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Original Article

Occupational and environmental exposures of overhead distribution lineworkers and environmental impacts of creosote: a cross-sectional study

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ABSTRACT

Introduction: Workers in overhead electrical distribution networks (OEDNs) face numerous physicochemical hazards. In Greece, wooden poles (WPs) used in OEDNs are typically treated with creosote, a complex mixture containing polycyclic aromatic hydrocarbons (PAHs), heteroaromatic compounds and tar acids/bases. Creosote is a probable human carcinogen and a skin and eyes irritant and can result in environmental contamination from creosote "bleeding".

Methods: A cross-sectional study of the health effects on workers in OEDNs in Northern Greece was conducted between January-September 2024. Fifty-six workers (70% response rate) completed a structured questionnaire on demographics, personal protective equipment (PPE) use, and perceived health and environmental risks associated with creosote-treated WPs. Data were analyzed using SPSS 23.0. Kolmogorov–Smirnov, chi-square, Mann–Whitney U and Spearman correlation tests were applied. A p-value < 0.05 was considered statistically significant. Ethical approval was obtained from the University of West Attica Ethics Committee (Ref. No. 4608, 24 Jan 2024).

Results: Frequent contact with creosote-treated poles was reported by 66.1% of participants. While climbing newly creosote-treated poles, workers reported skin burns (46.4%), eye irritation (32.1%) and dermatitis (25%). Symptoms were described as more intense during summer. Of the sample group, 66.1% recognized creosote-related health hazards, 42.9% were aware of potential for soil contamination and 30.4% for water contamination.

Conclusion: Based on the study findings, creosote remains a tangible occupational and environmental hazard for lineworkers, especially when climbing newly creosote-treated poles. Environmental contamination from treated WPs was mainly localized in the surrounding soil driven by creosote seepage and PAHs leaching.

Keywords: Creosote, Environmental impact, Occupational exposure, Overhead distribution networks

Introduction

Lineworkers primarily work at heights and in direct contact with electricity, using a portable ladder, basket vehicles, or climbing harnesses/climbing shoes in combination with PPE (work position, suspension and anti-fall safety belts). Due to the high risk of the work, specialized training is required before taking on duties, which includes theoretical knowledge and practical training on safe work procedures, proper use and maintenance of PPE, as well as escape and rescue protocols. In Greece, legislation also mandates periodic retraining (at least every three years) to maintain the necessary skill level and ensure continued adherence to safety rules.[1] Most of their work is done on WPs impregnated with chemical preservatives, such as creosote.[2]

Creosote is the most widely used wood preservative in Greece for WPs of OEDNs due to its high penetration ability and strong toxicity against microorganisms, as well as its fungicidal, insecticidal and sporicidal properties.[3,4,5] A dark brown to yellow-green viscous liquid with a characteristic strong tar-like odor and pungent aroma, creosote is classified as a restricted-use pesticide.[4,6] Creosote consists primarily of PAHs (up to 85%), and high concentrations of PAHs persist in creosote-impregnated wood decades after application.[7] Other components in creosote include heterocyclic aromatic substances and certain tar acids and bases.[8] Creosote is genotoxic and has been shown to cause skin cancer in animal studies. Studies in occupationally exposed groups indicate potential human carcinogenicity.[7] Additionally, creosote can cause eye irritation.[9]

While exposure through inhalation can occur during the production stages,[10] occupational exposure of overhead lineworkers occurs primarily through skin absorption from frequent direct contact with impregnated poles, during handling, maintenance, repair and installation of new poles and placement of fittings.[8] Epidemiological and toxicological studies have shown increased risks of cancer, respiratory, eye, and skin diseases in workers exposed to creosote.[5] Prolonged or repeated skin contact can also cause allergic reactions, changes in skin pigmentation, and benign skin lesions.[11]

Outdoor workers are increasingly facing prolonged exposure to high temperatures and intense ultraviolet (UV) radiation due to climate change, which can intensify both chemical absorption and physiological strain. Concurrent exposure to heat, humidity, and chemicals affects thermoregulation and enhances dermal absorption of chemicals.[12,13] Despite potential health problems from exposure, PPE (e.g., long sleeves, hats, sunscreen) is often considered uncomfortable, unsafe, or inconsistently worn due to workplace culture.[13]

Exposure to creosote is intensified by exposure to UV radiation. Simultaneous exposure to sunlight can lead to phototoxic or photoallergic reactions and long-term skin damage.[5,7,14] Lineworkers are among the professions with the highest exposure to UV[13] and workers exposed to both creosote and UV radiation develop photosensitivity, as UV radiation increases the toxicity of creosote, causing dermatitis in sun-exposed areas of the body.[14] This phenomenon is attributed to the photo-reactivity of PAHs, which leads to the formation of intermediate compounds that can cause irritation, redness, eczema and hyperpigmentation.[7]

Creosote also poses environmental concerns due to the "bleeding" phenomenon (Figure 1) observed in wood treated with creosote or its mixtures, in which the oil leaks or drips from the surface after application. The dark color of the stained wood leads to the absorption of a large amount of heat, resulting in the surface temperature, under direct sunlight, reaching up to 60 °C or higher. Bleeding is influenced by temperature, solar radiation, the injection method, the type and amount of preservative and the presence of air in the wood pores.[3]

Figure 1: Bleeding phenomenon

(Source: Authors' photograph)

The losses of creosote preservatives from the WPs are difficult to predict. Laboratory findings indicate that PAHs and heterocyclic compounds are primarily washed out within the first 24–48 hours following application.[15] Subsequent leaching rates are affected by treatment quality, pole age and environmental conditions and are temperature dependent. Creosote preservatives that remain in a liquid state within the wood cells move downward (due to gravity), resulting in the accumulation and darkening of the soil around the pole.[16]

The variability of PAH concentrations in soil around the poles is high and is influenced by many factors (e.g., soil, topography, pole age). Contamination is highest near the base of the pole, with PAHs concentrations up to 24.000 mg/kg. Highest concentrations are found at medium depths, particularly near the edge of the pole due to the direct deposition of creosote from the buried section of pole 3–8 inches underground. Concentrations of lighter PAHs (e.g., naphthalene, acenaphthylene) increase steadily with depth due to their increased water-solubility and lower soil adsorption coefficients (K_{OC}), while concentrations of heavier PAHs (e.g., indenopyrene) decrease steadily with depth due to their lower solubility and higher K_{OC} values.[17,18] Multiple contamination pathways such as direct deposition of preservatives from the surface of the WPs, volatilization, leaching from rain, runoff of preservatives from the edge of the pole, highlight the complexity of creosote migration in the environment. While at 4 °C up to 85% remain on the wood surface, at temperatures above 30 °C certain PAHs, such as acenaphthene and phenanthrene, are volatilized.[8] The main environmental sinks for PAH are sediments and soil.[19] The hydrophobic nature of PAHs,[10] as indicated by high octanol-water partition coefficient (K_{OW}) values, predicts a stronger affinity to organic matter compared to water and a slow groundwater migration.[20] In aquatic environments they migrate slowly through the co-transport of adsorbed colloidal pollutants.[19] Migration is influenced by various factors, such as the type of soil, hydrogeology, and the amount released.[5]

Although contamination decreases with distance from the pole, high PAH concentrations can still occur, posing risks to both soil and groundwater. Elevated levels of PAHs have been detected in trench water near railway lines with creosote-impregnated WPs, with an average concentration of 606.9 μg/L, raising concerns about chronic exposure to aquatic organisms despite non-lethal toxicity levels[21] due to their persistence and bioaccumulation potential in benthic organisms.[8]

Given these occupational and environmental concerns, the present study aimed to evaluate the exposure of lineworkers to OEDNs in creosote as a WPs preservative and its environmental impact. It examined the awareness and perceptions of lineworkers about the relevant occupational and environmental hazards. The findings aim to identify gaps in protection practices and to support preventive strategies in occupational and environmental health.

Methods

A cross-sectional study was conducted with the source population consisting of all active lineworkers in the country aged 18 and over. Data collection took place between January and September 2024 using convenience sampling. The research was based on a questionnaire created for the needs of the study and was formulated after a bibliographic review, author communication with lineworkers, and a trial test. Questions were closed-ended, with the option of either two "Yes/No" answers or more than two answers, including the five-point Likert scale that indicates the degree of agreement or disagreement with the following gradation: "not at all", "slightly", "moderately", "somewhat" and "very much", along with the additional option "I don't know". In collaboration with HEDNO SA services and a contractor in Northern Greece employing lineworkers, approximately 80 questionnaires were distributed. Due to the limited number of active lineworkers in the study area, the sample size was determined by accessibility to the available workforce during the study period. The study response rate was 70% (56/80). The questionnaires were either distributed in person to the respective employers or via email to ensure they were properly forwarded to all lineworkers. The questionnaire was accompanied by an introductory note that fully explained the purpose of the research and the importance of participation, informed consent, the right to withdraw, and included the researcher's contact information for additional information or clarification.

Dependent variables included participants' beliefs of the health and environmental risks associated with creosote-treated WPs and the rational PPE use score, which ranged from 5 to 25, with higher scores indicating more appropriate use. Independent variables included demographic and occupational characteristics such as age, marital status, education level, employment status and years of service.

For nominal variables, univariate analysis was performed by presenting the absolute (n) and relative frequencies (%), while for quantitative variables, measures of position and dispersion were presented, specifically mean, standard deviation, median, minimum and maximum. The Kolmogorov–Smirnov test was applied to assess the normality of quantitative variables. Age followed a normal distribution, whereas years of service and the rational PPE use score did not; therefore, non-parametric statistical tests were applied where appropriate.

Associations between two dichotomous variables were examined using, a χ^2 test. The Chi-square test for trend was used to assess associations between dichotomous dependent variables and ordinal independent variables. The Mann–Whitney U test was applied to examine associations between dichotomous variables and non-normally distributed quantitative variables. Spearman's correlation coefficient was used to assess associations between quantitative variables when at least one did not follow a normal distribution. The two-tailed significance level was set at 0.05. The data analysis was performed using IBM SPSS Statistics 23.0.

The study did not present any ethical or deontological issues. Participation of lineworkers was voluntary, anonymous and without coercion. All data were used solely for research purposes and written informed consent was obtained from all participants. Ethical approval for the study was granted by the University of West Attica Ethics Committee (Approval No. 4608, 24 January 2024). Permission for data collection was also obtained from HEDNO KILKIS S.A. and BALKAN ELECTRIC S.A. and the questionnaire was completed anonymously.

Results

The study population consisted of 56 participating lineworkers, all of whom were Greek citizens aged between 20 to 62 years old (mean age 40.6 years). In terms of education, 60.7% (n=34) had completed upper secondary education (Lyceum), 21.4% (n=12) were graduates of public IEK/OAED/private school, 7.1% (n=4) had completed lower secondary education, 8.9% (n=5) were university/TEI graduates and 1.8% (n=1) were elementary school graduates. A majority of 60.7% (n=34) were married/cohabiting, 33.9% (n=19) were single, 3.6% (n=2) were divorced, and 1.8% were widowed (n=1). 67.9% (n=38) worked for a contractor, while 32.1% (n=18) worked for HEDNO and 66.1% (n=37) were contract workers, compared to 33.9% (n=19) who were permanent employees. The average years of service were 9.4 years, with a minimum of 2 months and a maximum of 43 years.

A very high percentage of lineworkers reported adequate provision and use of PPE. Specifically, 82.1% (n=46) stated that they received the appropriate PPE, 14.3% (n=8) reported moderate provision and 3.6% (n=2) reported limited provision. Similarly, 80.3% (n=45) reported that they received sufficient information from their employer on the proper use of PPE, 16.1% (n=9) stated that the information was provided to a moderate extent and 3.6% (n=2) answered that none/little was provided. The use of PPE was considered very important by 96.4% (n=54) of the participants, while 91.1% (n=51) said they use it "a lot/very much". 89.3% (n=50) performed regular equipment checks. Among HEDNO employees, 100% (n=18) reported adequate PPE provision and 88.9% (n=16) reported adequate information on PPE use, while among contractor employees, the corresponding percentages were 73.7% (n=28) and 76.3% (n=29), respectively.

To further assess PPE practices, a composite score for rational use of PPE was calculated. The PPE score ranged from 5 to 25, with higher values indicating more rational use of PPE. The mean PPE score was 22.3 (S.D. = 2.6), with a median of 23, a minimum value of 15 and a maximum value of 25, indicating overall high adherence to recommended PPE practices among participants.

Bivariate associations between demographic and occupational characteristics and PPE rational use scores are presented in Table 1. No statistically significant associations were observed between PPE scores and age (Spearman's ϱ, p = 0.430), educational level (Mann–Whitney U, p = 0.422), marital status (Mann–Whitney U, p = 0.200), employer (Mann–Whitney U, p = 0.347), employment status (Mann–Whitney U, p = 0.746) or years of service (Spearman's ϱ, p = 0.948).

Creosote was ranked as the second most dangerous occupational hazard by 39.3% (n=22) by respondents after work under voltage. A total of 66.1% (n=37) of participants believed that creosote used as a wooden pole-impregnator had a negative effect on their health, while 30.4% (n=17) reported that they did not know whether such effects existed. Contact with creosote-treated WPs was reported as "fairly frequent" by 26.8% (n=15) of participants and "very frequent" by 39.3% (n=22). Symptoms reported after climbing newly creosote-treated poles are presented in Table 2. The most frequently reported symptom was skin burns (46.6%, n=26) followed by eye irritation (32.1%, n=18) and skin rashes (25%, n=14). Less frequently reported symptoms included difficulty breathing (8.9%, n=5) and headaches or dizziness (5.4%, n=3). The majority of 76.7% (n=43) of respondents reported that symptoms were more intense during the summer months, while 23.3% (n=13) reported that symptom intensity remained the same throughout the year.

Table 1: Bivariate associations between demographic and occupational characteristics of lineworkers and rational personal protective equipment use score.

Characteristic	Mean rational PPE use score (SD)	p-value
Age		0.430[a]
Educational level		0.422[b]
Up to high school graduates	22.4 (2.5)	
Higher/University education graduates	21.8 (2.9)	
Marital status		0.200[b]
Unmarried/Divorced/Widowed	21.6 (2.9)	
Married	22.6 (2.4)	
Employer		0.347[b]
HEDNO		
Contractor	22.9 (1.7)	
Employment status		0.746[b]
Permanent	22.6 (2.1)	
Contractor	22.1 (2.9)	
Years of service		0.948[a]

[a]Spearman correlation coefficient
[b]Mann–Whitney U test

Marital status was associated with perception of health risk related to creosote exposure. Married lineworkers (76.5%, n=26) reported that creosote-impregnated WPs pose a health risk more frequently compared with unmarried/divorced/widowed workers (χ^2 (1) = 4.175, p = 0.041; n = 56) (Table 3). Years of service were also significantly associated with perceived health risk, with workers having ≥5 years of service more frequently recognizing health risks compared with those with ≤4 years of service (80% vs. 54.8%; χ^2 (1) = 3.908, p = 0.048; n=56) (Table 4).

Table 2: Reported symptoms after climbing newly creosote-treated poles.

Characteristic	N (%)
Skin burns	26 (46.6%)
Eye irritation	18 (32.1%)
Skin rash	14 (25%)
Difficulty breathing	5 (8.9%)
Headache/Dizziness	3 (5.4%)

Table 3: Association between lineworkers beliefs about the health risks creosote-impregnated wooden poles and their marital status.

3a Association between knowledge of health risk of creosote-impregnated WPs and marital status					
			Creosote health risk		
			Yes	No/I don't know	Total
Marital status	Unmarried/ Divorced/ Widowers	Measurement	11	11	22
		% in marital status	50%	50%	100%
	Married	Measurement	26	8	34
		% in marital status	76.5%	23.5%	100%
Total		Measurement	37	19	56
		% in marital status	66.1%	33.9%	100%

3b Chi-Square Tests					
	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	4.175	1	.041		
Continuity Correctionb	3.078	1	.079		
Likelihood Ratio	4.144	1	.042		
Fisher's Exact Test				.050	.040
Linear-by-Linear Association	4.100	1	.043		
N of Valid Cases	56				

Table 4: Association between lineworkers beliefs about the health risks of creosote-impregnated wooden poles and their years of service.

4a Association between knowledge of creosote-impregnated WPs and years of service					
			Creosote health risk		
			Yes	No/I don't know	Total
Years of Service	Up to 4 years	Measurement	17	14	31
		% in years of service	54.8%	45.2%	100%
	5 years and above	Measurement	20	5	25
		% in years of service	80%	20%	100%
Total		Measurement	37	19	56
		% in years of service	66.1%	33.9%	100%

4b Chi-Square Tests					
	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	3.908	1	.048		
Continuity Correctionb	2.867	1	.090		
Likelihood Ratio	4.038	1	.044		
Fisher's Exact Test				.087	.044
Linear-by-Linear Association	3.839	1	.050		
N of Valid Cases	56				

Over half of the respondents (58.9%, n=33) reported that creosote used as a WPs impregnator may have negative environmental effects. Specifically, 42.9% (n=24) identified soil as potentially affected, 30.4% (n=17) identified the water table, 23.2% (n=13) identified biodiversity and 8.9% (n=5) air. A significant percentage (41.1%, n=23) reported that they did not know whether creosote had environmental impacts, while none of the respondents considered creosote to be environmentally harmless (Figure 1). A statistically significant association was observed between years of service and perception of environmental risk (χ^2 (1) = 8.285, p = 0.004; n=56). Workers with ≥5 years of service more frequently perceived creosote as posing an environmental risk compared with those with ≤4 years of service (80 % vs. 41.9% (Table 5).

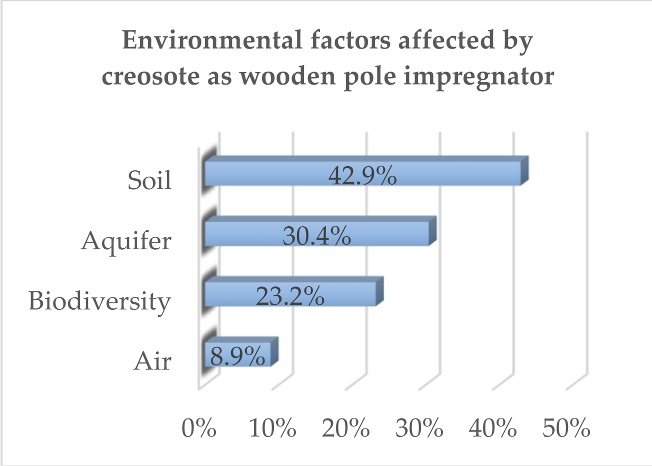

Figure 1: Environmental factors perceived by lineworkers as affected by creosote used as a wooden pole impregnator.

Table 5: Association between lineworkers beliefs about the environmental risks of creosote-impregnated wooden poles and years of service.

5a Association between knowledge about environmental risks of creosote-impregnated WPs and years of service					
			Creosote danger to the environment		Total
			Yes	No/I don't know	
Years of service	Up to 4 years	Measurement	13	18	31
		% in years of service	41.9%	58.1%	100%
	5 years and above	Measurement	20	5	25
		% in years of service	80%	20%	100%
Total		Measurement	33	23	56
		% in years of service	58.9%	41.1%	100%

4b Chi-Square Tests					
	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	8.285	1	.004		
Continuity Correctionb	6.787	1	.009		
Likelihood Ratio	8.652	1	.003		
Fisher's Exact Test				.006	.004
Linear-by-Linear Association	8.137	1	.004		
N of Valid Cases	56				

Discussion

The findings of the present study showed a high degree of correlation with the references in the studied literature. Although it provides significant benefits in extending the service life of WPs,[22] creosote also carries critical challenges for the environment and human health, primarily due to the presence of PAHs in its composition.[23]

Assessing the effects of creosote in occupational exposure is challenging, as workers are frequently co-exposed to various other carcinogens. Furthermore, exposure measurements are often inconsistent, with available data being predominantly qualitative. Consequently, research tends to focus on individual constituents, which may lead to generalized conclusions.[10,5]

This is the first study in Greece to assess the opinions and attitudes of OEDNs lineworkers regarding the use of PPE and the perceived health and environmental impacts of creosote-impregnated WPs and may serve as a foundation for future research in this field. There are limited studies regarding exposure of lineworkers, generally indirectly mentioned in some related studies as part of the groups exposed to creosote. Most studies focus on other occupations such as workers in impregnation plants or railroad ties.

Although lineworkers in OEDNs were not explicitly referenced among the occupational groups identified in the 2024 ILO global report as being simultaneously exposed to thermal stress and chemical substances, they clearly fall within this category. Their work is performed outdoors, often under high ambient temperatures, particularly during summer and involves direct contact with creosote-impregnated WPs.[13] As a result, lineworkers experience elevated occupational exposure, including thermal stress, intense UV exposure, exposure to chemical pollutants such as creosote, and an increased likelihood of parasitic diseases due to field conditions.

The findings of the present study, in which participants reported skin burns and eye irritation as the most frequent symptoms while climbing newly creosote-treated poles, are in agreement with the literature on the effects of creosote on lineworker health. During the summer months, exposure increased; workers reported that while working on impregnated creosote poles, a strong odor was released and oil secretion was observed,[2] and symptoms increased (this study).

The observed associations between marital status, years of service, and perceived health and environmental risks indicate that both personal and occupational experience may influence risk awareness among lineworkers. Greater recognition of risks among more experienced workers may reflect cumulative exposure and enhanced hazard awareness developed over time. Similarly, higher health risk awareness among married participants may be associated with increased concern for long-term health and family responsibilities. These findings are consistent with previous occupational health research showing that work experience and life circumstances shape risk perception and safety awareness.[24,25,26,27]

Despite the relevance of these findings, several limitations should be considered when interpreting the results. The convenience sampling used limits the generalizability of the findings to the broader population of lineworkers in Greece. The relatively small sample size (n=56) resulted primarily from practical constraints in recruiting potential participants, given the outdoor, highly mobile nature of linework. Nevertheless, because the total number of active overhead distribution line workers in Greece is limited, the number of questionnaires collected may be considered broadly representative of this occupational group. The sample size, determined by accessibility during the study period, was adequate for exploratory analysis but limits statistical power and the generalizability of the findings. Selection bias may be present, as participants who agreed to take part in the study may differ systematically from non-participants. In addition, reliance on self-reported measures may have introduced recall bias and limited objective verification of reported responses. Finally, an inherent limitation of self-reported instruments is the absence of mechanisms to ensure the objectivity of participants' answers.

Regarding infrastructure alternatives, while materials such as steel, concrete, composite poles, and underground cabling are available, each presents practical, economic, or technical limitations.[28] Underground networks entail substantially higher construction costs, reinforced concrete poles are suitable only for specific structural conditions and more environmentally friendly alternatives often involve higher costs and shorter service life. Consequently, WPs and creosote remain widely used in OEDNs due to their cost-effectiveness, durability, ease of installation and insulating properties, with regulatory approval for creosote use extending until 31/10/2029.[22,29]

Conclusion

The main cause of the negative effects on both line workers' health and the environment is the presence of PAHs in creosote. Ensuring their health and safety, as well as protecting the environment, requires a holistic and systematic approach. Greater emphasis needs to be placed on the use of PPE in conjunction with continuous retraining of employees to enhance awareness of risks and compliance with safety practices. At the same time, information and training on environmental protection during the execution of the works could represent an integral part of professional training. The findings highlight the importance of exploring more sustainable infrastructure solutions and less hazardous preservatives. Further scientific research is also needed on soil contamination caused by creosote-impregnated poles. Additionally, further studies should examine the health effects of occupational exposure to creosote among lineworkers, not only during contact with newly creosote-treated WPs, as assessed in the present study, but throughout the full duration of their work. Future research should account for additional modifying factors such as age, habits, medical history, daily work practices, occupational environment and climatic conditions, and should investigate the combined effects of all chemical constituents of creosote to enable comprehensive risk assessment and targeted preventive measures.

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