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Exposure assessment of magnetic field in dwellings with built-in transformers in Bulgaria

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Abstract: An exposure assessment study was performed within a sample of apartment buildings with built-in transformer rooms located throughout the Sofia city. This study was a part of the International project TRANSEXPO which goal was to find the epidemiologic association between extremely low frequency magnetic fields (ELF-MF) and childhood leukemia. The exposure assessment part was directed to estimation of magnetic field exposures in residences that are both near to and distant from the transformer room, based upon their location relative to the transformer station. Measurements of 50 Hz magnetic field (MF) were performed in 65 apartments, 21 buildings, with built-in transformer stations. In each building, measurements were made in the following types of apartments: 1. apartments that have rooms directly above and next to the transformer; 2. apartments selected on the same floor as the one directly above and next to the transformer; 3. apartments on the upper floors randomly selected among all the other apartments of the building; The measurement results show clear difference among the magnetic field values measured of the three categories of apartments, respectively 0,4 μT for the "exposed" apartments 0,23 μT on the same floor, and 0,1 μT on other floors. These results confirm that classification of magnetic field exposure based on apartment location is possible with specificity 0,91 and sensitivity 0,95 for cut-off point 0,4 μT. Values of 0,4 μT and above were measured in 18 out of 19 apartments that have rooms directly above and next to the transformer. The exposure assessment in the buildings with built-in transformer station shows that the apartments can be reliably categorized as an exposed, low exposed or unexposed based on their location to the transformer stations.

Keywords: Exposure Assessment, Transformer, Built-In, Magnetic Field, Measurement

1. Introduction

Since 80s of the last century the efforts of different scientific groups were focused on examining the possible effect of residential exposure to extremely-low frequency magnetic fields (ELF-MF) on childhood leukemia [1,2]. Magnetic field exposure was classified as a possible human carcinogen (2B classification) by the International Agency for Research on Cancer in 2001 [3]. WHO considers that this classification should not be changed basing on recent epidemiological studies [4]. In order to reduce the scientific uncertainty in this field international TRANSEXPO project was started launching innovative standard protocol for exposure assessment protocol and epidemiology design.

Its purpose is to evaluate the association between residential MF exposure and childhood leukemia incidence in an epidemiologic study of highly exposed population where the potential for selection bias is minimized or eliminated. [5]

This paper presents the results of exposure assessment of magnetic fields in apartment buildings with built-in transformer rooms in Bulgaria

2. Scope

The built-in transformer stations were identified in cooperation with Sofia electrical distribution company which provided information concerning the addresses of built-in transformers which meet the criteria of the study.

Randomly 43 buildings with built-in transformers were identified from all regions of Sofia. The selected buildings

were visited with representatives of the electrical company with performing measurements inside the transformer station. For each transformer station was made a file containing information about address, year of construction, technical characteristics, data of measurements inside the station and photos. During the visiting and measurements in transformer stations, attempts were made to contact the inhabitants of corresponding building.

Efforts were made to contact the house manager of the building in order to cooperate for ensuring access to the required apartments.

At last, we had access to 65 apartments in 21 buildings. According to the requirements of the TRANSEXPO project measurements were performed in the following types of apartments:

- "Exposed" apartments - the apartments that have rooms directly above and next to the transformer;
- "Unexposed" apartments - in the same building. One selected on the same floor as the "exposed" one, another - randomly selected among all the other apartments of the building.

Because of the location of the transformer in the building we found out 2 buildings with the required 3 apartments plus additional exposed one. First they were considered as exceptions but check out in the electrical company it was proved that such location of the transformer within the building is common for some types of the buildings.

Figure 1. *Example of a case with two "exposed" apartments.*

So, the data of measurements in these apartments are included in the processing of the results.

Characteristics of the studied transformer stations

The studied transformer stations are distinguished by type, rating and power.

1. Types of transformer stations: 14 basement type; 7 underground;
2. Transformer rating: 9 - 400 kVA (one of them with two transformers), 11 - 630 kVA, 1 - 20 kVA.
3. Power: 10-0,4 kV step-down (10/0,4 kV); one 20/0,4 kV.
4. Cables configurations in studied transformers
   - Primary (high voltage): rigid bus work to the transformer: 0,2 m; 0,5 m; 1,0 m from the ceiling of the transformer station;
   - Secondary (low voltage):
   - Rigid bus work from the transformer to the switchgear: 0,5 m; 0,8 m; 1,0 m; 1,8 m from the ceiling of the transformer station;
   - Cables from the transformer to the switchgear: floor; walls, 1,5 m; 1,0 m; 0,2 m from the ceiling of the transformer station.

3. Methods

3.1. Measurement Procedure

Measurements were accomplished in the summer period: in the time intervals 9 am - 1 pm, and 4 pm - 7 pm. Measurements were performed as follows: • at the center of each room and 1,4 m away from the corners of the room at height 0,5 and 1,0 m; in front of the apartments' doors; at the center of the beds. Additionally 24 h dosimetry in "exposed" and "unexposed" apartments was made.

Except for the obligatory according to the TRANSEXPO measurement protocol some additional measurements were performed as follows:

- Scanning of the rooms was made in order to find out the maximum. In the areas with maximum values of magnetic field vertical distribution of the field was examined on four levels above the floor – 0,2; 0,5; 1,0 and 1,8 m;
- In each transformer station - in front of transformers; in front of switch gears; primary and secondary distribution systems; center of the transformer In order to minimize the influence of electrical gear or electrical appliances in the case when the measurement point coincided or it was in close proximity to electrical appliance precaution was made to switch off the source station.

3.2. Equipment

For the short term and spot measurements we used EMDEX Snap and EMDEX II devices. For 24 h measurements we used EMDEX Lite, Enertech, USA. They have been calibrated in by the manufacturer, Enertech (USA).

4. Results

4.1. Spot Measurements

We performed spot measurements in 23 exposed apartments, 21 apartments on the first floor, 21 on the other floor. Some of the studied apartments were being used for other purposes - offices, a beauty saloon, stores. That is why these apartments were excluded from the statistics.

Results of measurements in front of the apartment's doors do not depend on the type of the apartment; they were influenced by other factors (security systems, alarms, electric lighting, other electrical systems, etc.). High values were

measured as in front of the exposed as in front of unexposed apartments. That is the reason that these results were excluded from further discussion.

On Table 1 are presented average magnetic flux density values for the three categories of apartments by building on the measuring height 0,5 m.

Table 1. *Measurements on height 0,5 m*

Buildings	**Apartment 1 "exposed"**			**Apartment 2 "on the same floor"**			**Apartment 3 "upper floor"**		
on 0.5 m	**average**	**min mean**	**max mean**	**average**	**min mean**	**max mean**	**average**	**min mean**	**max mean**
Building 1	*	*	*	*	*	*	0,06	0,05	0,08
Building 2	0,60	0,29	0,87	0,40	0,23	0,58	0,28	0,24	0,32
Building 3	0,57	0,12	1,36	0,41	0,35	0,48	0,14	0,12	0,16
Building 4	0,16	0,08	0,45	0,13	0,06	0,26	0,04	0,03	0,05
Building 5	0,38	0,20	1,59	0,30	0,07	0,86	0,08	0,01	0,21
Building 6	0,35	0,17	0,61	0,23	0,13	0,60	0,25	0,09	0,62
Building 7	0,49	0,27	0,83	0,42	0,32	0,49	0,15	0,11	0,18
Building 8	0,62	0,22	1,09	0,20	0,07	0,52	0,03	0,02	0,04
Building 9	0,47	0,30	0,69	0,25	0,20	0,31	0,19	0,15	0,30
Building 10	0,25	0,05	0,66	0,05	0,03	0,09	0,04	0,03	0,07
Building 11	*	*	*	*	*	*	0,04	0,03	0,05
Building 12	0,28	0,07	1,43	0,18	0,09	0,37	0,06	0,04	0,10
Building 13	0,28	0,07	0,70	0,08	0,05	0,17	0,05	0,03	0,08
Building 14	0,67	0,21	1,26	0,24	0,08	0,45	0,06	0,04	0,09
Building 15	0,14	0,08	0,23	0,09	0,07	0,12	0,03	0,02	0,03
Building 16	*	*	*	*	*	*	*	*	*
Building 17	0,32	0,06	1,14	0,07	0,04	0,11	0,05	0,03	0,09
Building 18	0,60	0,19	1,51	0,48	0,16	1,13	0,09	0,05	0,14
Building 19	0,37	0,10	1,51	0,19	0,03	0,61	0,15	0,15	0,15
Building 20	0,13	0,08	0,23	0,12	0,04	0,26	0,11	0,11	0,11
Building 21	0,60	0,29	1,36	0,17	0,10	0,28	0,13	0,07	0,17
Building 6 – additional app	0,39	0,17	1,05	-	-	-	-	-	-
Building 17 – additional app	0,49	0,09	2,04	-	-	-	-	-	-

On the following graphs are presented apartment averages for the three categories of apartments on height 0,5 m and 1,0 m.

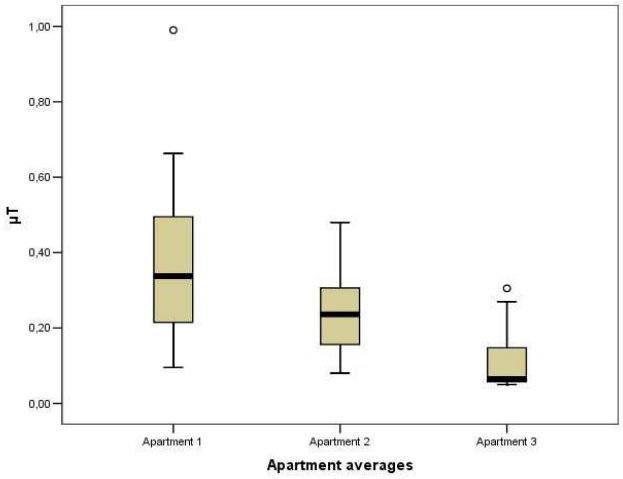


Figure 2. *Apartment averages for the three categories on height 0,5 m*

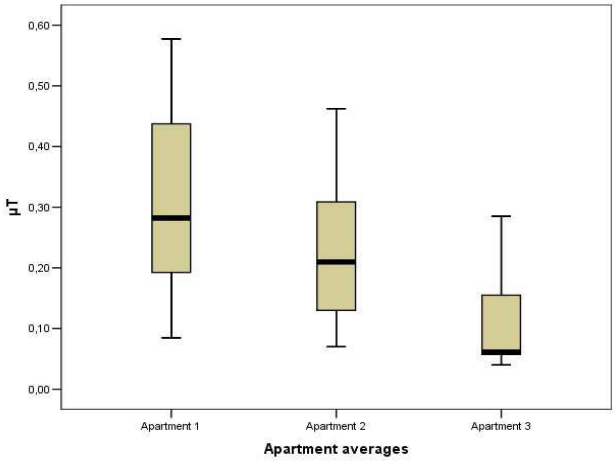
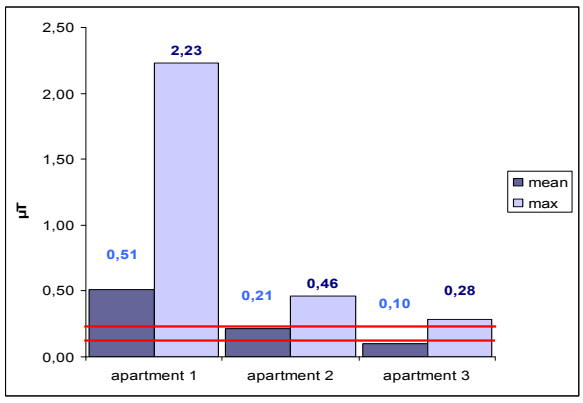


Figure 3. *Apartment for the three categories on height 1,0 m.*

The measurement results show that the most exposed room with prolonged stay is the bedroom. In the following figures are presented bedroom averages for the two heights. The data include magnetic field values measured at the center of the beds.

Additionally mean and maximum values on the centre of the beds are presented on the Fig. 4.



+ * - red lines correspond to cut-off points of 0,2 μT and 0,4 μT.

Figure 4. *Bedroom averages for the three categories on height 0,5 m*

Measurements in the center of the beds were performed on different height depending on the construction of the bed. The variability in the measured values is also due to the bed location towards the transformer (in relation to the cables and bus bars). Nevertheless, it is important to know the exposure provided that the bed is the place where people stay for a long time during the 24-h period.

4.2. Dosimetry

We performed 10 dosimetry measurements in several of the studied buildings. We made 6 dosimetry measurements in the so called "exposed apartments" and 4 measurements in unexposed apartments. Due to the problems with the access to the transformer room it was not possible to make 24-hour dosimetry in the transformer stations.

Measurements were performed using EMDEX LITE device and data were imported into EMCALC software for further proceeding. Sampling rate of 4 sec. was used. Broadband measurements in the range of 40-800 Hz were performed.

In the next tables are presented data from EMCALC for the 6 exposed apartments.

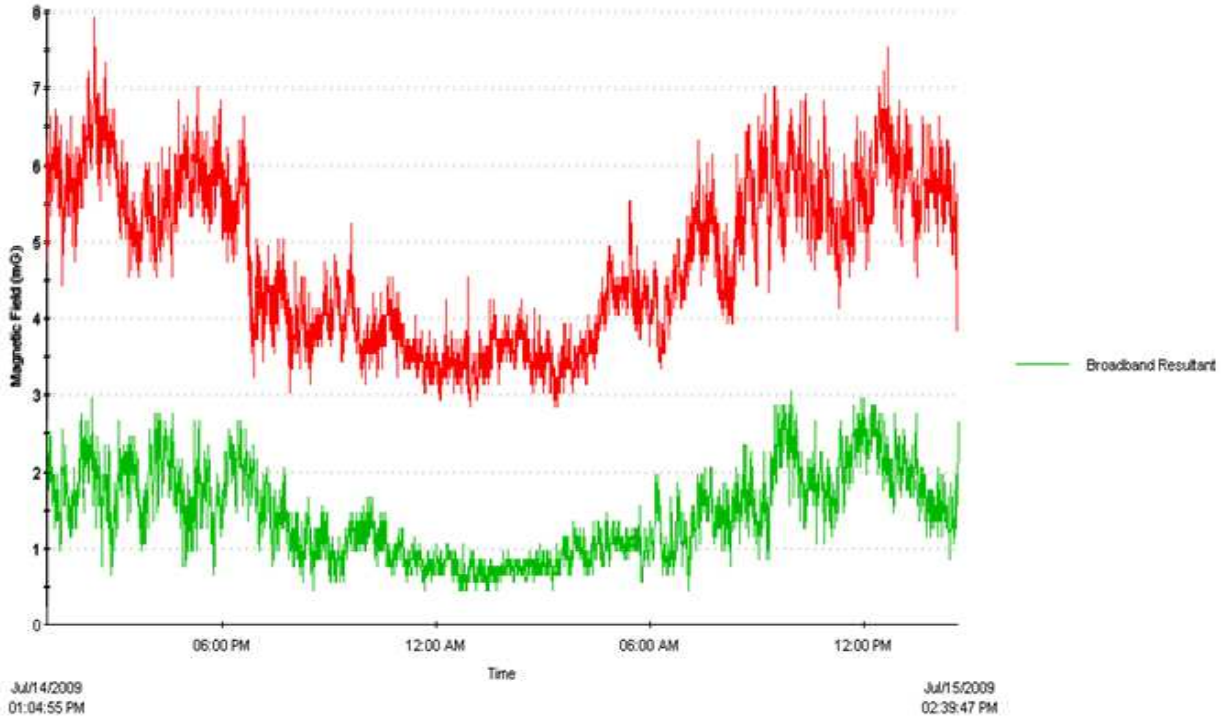
Table 2. *Data from EMCALC software for the 6 exposed apartments in the corresponding building*

Code of building	Minimum (μT)	Maximum (μT)	Mean (μT)	Standard deviation
Building 17	0,15	5,23	1,37	0,44
Building 4	0,09	0,56	0,41	0,06
Building 7	0,10	1,63	0,62	0,23
Building 10	0,12	0,49	0,26	0,027
Building 20	0,01	0,57	0,18	0,07
Building 9	0,28	0,79	0,47	0,103

As it could be seen, the maximal value of magnetic flux density is registered in the "exposed" apartment in building 17.

It was not possible to make all dosimetry measurements at the same time in one building.

In only one of the studied buildings we managed to do two 24-h dosimetry measurements in one and the same time interval, correspondingly in the "exposed" apartment and in the "unexposed" apartment. It could clearly illustrate the difference between magnetic flux densities in an exposed and unexposed apartment.



"Exposed" and "Unexposed" apartment in Building 9
* Data in the graph are in mG

Figure 5. *24-h dosimetry measurements performed in one and the same time interval in "exposed" and "unexposed" apartment.*

4.3. Measurements Additional to TRANSEXPO Protocol

The location of the transformer station in the building is of a great importance for the vertical distribution of the magnetic field. Scanning of the rooms was made in order to find out the maximum values of magnetic field. In the areas with maximum values of magnetic field vertical distribution of the field was examined on four levels above the floor – 0,2; 0,5; 1,0 and 1,8 m for the two types of exposed apartments – next to or above the transformer station.

As it could be seen, in the case when the transformer is under the apartment, values of the magnetic flux density decrease with the distance from the floor level. In the second case the values increase up to the height of the rims. The vertical distribution of the magnetic field at the places with max values in the "exposed" apartments above and next to transformers is presented on Fig. 6.

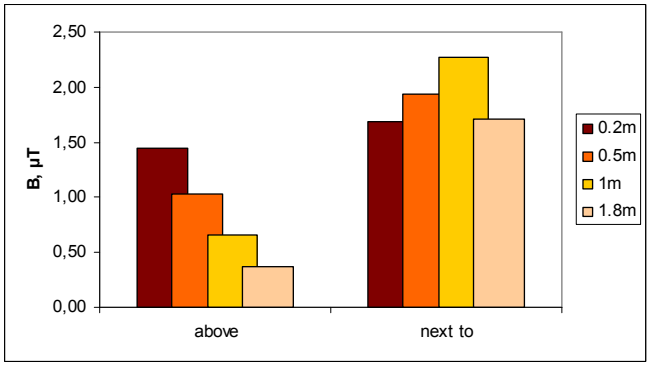


Figure 6. *Vertical distribution of the magnetic field at the places with max values in the "exposed" apartments above and next to transformers*

5. Discussion

The measurement results show clear difference among the magnetic field values measured of the three categories of apartments.

Exposed apartments with the highest measured values were those where the low voltage cables pass close to the ceiling of the transformer room in the case when the apartment is above the transformer. The average value in the cases when there is a common wall between the exposed apartment and transformer room is lower and it is hard to estimate the dependence of MF from height of low voltage cables.

The conducted additional measurements are very informative for the vertical distribution of the magnetic field in the case when the transformer has a common wall with the exposed apartment.

Average values of magnetic flux density on heights 0,5 m and 1,0 m do not differ significantly for the unexposed apartments on the same floor (0,23 µT vs. 0,20µT). For the category of apartments 3 there is no difference between mean values of magnetic field on both heights. This could be expected when the main source of MF is far away from the points of measurements.

A comparison of 24 h dosimetry in an exposed and unexposed apartments confirm the results received by spot measurements. There is significant difference in magnetic field values between exposed and unexposed apartments.

The total exposure received for the studied exposed apartments is in the range 4,31 (µT.h) – 33,04 (µT.h). The difference in total exposure is due to the fact that not always the bedroom is the most exposed room in the apartment.

The measurement results show clear difference among the magnetic field values measured of the three categories of apartments, respectively 0,4 µT for the "exposed" apartments, 0,23 µT on the same floor, and 0,1 µT on other floors. These results confirm that classification of magnetic field exposure based on apartment location is possible with specificity 0,91 and sensitivity 0,95 for cut-off point 0,4 µT. Values of 0,4 µT and above were measured in 18 out of 19 apartments that have rooms directly above and next to the transformer station.

In conclusion, the measured values depend on cables configurations in studied transformers, primarily on position of the secondary (low voltage) bus work of the transformer station.

Conducted measurements for the pilot TRANSEXPO study, show a clear distinction between the magnetic field values in the "exposed" apartments and all other apartments located on same buildings [6,7,8]. The apartments located on the same floor as the "exposed" ones can not be considered as an"unexposed", taking into account the measured values of the magnetic field. In further epidemiological study such apartments have to be treated as "low exposed".

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