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Odour Nuisance of Railway Sleepers Saturated with Creosote Oil

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In recent years, Europe has increased rapidly the use of concrete railway sleepers, however wooden sleepers are still used, mainly for technical reasons (eg. low sensitivity to temperature fluctuations), as well as economic (eg. costs of removal of very large number of sleepers). Wood used in the construction of the railway tracks is exposed during use on changing weather conditions, including temperature, humidity, UV light, as well as biological agents. Effect of these factors has a devastating impact on raw wood. Therefore, impregnating of wood material by suitable chemical compounds is carried out. The main goal is to maintain, protect it against destructive factors, eradicate biological corrosion, and to provide specific useful properties - for example, hydrophobic or increasing the biological resilience. For impregnating organic agents include, among others, carbolineum, dinitrophenol, sodium dinitrophenolan, pentachlorophenol, sodium pentachlorophenolate, naphthenates of copper, chloroacetamide and creosote. The last of these is the best known organic agent used to impregnate wooden railway sleepers (95% wooden railway sleepers impregnated in 2010.). Widespread use of creosote as a wood preservative creates the need to verify the current position on the impact of those compound on humans and the environment, especially considering its odor nuisance.
In the paper, the outline of the issues of wooden sleepers saturation with creosote oil was presented, with particular emphasis on the impact of the impregnation on the environment, including odors. For the purpose of illustrate the problem, there were presented the results of olfactometric analysis of two objects (technical-holding stations), where the creosote oil is used for sleepers impregnation. In addition, article contains the case of social conflict caused by the impact of one of these objects on the residential area. Tests were made using two types of field olfactometers - Nasal Ranger and Scentroid SM-100. Olfactometric analysis was accompanied by control of the current meteorological situation. On the basis of the research, identified the main sources of odor nuisance were identified and the range of influence of analyzed objects was designated. Further, in this article was compared the efficiency of use of two cited devices to olfactory impact assessment of railway sleepers.

1. Introduction

Sleepers impregnated with creosote oil are sources of olfactometric impact, and their use is associated with a number of complaints of the residents of surrounding areas.
Sleepers are beams running transverse to the track, where by means of special fastenings, the rail is fixed. The wooden sleepers are not conductive of electricity and they have highly effective vibration damping. In recent years, Europe has increased rapidly the application of concrete sleepers, but the wooden sleepers are still used in mainly technical reasons (eg. low sensitivity to temperature variations), as well as economic reasons (eg. cost of removal of very large number of sleepers). Woody material used for the construction of the railway surface is exposed during use to the changing weather conditions, among others, temperature, humidity, UV radiation, and also biological activities. Effect of these factors has a devastating impact on raw wood. Therefore, the impregnation of wooden material is carried out using suitable chemicals in order to maintain protection from the destructive of factors, eradicate biological corrosion, and to provide specific performance, for example hydrophobic or increase the biological resistance. The diversity of the protected

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material, method of impregnation and functions that impregnates have to be met make the issue of the treatment of wood is quite complicated. (Jaworska et al., 2013). Wood preservatives can be divided into inorganic and organic. For impregnation of organic include: carbolineum, dinitrophenol, dinitrofenolan sodium pentachlorophenol, pentachlorophenolate sodium, copper naphthenates, chloroacetamide and creosote. The last of these compounds is one of the best known and most used of the organic compounds for the saturation of wooden railway sleepers - 95% of impregnated wooden sleepers in 2010. (Jaworska et al., 2013). The use of this impregnation agent to protect wood sleepers increases the durability of 10 to 30 years. Creosote is an oily liquid with a characteristic odor (Kawczyński, 1972).

It is a mixture of products of the distillation of bituminous coal tar forming within a temperature range 200-360ºC. It consists of various aromatic compounds. The largest group of compounds of the impregnating oil are neutral constituents (80-90%). These are mainly polycyclic aromatic hydrocarbons: naphthalene, anthracene, phenanthrene, pyrene, chrysene, and others. The content of acidic components, mainly phenols, varies mainly in the range 4-16% (particular concentration allow standards of different countries). Basic components are the 3.5-4.5% oil impregnation. These are primarily pyridine and its derivatives, quinoline and its methyl derivatives, and other isoquinoline (Kawczyński, 1972). Wood impregnated with this material is characterized by unpleasant, sharp fragrance, perceptible sometimes within a few meters. The color of the treated wood is brown, sometimes black. Wood impregnated with creosote oil is characterized by increased susceptibility to fire, and the creosote oil is also highly flammable. Therefore, the accumulation of wood creosote in the vicinity of residential buildings may pose a risk of a potential fire hazard (Wasilewski and Stelmach, 2014). One of the major problems of the railway infrastructure is a high percentage of track laid on wooden sleepers, which largely exceeded nominal service life (17-18 years for softwood). According to the literature (Betlej, 2012), in Poland, the supply of waste wood treated with protection agents is about 120 000 Mg/year, and this number, in connection with the planned renovation of the railway network in the coming years, is likely to increase. Waste wooden pieces of railway tracks are sorted and partially re-used on the raceways (approx. 30%). The remaining part of this waste is stored at the premises of repair services of Polish State Railways (PKP) and offered for sale of garden, building and fuel purposes. Waste wooden pieces of railway tracks are often used in gardens to build gazebos, patios, fences, driveways and garden paths. They are used also to strengthen the slopes (Wasilewski and Stelmach, 2014).

2. Purpose and scope of the research

The main aim of the study was to assess the impact of olfactory sleepers saturated with creosote oil. In addition, the partial aim was to compare the use of two types of olfactometers field to determine the odour concentration of creosote oil from the railway sleepers. So far, odorimetric field studies were conducted using the olfactometer Nasal Ranger. During examinations of the present study, it was used also Scentroid SM-100 olfactometer, characterized by improved precision of determinations than the Nasal Ranger, because of the smaller step between the values of the ratio of the purified/contaminated air.

The scope of the research included the preliminary and field studies. They consisted of three stages: psychophysical tests using markers Sniffin'Sticks, field studies carried out on the parking PKP station and field research conducted at the Technical-and-Parking Metro Station.

3. Object of the study

Tests were carried out on the parking PKP station and Technical-and-Parking Metro Station. The drawings 1-3 shows the locations of points of research on these objects. Parking PKP station was established in the 30s of the last century. The main objects of the station is the roundhouse and the hall-of-whole-trains where the trains enter, are converted in a loop and then are prepared to go on tour. There are routed also tracks for long-distance trains. Trains, bypassing the stop, are directed at the city line. (Torowy.blogspot, 2016). Figure 1 shows the locations of all the points of research in the parking PKP station, while Figure 2 - the distribution of research points around stack of sleepers saturated with creosote.

Technical-and-Parking Metro Station is a station of the subway, which acts as the technical workshop and the first subway line. It was designed in the 70s of the twentieth century. There is a technical background of subway (where the necessary repairs are made), automatic carriage wash (wash has a sewage treatment plant, the water circuit is closed) and platforms to enable workers to maintain carriage and keep them clean. In the area of the station is also a section of track with a length of 1.200 meters, designed to test the subway trains. The station is located at the southern end of the line, on the border with forest. Surface station is 33 hectares. (STP, 2016)

Figure 1. Location of the points of research on the parking PKP station

Figure 2. Location of the points of research on the parking PKP station, around wooden sleepers stacks

Figure. 3. Location of the points of research on the Technical-and-Parking Metro Station

4. Results and discussion

4.1. PKP Station

The highest values of the odour intensity (i=2 - weak odor) were recorded at the measuring points in close proximity (about 0.5 meters) from the stack of sleepers (the stacks 1-3). At a distance of 3 meters from the stacks in the north - on the leeward side of the source - the value of odour intensity decreased to 1. On the windward side of the stacks, in the distance of 2 m odour is undetectable (odour intensity value equal to 0). Measurements conducted with both olfactometers Nasal Ranger and Scentroid SM-100 shows that the greatest odour concentrations of creosote oil on the PKP Station (6 ou/m^3) are in the immediate vicinity of stored logs, freshly saturated with creosote. Lower concentrations (maximum value of odour concentration 4 ou/m^3) are detected near piles from 2013. In the other measuring points, located directly on the railroad tracks, odour concentrations were ranged from 0 to 4 ou/m^3. The greater the distance measuring points from the source of the smell - of railways saturated with creosote - the lower the concentration of the smell of creosote. Based on the observations it can be concluded that approx. 3-5 m from the source, the concentration decreases by 1-2 ou/m^3.

4.2. Technical-and-Parking Metro Station

The value of odour intensity recorded in the Technical-and Parking Station ranged from 0 to 2. The highest among them were found in the eastern part of the subway, approx. 0.5 m from the uncovered sleepers. Measurements conducted both olfactometers Nasal Ranger and Scentroid SM-100 shows that the greatest odour concentrations (2-6 ou/m^3) of creosote oil on the Technical and Parking-Warsaw Station are on the east side of the station. In other measurement points, located at distances of 0.5-3 m to the railway tracks, the odor concentration from 0 to 4 ou/m^3 has been found. The maximum range of influence of sleepers saturated with creosote oil was 8 m. After the distance from the source at a distance of 3 meters (leeward side), there was a decrease in the concentration of odor from 3 ou/m^3 to 2 ou/m^3, then, after another 5 m – from 2 ou/m^3 to 0 ou/m^3. Based on the observations it can be concluded that on average at 3-5 m, the concentration decreases by 1-2 ou/m^3. In the distant points located near buildings located approx. 50 meters from the railway sleepers, there were no impact of odour of sleepers saturated with creosote oil.

4.3. Comparison of two kinds of olfaceomteres

For a comparison of results of the odour concentration using two types of olfactometers, the statistical analysis was performed. The results are summarized in Table 1.

Table 1: Statistical analysis results of comparison of two kinds of olfactometers

Olfactometer	Five Tukey numbers					Saphiro-Wilk		F-Snedecor		Mann-Witney		Cor
	min	low	med	up	max	W	p-val	F	p-val	F	p-val	
	PKP Station											
Nasal Ranger	0	2	2	4	6	0.897	0.0005	0.9701	0.92	1036	0.81	0.94
SM-100	0	2	3	4	7	0.913	0.0020					
	Technical-and-Parking Station											
Nasal Ranger	0	0	0	2.5	6	0.789	$1x10^{-5}$	0.852	0.673	638	0.551	0.99
SM-100	0	0	0	3	7	0.778	$6x10^{-6}$					

To check whether the data come from a normal distribution, the Shaphiro-Wilk tests were performed. In both cases, the p value is less than a predetermined level of significance (0.05), therefore the hypothesis of normality must be rejected. Based on the result of the F-Snedecor test it should be recognized that there are no reasons to reject the hypothesis of homogeneity of variance. Due to the fact that the data are not normally distributed, to determine the degree of agreement between the odour concentration examined using two kinds of olfactometers - Nasal Ranger and Scentroid SM100 - Mann-Whitney-Wilcocxon test had been chosen. Based on the Mann-Whitney-Wilcoxon test it was concluded that the sample did not differ significantly.

In addition, Spearman rank correlation coefficient was calculated for the odour concentration indicated by the olfactometer Nasal Ranger and Scentroid SM-100. The value of this coefficient was 0.94, which means that the correlation between the results obtained using the above olfactometers is very high.

A similar analysis was performed for the results of research concentration and odor intensity made in the Technical-and Parking Station. In both cases, the hypothesis of normal distribution has to be rejected. There is no reason to reject the hypothesis of homogeneity of variance. P-value is greater than a predetermined level of significance, so there is no reason for this to reject the null hypothesis of Mann-Whitney-Wilcoxon test - tested values did not differ significantly. The Spearman rank correlation coefficient was 0.99, which means that the correlation between the results obtained using Nasal Ranger and SM-100 olfactometers is very high.

Figure 4 summarizes the results of scatter plots the concentration of odor obtained by olfactometers Nasal Ranger and Scentroid SM-100. There is also a regression curve and the parameters of the coefficient χ^2_r (reduced χ^2 - divided by the number of freedom degrees of freedom), R^2 (determination coefficient) $R^2_{adj.}$ (Adjusted determination coefficient), RMSE (root mean square error) and RSS (sum of squared residuals). The coefficient R^2, which measures the degree of approximation regression fit as a linear relationship between the relevant variables is more than 0.9, which means that the proposed model explains more than 90% variation. Analysis of these graphs confirmed the results of statistical analysis.

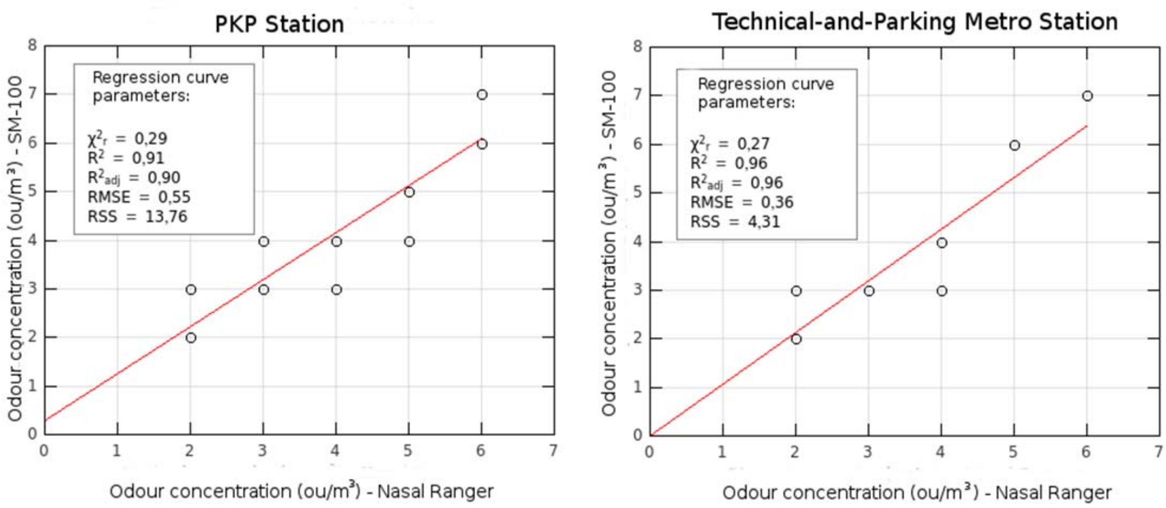

Figure 4. Scatterplots of odour concentration recults achieved by using two kinds of olfactometers on the PKP Station and Technical-and-Parking Metro Station, with regression curve and its primary parameters.

5. Conclusions

Obtained results allowed the following conclusions:

- Statistical analysis shown that the concentrations achieved by the two olfactometers (Nasal Ranger and Scentroid SM-100) under field conditions are not significantly different. It follows, that they can be used interchangeably.
- Tested olfactometers are useful for measuring the impact of olfactory sleepers saturated with creosote oil. Values of odour concentrations contained in the determination range of both olfactometers.
- A more accurate is Scentroid MS-100 olfactometer, because of the smaller dilution steps.
- Protests related to the impact of the Technical-and-Parking Station were most likely caused by the storage of railway sleepers in the open area in the eastern part of the station. Primers were inadequately protected - only covered with foil. Currently, they are stored in a locked room and are less odour burdensome, also due to the time elapsed since their soaking.
- For raceways on both the Technical-and-Parking Station and the PKP Station, are still odour affecting sleepers soaked with creosote oil. They are not covered with ballast due to the fact that they are usually moving parts of the tracks (crossovers).
- The maximum range of odours of sleepers saturated with creosote oil is less than 10 m. The biggest problems with nuisance odor are related to storage of sleepers impregnated with creosote oil.

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