-cell (Bethell) process was the most widely used preservation method, offering deep penetration and long-term wood protection, though improper storage practices, like exposure to rain and poor stacking, increased moisture content and weakened wood quality. Occupational health assessments indicated that workers exposed to CCA faced respiratory issues, skin irritation, and allergic reactions, with inconsistent PPE use and limited health training heightening their risk. These findings highlight a need for improved quality control in preservative composition, storage practices, and safety measures to ensure both the longevity of treated poles and the health of workers handling them.

Recommendations

Based on this study's findings, we propose several recommendations to improve wood preservation practices and worker safety in the Mufindi District. These suggestions aim to rectify discrepancies in preservative formulations, storage practices, and safety protocols, all of which are crucial for maintaining the integrity and longevity of treated wooden poles. To address gaps identified in this study, we recommend the following improvements to wood preservation practices and worker safety in the Mufindi District:

- Adjustment of Chromium Content in Preservative Formulations: Industries should adjust preservative formulations to meet standard chromium levels, as current averages fall short, compromising pole durability and corrosion resistance.
- Implementation of Improved Storage Practices: Implementing covered storage areas, proper stacking, and retention ditches would reduce moisture content and help maintain preservative efficacy.

- Solidification of Worker Safety Protocols: Enforce consistent PPE use and conduct regular safety inspections to minimize chemical exposure risks for workers handling CCA-treated poles.
- Expansion of Health Monitoring and Training Programs: Establish comprehensive health monitoring and regular safety training to emphasize the risks of preservative handling, the importance of PPE, and safe work practices.
- Exploration of Alternative Preservatives: Consider transitioning to preservatives that maintain efficacy without chromium or arsenic, such as Copper Boron Azoles (CBA) or Micronized Copper Quaternary (MCQ), to enhance worker safety and environmental sustainability.

ACKNOWLEDGEMENTS

The authors extend sincere appreciation to the management of the Sokoine University of Agriculture for their financial support of this work, as well as to the management of the industries that contributed to the successful completion of this study.

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