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Communication to the Editor

Protection of Wood against the House Longhorn Beetle *Hylotrupes bajulus* with Sodium Chloride and Potassium Chloride

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Abstract: The effectiveness of aqueous solutions of sodium chloride and potassium chloride as wood preservatives was tested against larvae of the house longhorn beetle *Hylotrupes bajulus* (L.). Immersion of pine (*Pinus sylvestris* L.) blocks for 24 h provided only a shallow protective layer. In a test series according to EN 46 a concentration of 200 g $litre^{-1}$ potassium chloride was required for complete larval mortality within 12 weeks; 200 g $litre^{-1}$ sodium chloride failed to achieve this. With vacuum impregnation in tests according to EN 47 a concentration of 100 g $litre^{-1}$ sodium chloride achieved complete mortality of larvae within four weeks. Vacuum impregnation of 100 g $litre^{-1}$ potassium chloride attained complete mortality only after 12 weeks. Ovipositing female beetles did not avoid wooden blocks treated with either salt.

Key words: *Hylotrupes bajulus*, oviposition, wood protection, sodium chloride, potassium chloride

1 INTRODUCTION

Under dry indoor conditions wood generally only needs to be protected against insect attack. In Central Europe, the house longhorn beetle (*Hylotrupes bajulus* (L.)) is the most serious pest of construction timber. The use of organic wood preservatives (generally containing pyrethroids as active ingredients) is decreasing. Their replacements are mainly boron-based insecticides which have a low vapour pressure and good protective action against wood-boring beetles. However, clients are today cautious about the use of all artificial substances because of possible health risks. Furthermore, the problems involved in the disposal of toxic waste are of increasing importance and can no longer be ignored.

It is surprising that the use of sodium chloride as a protective agent has so far not been investigated in more detail. Although there is some mention of it in the 19th century,[1] comprehensive tests on its insecticidal and/or fungicidal effects are lacking. The following data will give evidence of the usefulness of both sodium chloride and potassium chloride.

2 METHODS

Tests were carried out with freshly hatched larvae (egg larvae) and adult females of the house longhorn beetle *H. bajulus* which were taken from the laboratory culture maintained at the BAM.

2.1 Surface application

2.1.1 Basic routine

Experiments were performed according to European standard EN 46.[2] Test specimens consisted of pine (*Pinus sylvestris* L.) sapwood blocks (50 × 25 × 15 mm). Six replicates for each test duration were immersed for

24 h in each test concentration of aqueous salt solution, or in water as a control. The application rates were calculated by weighing the uptake of the solution. Subsequently the blocks were allowed to dry for two weeks in an air-conditioned room (21°C, 70% RH). A glass slide was attached to one of the large faces of each wood block so as to form a small gap between glass and wood, into which 10 newly hatched larvae were placed at the beginning of the tests. At the end of each test period the wood was examined for living larvae by cutting it into small pieces.

2.1.2 Penetration of salt solutions

The depth of penetration of sodium chloride and potassium chloride was estimated by adding 50 g litre^{-1} ferric chloride stain to 100 g litre^{-1} solutions of both salts and immersing the test blocks for 24 h. After drying, 10 treated blocks for each salt were cut into two pieces, each 25 × 25 × 15 mm. The penetration of the stain on one cut face of each block was measured at four positions along a 25-mm edge and two along a 15-mm edge, each 5 mm apart, starting at 5 mm from the corners. The corresponding measurements of the 10 test blocks were averaged and the data used as a rough indication for the penetration depth of the salts investigated.

2.1.3 Concentration dependence

The concentration dependence of the preventive action of sodium chloride and potassium chloride was investigated after a test duration of 12 weeks. Concentrations used and salt uptake rates are given in Table 1.

2.1.4 Time dependence

The time dependence of the preventive action of sodium chloride and potassium chloride was studied for test durations of 4, 12, 16 and 20 weeks. The four concentrations used and the salt uptake rates are given in Table 2.

2.1.5 Oviposition choice test

The test specimens were prepared and treated with 200 g litre^{-1} salt solutions as described under Section 2.1.1. To find out whether the attractiveness of the wood might be influenced by the salt treatment, a choice test was performed, i.e. one salt-treated wood block and one untreated control were offered simultaneously to a mated female beetle for oviposition. Seven replicates were made for each salt, so in total 14 tests with different females, each given the choice of a fresh pair of blocks, were performed. Exposure time was one week. The test arena was a glass Petri dish (diameter: 19 cm), its bottom covered by a filter paper. Climatic conditions were 26°C and 65% RH. Blocks were examined for hatched and tunnelling larvae by cutting up the wood after 15 weeks.

2.2 Vacuum impregnation

These tests were performed according to the European standard EN 47,[3] which is used to determine the effectiveness of a wood preservative against larvae of *H. bajulus*. The test specimens were pine sapwood blocks (50 × 25 × 15 mm), which were vacuum-impregnated with aqueous solutions of different concentrations of sodium chloride and potassium chloride. The controls were impregnated with water. The salt uptake was calculated by weighing the wood blocks after impregnation. Retention rates are given in Table 3. Six small holes were pierced into each test block with an awl. A newly hatched larva was placed into each hole with its

TABLE 1

Mean Uptake Rates after 24 Hours of Immersion of Wood to determine the Concentration Dependence of Larval Mortality

Concentration (g litre^{-1})		*Control*	*1·0*	*10*	*50*	*100*	*200*
Uptake (g m^{-2}) (±SD) (per concentration $n = 6$)	NaCl	0	0·73 (±0·11)	6·45 (±0·8)	44·3 (±7·7)	80·8 (±15·5)	150·2 (±28·9)
	KCl	0	0·85 (±0·12)	7·7 (±2·6)	45·0 (±8·8)	92·0 (±14·0)	179·7 (±30·9)

TABLE 2

Mean Uptake Rates after 24 Hours of Immersion of Wood to determine the Time Dependence of Larval Mortality

Concentration (g litre^{-1})		*Control*	*50*	*100*	*150*	*200*
Uptake (g m^{-2}) (±SD) (per concentration $n = 24$)	NaCl	0	32·9 (±8·5)	59·3 (±19·8)	89 (±28·4)	101 (±32·7)
	KCl	0	33·2 (±6·5)	69·9 (±20)	113·4 (±25·1)	133 (±36·3)

TABLE 3
Mean Retention Rates after Vacuum Impregnation

Concentration (g litre^{-1})		*Control*	*1·0*	*10*	*50*	*100*	*150*	*200*
Retention (kg m^{-3}) ($\pm$SD) (per concentration $n = 10$)	NaCl	0	0·66 ($\pm$0·05)	6·8 ($\pm$1·4)	28·2 ($\pm$5·3)	65·4 ($\pm$5·2)	92·9 ($\pm$21·8)	132·3 ($\pm$23·4)
	KCl	0	0·67 ($\pm$0·02)	6·6 ($\pm$0·4)	35·4 ($\pm$2·2)	70·7 ($\pm$10·3)	110·5 ($\pm$6·3)	153·0 ($\pm$7·3)

head facing into the wood. There were ten replicate blocks for each treatment. After four weeks the blocks were examined for living larvae by cutting up the test specimens. If a live larva was found, the remaining test specimens were kept for a further eight weeks, leaving <10 replicates for final examination.

3 RESULTS

Treatment of the wood with the various concentrations of the two salts (surface treatment by dipping or vacuum impregnation) did not cause any visible change of the wood surface. After evaporation of the solvent (water) no noticeable hygroscopic effect was observed under the test conditions of 21°C and 70% RH.

3.1 Surface application

3.1.1 Penetration of salt solutions

The penetration of the salts was estimated by adding 50 g litre^{-1} ferric chloride stain to the immersion solutions. As there is no information on a possible interaction of the stain with potassium chloride or sodium chloride, the data have to be treated with some reservation.

When pine sapwood was dipped in stained aqueous solutions of potassium chloride and sodium chloride for 24 h, potassium chloride solutions penetrated better than sodium chloride solutions. Mean penetration values for potassium chloride solutions were 1·1($\pm$0·3) mm parallel and 3·3($\pm$0·7) mm perpendicular to the growth rings. For sodium chloride solutions the mean depth of penetration was 0·7($\pm$0·1) mm parallel and 1·7 ($\pm$0·9) mm perpendicular to the growth rings. Retention data confirm the better uptake of potassium chloride solutions (Table 1).

3.1.2 Dependence of mortality on concentration

In a first experiment, the survival of the larvae in the wood was correlated with the salt concentration applied to the test specimens in the 24-h dipping treatment. The uptake rates are given in Table 1.

Figure 1 gives the results for a 12-week test period. It shows that up to a salt concentration of 50 g litre^{-1} (mean uptake rate for sodium chloride: 44·3($\pm$7·7) g m^{-2}, for potassium chloride: 45·0($\pm$8·8) g m^{-2}) larval survival is not substantially affected. At and above 100 g litre^{-1} (sodium chloride: 80·8($\pm$15·5) g m^{-2}, potassium chloride: 92·0($\pm$14·0) g m^{-2}) survival is markedly reduced. In this test series wood treatment with a 200 g litre^{-1} solution of potassium chloride had already killed all larvae within four weeks.

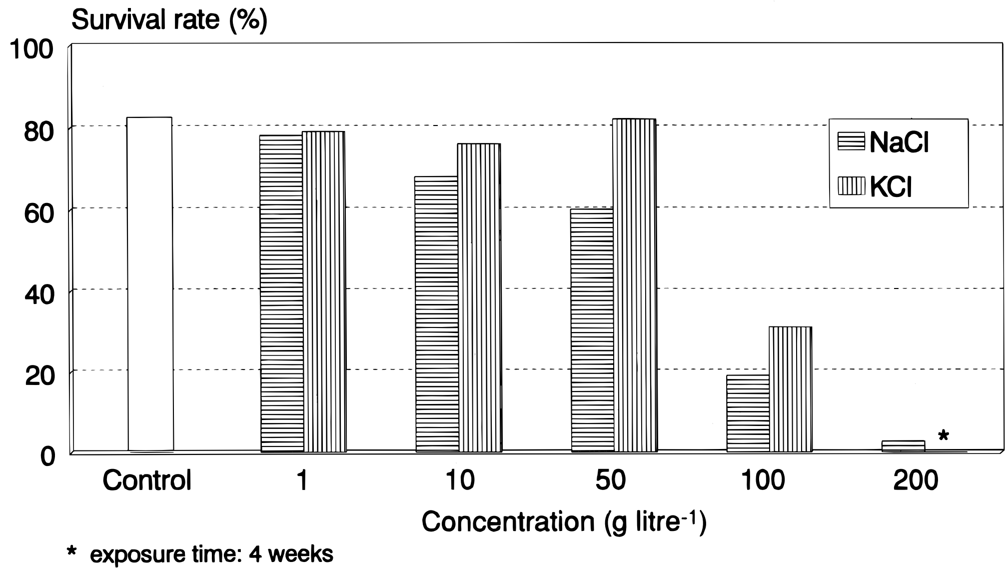

Fig. 1. Preventive effect of wood surface treatment with aqueous potassium chloride and sodium chloride solutions against *Hylotrupes bajulus* larvae after a 12-week test period.

3.1.3 Dependence of mortality on exposure time

In a second test the influence of the exposure time to potassium chloride- and sodium chloride-treated wood was examined to determine whether a prolonged test period would produce a higher mortality rate in *Hylotrupes* larvae (Fig. 2). The uptake rates, given in Table 2, are considerably lower than in the previous test, probably because the wood was taken from a different tree.

The data obtained here after four and 12 weeks of exposure confirm those of the previous test, which was run under comparable conditions (Fig. 1). The results show that even after 20 weeks, wood treated by immersion in 50 g litre^{-1} aqueous solutions of sodium chloride (32·9($\pm$ 8·5) g m^{-2}) and potassium chloride (33·2($\pm$ 6·5) g m^{-2}) did not give adequate control. Doubling the sodium chloride concentration to 100 g litre^{-1} (59·3($\pm$19·8) g m^{-2}) caused a marked decrease in the survival rate of the larvae, whilst with potassium chloride a comparable effect was achieved by tripling the concentration to 150 g litre^{-1} (113·4($\pm$25·1) g m^{-2}).

The data suggest that a longer exposure time causes little if any increase in larval mortality. Mortality generally occurs within the first four weeks of exposure to the treated wood. Most of the larvae which survive this first period will not be killed by prolonged exposure. The amount of damage in terms of wood consumed by these larvae was not determined.

3.2 Vacuum impregnation

The toxic values of sodium chloride and potassium chloride against *Hylotrupes* larvae were determined with vacuum-impregnated wood. The retention rates are given in Table 3.

In experiments with sodium chloride the concentration necessary for complete eradication of the larvae was between 50 and 100 g litre^{-1}, which are equivalent to 28·2($\pm$5·3) and 65·4($\pm$5·2) kg m^{-3} (Fig. 3). A four-week exposure time was sufficient. The potassium chloride concentration required for a complete eradication within four weeks was above 200 g litre^{-1} ($>$153 kg m^{-3}), while in a 12-week test the concentration for total mortality was also between 50 and 100 g litre^{-1} (equivalent to 35·4($\pm$2·2) and 70·7($\pm$10·3) kg m^{-3}). Survival in the control group was good.

3.3 Oviposition choice test

A choice test was used to investigate whether the salt treatment of wood has an influence on the oviposition behaviour of *Hylotrupes*. Fourteen beetles were examined in successive approaches, in which surface-treated wood and water-treated controls were offered simultaneously. The results of this experiment are given in Table 4.

Offered the choice between sodium chloride-treated and water-treated wood, four beetles did not make use of the crevice between the glass plate and the wood. They placed their eggs on the filter paper that covered the bottom of the test arena. These eggs were not considered for evaluation. Two other beetles placed their eggs on salt-treated wood only; a third chose both the salt- and the water-treated wood blocks for oviposition.

When offered potassium chloride-treated and water-treated wood simultaneously, two beetles placed their eggs only on the filter paper. Two beetles chose only the salt-treated wood, and one other chose the salt- and the water-treated wood. Two laid their eggs only on the control block.

Treatment with sodium chloride and also with potassium chloride solutions caused no salt-specific inhibition of oviposition, as these wood blocks were accepted

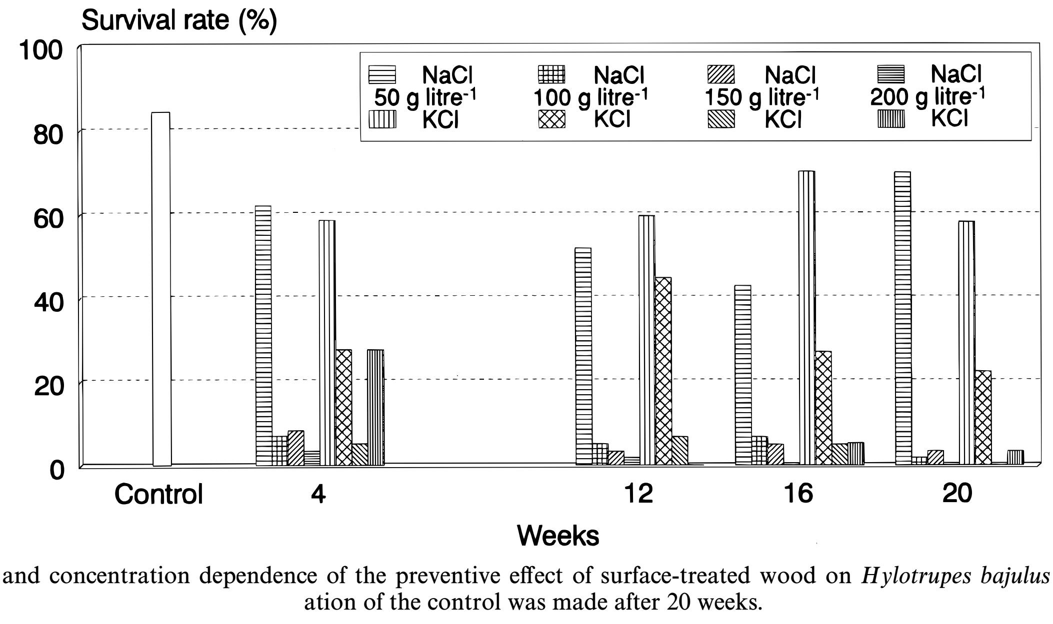

Fig. 2. Time and concentration dependence of the preventive effect of surface-treated wood on *Hylotrupes bajulus* larvae. Evaluation of the control was made after 20 weeks.

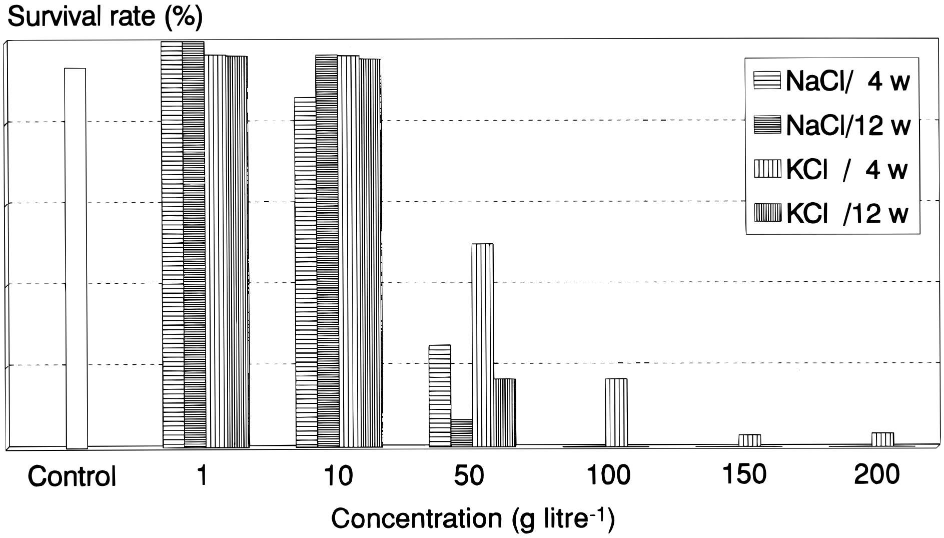

Fig. 3. Eradicating effect on *Hylotrupes bajulus* larvae of aqueous solutions of potassium chloride and sodium chloride after vacuum treatment of wood with various concentrations. The salts are slow-acting, the lethal effect increasing with duration of exposure. Evaluation of the control was made after 12 weeks.

even more frequently than the water controls by *Hylotrupes* females. The oviposition on the filter paper covering the bottom of the test arena instead of using the gap between the wood and the filter paper confirms observations by Hinze.[4] She showed that near-field orientation to an oviposition place is strongly guided by surface structures of potential oviposition sites.

The salt treatment of wood has no ovicidal effect. The hatching rates on sodium chloride-treated wood (86%) and on potassium chloride (83%) were close to those measured on the water controls (78% in the sodium chloride test, 84% in the potassium chloride test). The preservative effectiveness of the salts differed slightly. While no larvae survived the test period of 15 weeks on the sodium chloride-treated blocks, around 10% survived on the potassium chloride treated blocks.

4 DISCUSSION

The tests reported above show that the application of sodium chloride solutions, and, with slightly lower success, potassium chloride solutions, is an effective method of protecting pine wood against the attack of the longhorn beetle *H. bajulus*. One explanation for this effect may be the dehydration of larvae when feeding on the salt-treated wood. This suggestion is supported by current investigations on the preventive action of salt solutions against termites (Hertel, H., unpublished): the data show that drywood termites, which have no access to open water and gain it almost exclusively from their metabolism, are as susceptible to sodium chloride-treated wood as *Hylotrupes* larvae. On subterranean termites, however, there is only minor impact. As these

TABLE 4
Oviposition by Adult Female *Hylotrupes bajulus* given a Choice between Salt-Treated and Control (Water-Treated) Pine Sapwood, and Egg Development after 15 Weeks

			Larvae after 15 weeks			
Treatment[a]	*Batches* (n)	*Eggs* (n)	*Hatched* (n)	*Living* (n)	*Dead* (n)	*Survival rate based on the numbers of hatched eggs* (%)
200 g litre^{-1} NaCl	3	149	128	0	128	0
Water control	1	114	89	86	3	96·6
Filter paper	4	—	—	—	—	—
200 g litre^{-1} KCl	3	161	134	14	120	10·4
Water control	3	129	109	107	2	98·2
Filter paper	2	—	—	—	—	—

[a] Treatment was by immersion.

are able to take water to their food source and so dilute its salt concentration, they can feed on sodium chloride-treated wood. Differential susceptibility of gut flora may also be an explanation.

Treatment of wood by immersing it in a salt solution for 24 h produces a surface protection that is restricted to a shallow layer of only a few millimetres; it varies considerably between different test specimens and salt components. The strong influence of the wood quality becomes evident by comparing the salt uptake by the test specimens used for the tests to determine the concentration (Section 3.1.2) and the time dependence of mortality (Section 3.1.3). The wood, which was taken from different trees for the two sets of experiments, had in the first set (Section 3.1.2) an average mass of $11{\cdot}09(\pm 0{\cdot}86)$ g per test block prior to immersion; in the second set (Section 3.1.3) this was $9{\cdot}8(\pm 0{\cdot}8)$ g; here the salt uptake rate was reduced by about one-quarter (Tables 1 and 2). Numerous routine laboratory tests of biocides according to EN 46, however, give no consistent correlation between the density of the wood and the uptake of the solution (Hertel, H., unpublished).

A detailed analysis of the data revealed that some larvae survived in wood blocks with low uptake within the range for a given concentration. The test duration plays only a minor role, as an extension of longer than 12 weeks has almost no effect in increasing mortality. Apparently the protective action can only be achieved if the salt concentration is sufficiently high to kill the larva before it bores through the treated wood layer. When hatching larvae manage to cross this barrier they may survive and damage deeper layers of the wood. The variability in penetration of the solvent, which confronts the larvae with layers of different thickness of salt-treated wood, may be one explanation for the variation of the survival rate at immersion concentrations of 100 g $litre^1$ and higher.

In all laboratory tests for the determination of the eradicant action against larvae of *H. bajulus* according to European standard EN 22[5] the locations of larvae after a test period of 12 or 24 weeks are measured. Data from tests on a number of standard wood preservatives (Hertel, unpublished) show that larvae only survive such treatments if they manage to penetrate into deeper, untreated zones. The next time these larvae come into contact with the insecticide is at the end of their development, when shortly before pupation they prepare an exit tube that ends close to the wood surface. Only a thin layer of wood is left, which will be penetrated when the imago leaves the wood through a flight hole. Here the uptake of treated wood might kill the mature larva or prevent the beetle from emerging.

A detailed look at the data (Fig. 2) shows that immersion of wood in a 100 g $litre^{-1}$ solution of sodium chloride is sufficient to kill more than 90% of the larvae within four weeks, and after 20 weeks only 5% are still alive. The median wood consumption by one larva during its lifetime is about 78 cm^3,[6] so the damage caused by the small numbers of survivors could probably be tolerated. Currently a preservative is only accepted in Europe if it causes complete mortality in tests according to EN 46 treatment. This should be reassessed, because a less strict requirement would help considerably to reduce the quantity of wood preservatives applied.

The salt retentions which are required to provide an adequate protection of wood were determined by the method of European standard EN 47 using vacuum-impregnated test specimens treated at different concentrations. For a four-week testing period the critical concentration of sodium chloride is between 50 and 100 g $litre^{-1}$ for fully impregnated wood, whereas with potassium chloride even at the highest concentration tested (200 g $litre^{-1}$) some larvae were still alive. When the test period was extended to 12 weeks, however, all larvae were killed.

For practical use, the problem of corrosion of metal fixings has to be considered. At relative humidities above 76% and 85%, which are the dew points of sodium chloride and potassium chloride at 25°C, these salts will absorb airborne water. Carbon dioxide from the air will combine with water to form H_2CO_3, which will cause corrosion, for example on iron fixings, according to the reaction: $Fe + 2\ H_2CO_3 = Fe(HCOH)_3)_2 + H_2$.

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