Effect of Cell-Phone EMFr on the Biology and Behavioural Aspects of the Honey Bee (*Apis mellifera* L.)

**Introduction and Rationale**

Over the last decade, there has been a rapid increase in the number of cell-phone users, the towers serving them, the area covered by the EMFr and accordingly the EMFr levels in the environment. Concomitantly, there have been several researches reporting the influence of cell-phone radiations on human physiological processes (Mann and Roschke, 1996; Weyandt *et al.*, 1996; Hocking, 1998; Boscol *et al.*, 2001; Wahab *et al.*, 2006). This risk is restricted not only to man but extends to the diversity of life we see around us. Electromagnetic radiations and phone networks have been implicated in the behavioural, biological and biochemical changes observed in birds, mice and wildlife (Lai and Singh 1995, 1996; Everaert and Bauwens, 2007; Balmori, 2009). Among insects, a few studies have been carried out on honey bees for understanding the influence of such radiations (Harst *et al.*, 2006; Stefan *et al.*, 2007).

**Honey Bees**

Honey bees belonging to genus *Apis* (Hymenoptera: Apoidea: Apidae) are social insects. They live in colonies comprising different types of individuals and exhibit division of labour. They cooperate in performing a variety of functions. There are three castes in the honey bee society: i) Workers, ii) Queen, and iii) Drones. Workers are smallest bees in the colony. They are sexually underdeveloped females. The workers feed the queen, the larvae and the drones. They are responsible for raising the comb, cleaning the hive, foraging for pollen, nectar and water. Queen is the only sexually developed female in the hive and the largest bee in the colony. She is capable of laying about 2500-3000 eggs per day during favourable conditions. Life span of queen bee is 1-3 year. Drones are the male bees without stingers. Drones do not collect food or pollen. Their sole purpose is to mate with queen and increase progeny.
Honey bees enjoy an enviable position in the insect world because these are the most extensively studied species. The recent advances in our knowledge of honey bee biology and Behaviour have been made possible by the modern bee keeping methods with potential for industrial products like honey, bees wax, royal jelly, pollination services and for using honey bees as a scientific tool for the monitoring of biodiversity and the local environment. The bees are reliable biological indicators since they possess several important ecological, ethological and morphological characteristics. They sample most of the environmental sectors like vegetation, water, soil and air. Presence of a beehive is indicative of the availability of vegetation, water and non polluted air. Man’s beekeeping assures an unlimited supply of suitable biological material to be easily sampled and analyzed throughout the year. A forager bee flies about the surrounding area of up to 4–6 km from the hive using orientation cues from the direction of sun and earth’s magnetic field, picking up air borne particle with its body hair while collecting pollen, nectar from flowers. It is because of this large exposure that the honey bees and their products have been proposed as suitable bioindicators of environmental pollution with xenobiotics like pesticides, heavy metals, radioactive molecules and radations particularly those emitted by modern electronic gadgets, microwaves, transmission towers and lately the popular cell-phones and cell-phone towers.

Honey bees are known for their navigation skills. They orient themselves according to the earth’s magnetic field and are rare species to possess magnetite in their abdomen which helps in this orientation mechanism. It is only to be expected then that the Behaviour of bees will in one way or another be influenced by electromagnetic radiations. EMFr have been reported to decrease the weight of honeycomb and the return rate of bees to hives apart from increasing mortality (Harst et al., 2006; Stefan et al., 2007).

Honey bees are crucial to crop pollination and a vital element in agriculture and food production. Approximately 80% of all insect pollination is accomplished by honey bees (Martin, 2007). However, recently, a sudden disappearance of bees from the hives, with little sign of disease or infection, has been reported from the world over (Hamzelou, 2007). It has been termed as Colony Collapse Disorder (CCD). Since honey bees are crucial to crop pollination and a vital element in agriculture and
food production, such decimation of bees is seen as a grave risk to the delicate equilibrium of the ecosystem (Martin, 2007). Though not studied, it has been linked to the increasing EMF levels in the environment. Therefore, there is an urgent need to understand the complicity of interactions involved in the influence of mobile telephony on honey bee biology and to work out a strategy of development with minimal environmental implications.

Objectives: To study the influence of cell-phone EMF on:

(a) Honey bee biology in terms of queen prolificacy and brood rearing, and
(b) Honey bee behaviour in terms of foraging efficiency, honey hoarding and pollen stores.

Materials and Methods

Experimental Material
Eight colonies of honey bees (*Apis mellifera* L.; Italian bees) kept in standard Longstroth hive were taken for each experiment in the apiary of Zoology Department, Panjab University, Chandigarh (Fig. 4.1a). The brood chamber of each hive was 240 mm long, 250 mm wide and 172 mm in height. Each box contained 8 frames (230 mm length × 145 mm breadth). The colonies were maintained to bring them to almost equal strength (~10,000 bees per colony), brood and pollen status. The age of queen was 1 year. Four colonies (T₁, T₂, T₃, and T₄) were marked as test colonies (Fig. 4.1b).

Experimental Set-up
Each colony was provided with two functional cell-phones of GSM 900 MHz frequency band and the average power density in hives was 8.549 μW/cm². The cell-phones were placed on the two side walls of the beehive in call mode. One served as receiver while the other was connected with tape recorder to keep sound intact and served as the transmitter. EMF power density was measured with the help of RF Power Density Meter (Fig. 4.2a). Two colonies marked as Blank (B) were equipped with dummy cell-phones (Fig. 4.2b), while a set of another two colonies without any cell-phone were maintained as Control (C) (Fig. 4.3a).
The experiments were performed during March–May, and September–November as these are the best seasons for the honey bee activity. The comparative performance of the colonies maintained at the same locus in terms of biological and behavioural aspects upon exposure to cell-phone radiations for two different time durations was studied. Experimental area was free from any kind of EMF radiations (Fig. 4.3b).

Fig. 4.2. a) Experimental set-up in the test colony showing placement of cell-phones and RF Power Density Meter, and b) Placement of blank colonies in the Apiary.

Fig. 4.1. a) Research apiary at the Department of Zoology, Panjab University, Chandigarh, and b) Location of test colonies (T1 to T4) in the apiary.
Fig. 4.3. a) Placement of control colonies in the apiary, and b) The experimental area of the Apiary.

EMFr Exposure
The honey bees were exposed to cell-phone EMFr for two durations of time.

a) Exposure was given to the test colonies (T₁, T₂, T₃, and T₄) twice a day, each time for 15 minutes during the period of peak bee activity (1100 hrs and 1500 hrs) two days per week for 8 weeks between March 15 and May 15, 2008.

b) Exposure was given to the test colonies (T₁, T₂, T₃, and T₄) twice a day, each time for 30 minutes during the period of peak bee activity (1100 hrs and 1500 hrs) two days per week for 8 weeks between September 15 and November 15, 2008.

Parameters Studied

Biological Aspects
The following parameters were recorded during observations:

(i) Brood Area: The total area under brood comprising eggs, larvae, and sealed brood was recorded in all the experimental colonies. Following the method of Al-Tikrity et al. (1971), this was measured with the help of a 1 cm² grid mounted on a comb frame (Fig. 4.4a).

(ii) Queen Prolificacy: Following the widely used method given by Sharma (1958), it was measured in terms of egg laying rate of the queen. In order to determine the number of eggs laid by the queen per day, the total brood area measured with the help the grid (Fig. 4.4b) was multiplied by a factor of 4 to calculate the total
number of cells containing brood (there are 4 cells per cm$^2$ of comb). This number was divided by 21 (as the average time taken for an egg to change into an adult worker is 21 days) to get the egg laying rate of the queen. Thus, queen prolificacy (QP) was calculated as:

$$QP = \frac{\text{Total brood area (cm}^2\text{)} \times 4}{21}$$

Fig. 4.4. a) The 1 cm$^2$ grid used for taking measurements, and b) Grid superimposed on brood to measure total brood area.

Behavourial Aspects

The foraging behaviour of bees and the pattern of colony growth upon exposure to cell-phone EMF were studied as given below:

(i) **Foraging Behaviour**: This was studied as flight activity, pollen foraging efficiency and returning ability of bees before and during exposure.

(a) **Flight Activity** was measured as number of worker bees leaving the hive entrance per minute before and during exposure.

(b) **Pollen Foraging Efficiency** was measured as number of worker bees returning to the hive entrance with pollen loads per minute before and during exposure.

(c) **Returning Ability** was determined by counting the total number of worker bees returning to the hive per minute before and during exposure.
(ii) **Colony Growth:** This was studied in terms of bee strength, honey store and pollen stores.

(a) **Bee Strength** was measured as total number of bee frames (frames fully covered with bees) per colony.

(b) **Honey Stores**, the area containing ripe and unripe (sealed and unsealed) nectar, (Fig. 4.5a) was measured in cm$^2$ with the help of grid (Al-Tikrity *et al.*, 1971)

(c) **Pollen Stores**, the portion of comb containing cells filled with stored pollen (Figs. 4.5b) was measured by the grid method described above and expressed in cm$^2$.

**Fig. 4.5.** Comb frame showing a) sealed and unsealed honey, and b) stored pollen.

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**Results**

**Colonies Exposed to Cell-Phone EMFr for 15 minutes**

The results of the studies carried out on biological and behavioural aspects of honey bee colonies exposed to cell-phone radiations for 15 min are presented here under. The blank did not show any difference as compared to control and was therefore not included for detailed observations. This experiment was conducted during March – May. Late spring in Chandigarh is a period of intense honey bee activity. The
response of the *A. mellifera* colonies to experimental conditions is described under suitable heads and tabulated in Tables 4.1, 4.2, and 4.3.

1. **Biological Aspect**

**Total Brood**

The mean area under brood in the control colony was 1975.4±46.3 cm$^2$ at the start of the experiment and 2033.8±60.9 cm$^2$ at the end of the experiment while it was 1966.4±56.3 cm$^2$ in the experimental colony at the start and 521.2±37.0 cm$^2$ at the end of the experiment during which two fifteen minute exposures per day were given twice a week over the period extending from March to May (Table 4.1). Comparison of the data for control and treated colonies at the end of the experiment revealed that there was significant ($P<0.01$) decline in the area under brood (Table 4.1).

**Table 4.1. Changes in the colony status in terms of brood area and queen prolificacy of *Apis mellifera* exposed to cell-phone radiations for 15 and 30 min, respectively.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control</th>
<th>EMFr Exposure (15 min)</th>
<th>Control</th>
<th>EMFr Exposure (30 min)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Total Brood Area</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>(cm²/colony)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start</td>
<td>1975.4±46.3</td>
<td>1966.4±56.3 *m</td>
<td>2008.7±32.8</td>
<td>1962.0±37.7 *m</td>
</tr>
<tr>
<td>End</td>
<td>2033.8±60.9</td>
<td>521.2±37.0 ** &amp; ^</td>
<td>2150.9±37.3</td>
<td>70.6 ±2.4 ** &amp; ^</td>
</tr>
<tr>
<td><strong>2. Queen Prolificacy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Eg./laying rate/day)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start</td>
<td>376.2±10.6</td>
<td>368.9±11.2 *m</td>
<td>382.5±14.8</td>
<td>371.3±5.9 *m</td>
</tr>
<tr>
<td>End</td>
<td>387.4±12.4</td>
<td>98.8±7.3 ** &amp; ^</td>
<td>409.5±16.4</td>
<td>13.3±4.6 ** &amp; ^</td>
</tr>
</tbody>
</table>

Data presented as mean±SE; For a particular exposure duration, ns, * and ** represent not-significant, or significant difference between control and EMF exposed at $P<0.05$ and 0.01 for respective parameter. Letter (A) in a column, for a particular treatment between start and end of experiment represent significant difference at $P<0.01$
**Queen Prolificacy**

The mean egg laying rate of the queen in the control colony was 376.2±10.6 and 387.4±12.4/day at the start and end of the experiment respectively. It was 368.9±11.2 and 98.8±7.3/day in the colony exposed to the cell-phone radiations. The reduction in queen prolificacy was significant (P<0.01) (Table 4.1).

**2. Behavioural Aspects: Foraging Behaviour**

**Flight Activity**

Observations were taken for the number of bees leaving the hive entrance per minute immediately before the start of the experiment and during the 15 min exposure to cell-phone radiations. Though there were almost no fluctuations in case of the control for these times of observation, the experimental colonies recorded a definite decline which reached a 22.8±1.4 bees/min as compared to 34.1±2.6 before exposure and 35.9±2.3 bees/min in case of control (Table 4.2).

**Returning Ability**

The number of bees returning to the hive per minute during the experimental period was recorded. It was 39.6±3.3 bees/min for the control and 36.4±2.8 for the experimental colonies before the start of cell-phone radiation exposure. After exposure the number was seen to fall in case of the treated colonies and reduced to 28.3±1.9 bees/min (Table 4.2).

**Pollen Foraging Efficiency**

Worker bees returning to the hive with pollen were counted at the hive entrance. It was observed that number of pollen foragers was almost same (7.0±0.5/min and 6.8±0.5/min) for the control and experimental colonies before the start of exposure (Table 4.2). However, after the fixed duration of exposure to cell-phone radiation there was a fall in number of pollen foragers in case of the treated colonies (4.6±0.4 bees/min) (Table 4.2).

**3. Colony Growth**

**Bee Strength**

The number of comb frames completely covered with bees is a good index of colony growth. Experiment was started with 8 bee frames in all the colonies. At the end of
the experiment it was observed that there were 9 bee frames in the control (Fig. 4.6a) 
and five in the treated colonies (Table 4.3).

**Table 4.2. Changes in the foraging behaviour of *Apis mellifera* exposed to cell-
phone radiations for 15 and 30 min, respectively.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control</th>
<th>EMFr Exposure (15 min)</th>
<th>Control</th>
<th>EMFr Exposure (30 min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Flight Activity</td>
<td></td>
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<td></td>
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<tr>
<td>(No. of workers bees leaving</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>the hive entrance/ min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before exposure</td>
<td>35.9±2.3</td>
<td>34.1±2.6 ns</td>
<td>20.4±1.6</td>
<td>18.7±1.8 ns</td>
</tr>
<tr>
<td>During exposure</td>
<td>37.2±2.3</td>
<td>22.8±1.4 **     *</td>
<td>21.9±1.8</td>
<td>7.3±0.9 ** *</td>
</tr>
<tr>
<td>2. Returning Ability</td>
<td></td>
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<td></td>
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<tr>
<td>(No. of worker bees returning</td>
<td></td>
<td></td>
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<tr>
<td>to the hive/min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before exposure</td>
<td>39.6±3.3</td>
<td>36.4±2.8 ns</td>
<td>28.4±2.2</td>
<td>26.1±1.0 ns</td>
</tr>
<tr>
<td>During exposure</td>
<td>41.3±3.3</td>
<td>28.3±1.9 ** *</td>
<td>29.8±2.7</td>
<td>3.3±0.5 ** *</td>
</tr>
<tr>
<td>3. Pollen Foraging Efficiency</td>
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<td></td>
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<tr>
<td>(No. of worker bees returning</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>with pollen loads/min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before exposure</td>
<td>7.0±0.5</td>
<td>6.8±0.5 ns</td>
<td>5.3±0.4</td>
<td>4.9±0.3 ns</td>
</tr>
<tr>
<td>During exposure</td>
<td>7.2±0.5</td>
<td>4.6±0.4 ** *</td>
<td>5.1±0.4</td>
<td>0.6±0.2 ** *</td>
</tr>
</tbody>
</table>

Data presented as mean±SE; For a particular exposure duration, ns, * and ** represent not-
significant, or significant difference between control and EMF exposed at *P*≤0.05 and 0.01 for 
respective parameter. Letter (A) in a column, for a particular treatment between start and end 
of experiment represent significant difference at *P*≤0.01.

**Honey Stores**

There were two frames of honey in the control colony at the end of the experiment but 
this was not harvested (Fig. 4.6b). The area under honey stores in the experimental 
colonies was greatly reduced at the end of the experiment being only about one fourth 
frame (Fig. 4.7a) (Table 4.3).
Table 4.3. Changes in the colony growth measured in terms of bee strength, honey stores, and pollen stores of *Apis mellifera* exposed to cell-phone radiations for 15 and 30 min, respectively.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control</th>
<th><strong>EMFr</strong> Exposure (15 min)</th>
<th>Control</th>
<th><strong>EMFr</strong> Exposure (30 min)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Bee Strength</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start</td>
<td>8 frame</td>
<td><strong>8 frame</strong>&lt;sup&gt;ns&lt;/sup&gt;</td>
<td>8 frame</td>
<td><strong>8 frame</strong>&lt;sup&gt;ns&lt;/sup&gt;</td>
</tr>
<tr>
<td>End</td>
<td>9 frame</td>
<td>5 frame <strong>&lt;sup&gt;•&lt;/sup&gt;A</strong></td>
<td>8 frame</td>
<td>2 frame <strong>&lt;sup&gt;•&lt;/sup&gt;A</strong></td>
</tr>
<tr>
<td><strong>2. Honey Stores</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(cm&lt;sup&gt;2&lt;/sup&gt;/colony)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start</td>
<td>2200</td>
<td>2180</td>
<td>2800</td>
<td>2600</td>
</tr>
<tr>
<td>End</td>
<td>3200</td>
<td>400</td>
<td>4800</td>
<td>Nil</td>
</tr>
<tr>
<td><strong>3. Pollen Stores</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(cm&lt;sup&gt;2&lt;/sup&gt;/colony)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start</td>
<td>230.5±11.2</td>
<td>218.2±11.3&lt;sup&gt;ns&lt;/sup&gt;</td>
<td>143.5±6.3</td>
<td>150.4±5.0&lt;sup&gt;ns&lt;/sup&gt;</td>
</tr>
<tr>
<td>End</td>
<td>246.7±7.8</td>
<td>154.7±2.8 <strong>&lt;sup&gt;•&lt;/sup&gt;A</strong></td>
<td>197.2±8.9</td>
<td>30.0±5.3 <strong>&lt;sup&gt;•&lt;/sup&gt;A</strong></td>
</tr>
</tbody>
</table>

Data presented as mean±SE; For a particular exposure duration, ns, * and ** represent non-significant, or significant difference between control and EMF exposed at *P*<0.05 and 0.01 for respective parameter. Letter (A) in a column, for a particular treatment between start and end of experiment represent significant difference at *P*<0.01.

**Fig. 4.6.** a) Control colony with nine bee frames at the end of the experiment, and b) Comb full of honey from control colony

a) ![Control colony](image1.png)  b) ![Comb full of honey](image2.png)
**Pollen Stores**

The area under pollen stores for the control colony was 230.5±11.2 and 246.7±7.8 cm², respectively, at the start and end of the experiment (Fig. 4.7b). In the colonies exposed to EMFr there was a decline from 218.2±11.3 cm² to 154.7±2.8 cm² which was significant (*P*<0.01) when compared to the corresponding value for control (246.7±7.8 cm²) (Table 4.3).

**Fig. 4.7. a) Comb frame from treated colony showing lesser honey stores, and b) Comb frame showing area under pollen stores in the control colony**

**Colonies Exposed to Cell-Phone EMFr for 30 minutes**

The experiment was conducted during September–November. The results obtained after two exposures of 30 min each per day given twice in a week are given in Tables 4.1–4.3.

**1. Biological Aspect**

**Total Brood**

The mean area of the comb occupied by eggs and developing brood was 1962.0±37.7 cm² in the experimental colony at the start of the experiment while that of the control was 2008.7±32.8 cm². After exposure to cell-phone radiations at the rate and time specified for the experiment, it was observed that the total area under brood declined to 70.6±2.4 cm² in the treated colony while that in the control increased to 2150.9±37.3 cm². This difference was highly significant (*P*<0.01) (Table 4.1).
Queen Prolificacy
The mean egg laying rate of the queen was 382.5±14.8 and 371.3±5.9 eggs/day in the control and experimental colonies respectively at the start of the experiment. After exposure to cell-phone radiations, however, there was a significant (P<0.01) reduction in the number of eggs laid per day in case of the treated colony (13.3±4.6 against 409.5±16.4 in case of control) (Table 4.1).

2. Behavioural Aspects: Foraging Behaviour

Flight Activity
Honey bee activity was monitored by recording the number of bees leaving the hive entrance per minute immediately before the start of experiment and during exposure of 30 min. The control colony did not show much variation during all these times. In the treated colony there was recorded a decline in the number of bees leaving the colony after the cell-phone EMFr exposure (Table 4.2).

Returning Ability
The mean number of bees returning to the hive per minute during the experimental period was recorded. It was 26.1±1.0 before exposure in the experimental colony and 28.4±2.2 bees/min in the control. It declined to 3.3±0.5 after exposure which was significantly less than the control (Table 4.2).

Pollen Foraging Efficiency
Pollen foragers returning to the hive were monitored in the control and experimental colonies. Exposure to cell-phone radiations significantly reduced the number to 0.6±0.2 in the treated colony as compared to 5.3±0.4 in case of the control (Table 4.2).

Colony Growth
Bee Strength
There were 8 bee frames each in the control and experimental colonies at the initiation of the experiment. The experimental colony suffered heavy loss due to exposure to cell-phone radiations and barely survived with just 2 bee frames as compared to 8 in case of the control (Table 4.3).
**Honey Stores**

There was good honey flow in the control with honey stores equivalent to 3 comb frames. The treated colony had neither brood nor honey or pollen stores at the end of the experiment (Table 4.3).

**Pollen Stores**

Area under pollen stores was merely 30.0±5.3 cm² in exposed colony at the end of the experiment as compared to 197.2±8.9 cm² in case of the control (Table 4.3).

**Discussion**

During the present investigation, using GSM mobile phones installed in the bee hive in the listen+talk mode, it was observed that total bee strength was significantly higher in the control being 9 comb frames as compared to only 5 in the treated colony at the end of first experiment during which an exposure of 15 min. was given each time. Strength decreased further (2 bee frames) on increasing the exposure time till ultimately the exposed colony collapsed altogether. There were no dead bees in the vicinity of hive as is characteristics of this disorder reported by other workers (Richter, 2008; EMRX, 2008) The area under brood declined to 521.2±37.0 cm² during the first experiment which was significantly less than the control (1975.4±46.3 cm²). The 30 min. exposure produced drastic decline and the total brood area diminished to a mere 70.6±2.4 cm² as compared to 2150.9±37.3 cm² in the control. The colony began to show signs of failure. Greenberg et al., (1981) had reported impaired hive weight gain and decreased sealed brood in honey bee colonies under high voltage transmission lines. Harst et al., (2006) observed in a comparative study that colony weight and brood area were more in the unexposed colony. The queen exposed to cell phone radiations for the 15 and 30 min. exposure produced fewer eggs/min (98.8±7.3 and 13.3±4.6 respectively) as compared to the control (376.2±10.6 and 409.5±4.6 respectively). Greenberg et al. (1981) observed queen loss in colonies exposed to high voltage transmission lines while Brandes and Frisch (1986) reported that exposure of the queen bee to cell phone radiations stimulated her to produce only drones. Eskov (1982) had reported that drone reacted to a field of 30-80 V/cm at 500 Hz by attempting to fly away and never return back.
Installation of DECT phone station in the bee hives resulted in fewer bees returning to the hive and also the returning time of the returning bees was longer as compared to the unexposed control (Harst et al., 2006). These authors suggested that there was scope for modification in the physical design of the study as for example it would be more interesting to study the frequency and power ranges of daily life usage. Further besides cordless DECT phones, which are mostly used within buildings, other mobile phones for example GSM mobile phones could be used. They (Harst et al., 2006) also proposed that the phones should be used in active process. All these suggestions were incorporated during the present study in which GSM mobile phones in active mode were used to give exposure of different durations in order to study changes in honey bee Behaviour. The results confirm that the foraging ability of the honey bees is altered as a result of exposure to EMF. The number of returning bees declined at the exposure time of 15 min. being 28.3±1.9 as compared to 39.6±3.3/min in control and the decline was enhanced when exposure time was increased to 30 min.(28.4±2.2 and 3.3±0.5 bees/min in control and experimental colonies respectively). Harst et al. (2006) observed that more than 6 exposed bees never arrived at the hive and several times none came back to the hive within 45 minutes. At every sequence of the experiment returning non-exposed bees were however observed. The number of returning bees in exposed hive were lesser and the returning time of the exposed bees distinctly longer in their experiment. Another finding of interest during the present study was that the number of bees leaving the hive also decreased following exposure (Table 4.2). There was no immediate exodus of bees as a result of this interference, instead the bees became quiet and still or confused as if unable to decide what to do. Such a response has however not previously been studied/reported.

The efficiency of foraging for pollen was observed to be reduced as a result of both the exposures i.e. 15 min. and 30 min. This was related to the number of bees returning to the hive.

The experimental and control colonies had honey stores equivalent to 2 comb frames at the start of the experiment. At the end of the 15 min exposure phase honey stores in the treated colony were significantly less than the control. The honey storing ability declined further due to loss of returning bees and at the end of the experiment...
there was neither honey, nor pollen or brood and bees in the colony resulting in complete loss of the colony. Similar conditions have been observed by other workers in case of honey bees under the influence of high tension lines (Wellenstein, 1973; Warnke, 1976). Carstensen (1987) reported that bee hives located near high voltage power lines in fields as low as 4 kV/m produced less honey and had high mortality rates. The present study therefore suggests that though, no such observation of CCD has been made in India, yet reduced number of bees returning to hives under the influence of cell-phone EMFr could be an initial step / prelude to CCD. In other words, may be that EMFr levels have not reached that peak to cause CCD as observed in other developed nations of the world.