Electromagnetic Radiation: Influences on Honeybees (*Apis mellifera)*

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ABSTRACT

Focussing on the influences of non-ionizing radiation towards the behaviour of the honeybee (*Apis mellifera*), the here presented study reports partially significant results. Nowadays, there is a certain increase of radiation impact in today's environmental ecosystems, and the influence of higher frequencies on honey bees is analyzed by the workgroup "educational informatics" since 2001 (Stever & Kuhn 2001; Kuhn & Stever 2001; Kuhn & Stever 2002). In ecotoxicology, the honeybee (*Apis mellifera*) is of great importance as a tested species for agricultural chemicals, e. g. plant protection products and pesticides. In this case, significant variations in the behaviour of *Apis mellifera* under the influence of non-ionizing radiation were tested. The presented data set is based on earlier studies from 2005, which showed significant differences in returning, 39.7% of the non-irradiated bees came back compared to 7.3% of the irradiated ones.
Standard commercial DECT telephones were used as exposition source. Concerning possible variations in behaviour an experimental setup with irradiated and non-irradiated bee hives was assembled. The main emphasis of this study was the investigation on significant changes in the foraging flight under electromagnetic radiation influence.

Keywords: Honeybees, electromagnetic radiation, learning process, changing behaviour, ecotoxicology.

1. INTRODUCTION

This study focuses on the effects of an electromagnetic exposition caused by DECT Telephones on the behaviour of the honeybee. All researches and tests have been carried out at the Dienstleistungszentrum Ländlicher Raum (DLR), Fachzentrum Bienen und Imkerei, in Mayen during June/July 2006. There have been several scientific investigations throughout the past years concerning the electromagnetic radiation and its effects (Greenberg et al., 1981; Hartsgrove et al., 1987; Eulitz et al., 1998; Rothmana, 2000). In context of the increasing non-ionising radiation, this study focus on the effects of electromagnetic exposition on the behaviour of the honeybee. Especially towards crop pesticide testing, Apis mellifera is a confirmed test species in ecotoxicological researches. Furthermore the honeybee shows an effective learning behaviour, resulting in olfactory amenities and even forms, structures and faces and also in training abilities on certain plants (Vareschi & Kaissling, 1970; Hoefer & Lindauer, 1976; Dyer et al 2005). Apis mellifera is well suited as a bioindicator, because its brain anatomy as well as the learning regions of the bee brain are well known (Menzel & Müller, 1996; Zhang et al., 1999; Schwärzel & Müller, 2006) and the brain structure of the honeybee concerning associative learning is comparable to those of vertebrates (Bliss & Collinridge, 1993; Eichenbaum, 2004; Giurfa, 2003; Schwärzel &

Müller, 2006). Concerning the effects of electromagnetic radiation it might be possible to draw conclusions towards other organisms based on the results according to the monitoring of honeybees.

2. MATERIAL AND METHODS

2.1 Physical aspects

In this case, base stations of everyday used DECT telephones (Digital Enhanced Cordless Telecommunications) were fixed as radiation sources. Investigating on non-thermal influences of electromagnetic fields towards the learning behaviour of bees requires an exposition with an appropriate radiation frequency. The stations send out continually electromagnetic radiation with a frequency $f_S \approx 1900$ MHz and an average transmitting power P_S of 10 mW. The peak power is 250 mW and the sending signal throughout a talk is frequency modulated and pulsed with a frequency f_p of 100 Hz. For this study the base station is used as radiation source at a permanent standby mode reached with an average transmitting power of $P_S = 2.5$ mW. To analyze a possible effect of the radiation intensity, cubic radiation shields made of reed and clay were build around some of the DECT base stations (experimental group 2, EG2, refer to 2.2), which is completely permeable to the low-frequency pulse mentioned above, but enables a reduction of the high-frequency sending radiation about 50% (Moldan & Pauli, 2000). We also installed metal lattices (width 1x1 mm) between the exposed bee hives (experimental group) in order to avoid possible influences of the radiation on the non-exposed bee hives (control group, CG).
The stations were put at the bottom of a beehive, right under the honeycombs (Fig. 1).

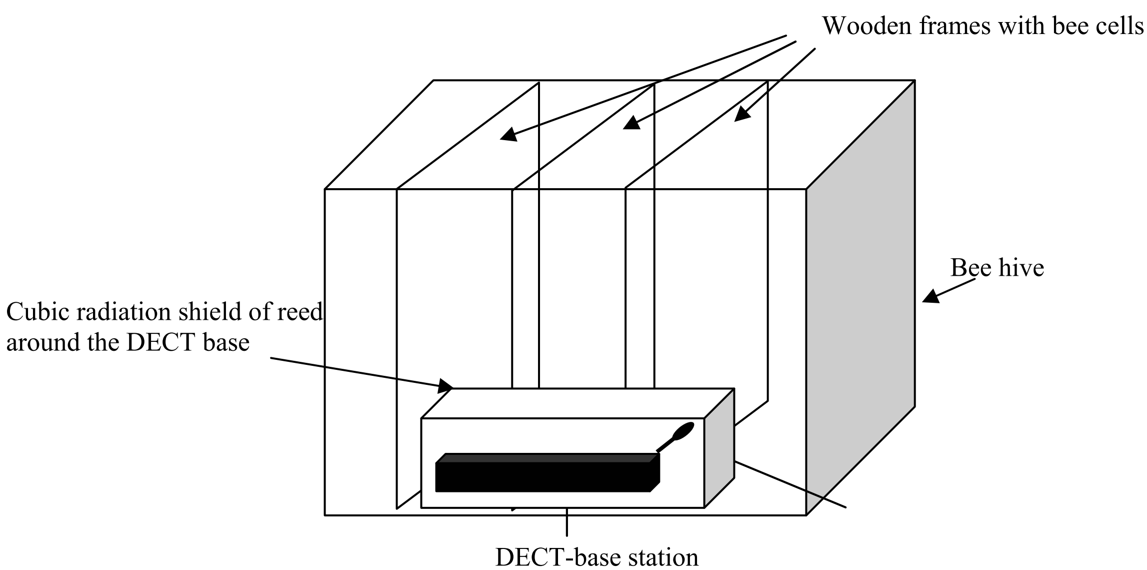

Fig. 1: Position of DECT base station within a bee hive

2.2 test objects and method

Overall, 16 Bee colonies of *Apis mellifera carnica* were used as test objects. With a permanent connection establishment between the wireless cells and the DECT base stations, the average sending power P_s could be estimated. Five of eight exposed hives were under fully electromagnetic exposure (experimental group EG 1), while in three of the exposed colonies the radiation was shielded down to 50% (experimental group EG 2, see Fig. 1). The following figure shows the whole experimental set-up:

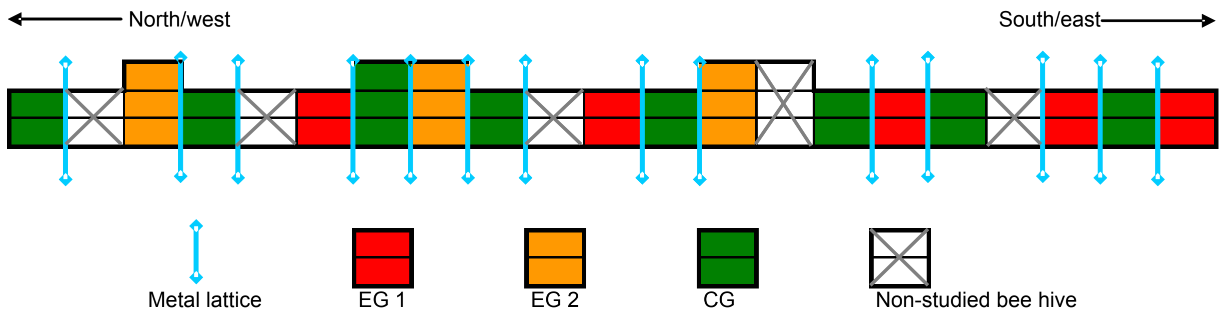

Fig. 2: Experimental set up

For one test run, 15 bees flying out of the hive were trapped with the help of plastic tubes at the hive entrance. All catched bees were short term paralyzed (using CO_2) and got marked with a marker dot on the thorax. At a distance of about 500 m to the hive all marked bees were set free simultaneously and got timed from that moment. Concerning the returning behaviour, in every test run irradiated bees were checked against non-exposed ones (EG 1 vs. CG; EG 1 vs. EG 2; EG 2 vs. CG). Time of flight for every single bee as well as certain aspects like weather, temperature and hive activity in common was reported. The returning bees were intercepted at the bee hive's entrance and the returning time was documented. The observation time lasted 45 minutes, bees that came back afterwards were disregarded in order to avoid possible mistakes for following test runs.

3. RESULTS

All results are based on collected data from June, 28.–29., and July, 9.-19., in 2006.

3.1 statistics

52 paired comparisons had to be taken into consideration, 31 pairs of bee colonies "EG 1 vs. CG", 15 pairs "EG 2 vs. CG" and finally 6 pairs "EG 1 vs. EG 2". In 22 of the 31 tested pairs "EG 1 vs. CG" more of the non-exposed bees (CG) returned to their colonies. With the total amount of returned bees (non-exposed 293 = 63.0%, exposed 229 = 49.2%) the tendency of earlier researches (Stever et al., 2005) could be confirmed.
Overall, 482 (63%) bees of the CG, 203 (56.4%) bees of the EG 2 and 365 (54.1%) bees of the EG 1 returned to their hive. These differences between the groups were not significant (Kruskal-Wallis H test).
One of the main problems of the statistical analysis was to combine the amount of returning bees with their returning time in one single value (tn_r), which reflects the predominate circumstances and enables a comparison between different testing properties. The following term presents a possible solution to this problem:

$$tn_R = n_R * 46 - \Sigma\, t_R$$

In this term the amount of returning bees n_R is multiplied by the maximum observation time + 1, then the sum of the returning time of each bee t_R, which were actually returned, is subtracted from this product. To standardize the tn_R-Index its term is related to the maximum value (for this study (n_{Rmax} = 15 bees * [45min + 1]), the tn_{max} is up to 690):

$$tn = tn_R * 100 / tn_{max}$$

It became obvious that in 29 of 31 tested pairs the *tn*-index was higher for non-exposed bees, with *tn*-index-mean ratio of 48.97 (SD 20.74) for non-exposed bees against a *tn*-index-mean ratio of 38.48 (SD 16.41) for exposed bees.
The comparison in pairs between bees of the EG 1 with bees of the CG is presented in Fig. 3:

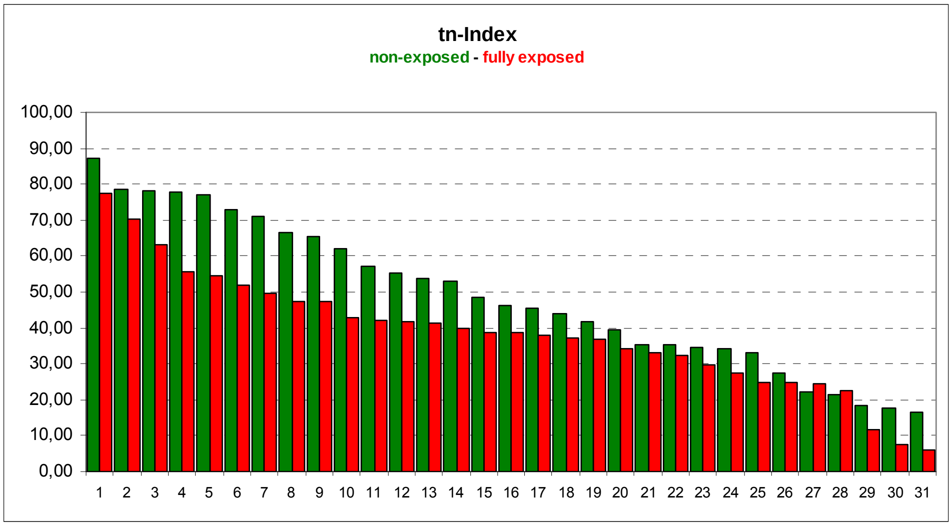

Fig. 3: *tn*-Index comparison CG (green) vs. EG 1 (red), decreasing ranks

3.2 tn-index mean comparisons for all tested groups

All deviations concerning the mean ratio for each compared group are tested for significant differences by conducting the t-test for independent variables.
Referring to the results of the t-test, mean differences between non-exposed and exposed honeybees (CG vs. EG 1) were significant ($p = 0.031$), whereas the other two tested pairs (CG vs. EG 2; EG 1 vs. EG 2) showed no significant differences.
Furthermore no correlations of uncontrollable factors like weather, temperature and flight frequency with the *tn*-Index were found, which shows that there is no influence of these uncontrollable factors concerning our results.

4. DISCUSSION

Obviously certain factors concerning the experimental set up are hard to control, but aspects such as homogenous bee colonies, the location of the tested hives and the interaction between studied bee colonies and disregarded neighbour colonies must be observed and controlled before starting a following study. Also the testing place should be selected as soon as possible, in order to allow the bees selecting a preferred region for collecting food.
The results of this study are much more heterogenic compared to our examination in 2005. But despite this aspect, still a significant difference between exposed and non-exposed bee colonies could be observed. A correlation between the independent factors weather, flight frequency and temperature on the *tn*-index could not be determined. A possible influence of the radiation intensity could not be proven by this study, because no significant differences between the group-pairs CG and EG 2 as well as EG 2 and EG 1 could be detected. Also, a clear distinction between the low-frequency pulse of the DECT base station and its high-frequency sending radiation could not be drawn, despite the fact that a significant difference between the non-exposed bees and the fully

irradiated ones can be counted as a result of the influence of high-frequency electromagnetic radiation.
A certain method to improve the experimental set up can be found in automating the testing intervals, e.g. by using a lock at the hive entrance for automatically collecting the bees. Finally, it would be also very important to measure the exact radiation intensity within the hives as well as the concrete character of the used radiation.

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