TransExpo: International Study of Childhood Leukemia and Residences Near Electrical Transformer Rooms

Protocol 2010
TransExpo: International Study of Childhood Leukemia and Residences Near Electrical Transformer Rooms

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ABSTRACT

In order to reduce the scientific uncertainty surrounding the epidemiologic association between extremely low frequency magnetic fields (ELF-MF) and childhood leukemia, new approaches in epidemiology are required. Childhood leukemia and average exposures to ELF-MF above 0.3/0.4 μT are both quite rare, and retrospective assessment of ELF-MF exposure is prone to errors. Only studies designed to minimize biases from different sources while maximizing the ability to detect an association, should one exist, would have a potential to further contribute to scientific understanding. This report describes a protocol for one such study—a novel international study of childhood leukemia among children living in apartment buildings with built-in electrical transformers. The attraction of the study is the ability to select study subjects (affected or not by the disease of interest) from a similar environment, and then ascertain exposure status based on the location of the residence without requiring subject participation. The proposed study thereby will avoid some of the control selection and participation biases and problems that have plagued previous ELF-MF studies, while focusing on a population with higher than average exposure to ELF-MF. Results of pilot work completed in several countries are very encouraging and confirm that classification of ELF-MF exposure based on apartment location is feasible with remarkable specificity and sensitivity. Additional countries having a sufficient number of buildings with transformers are needed to ensure study precision.

To facilitate implementation of such a novel and complex ELF-MF exposure study, the protocol developed describes the study, identifies the data needed, and presents various study designs. It is expected that this detailed protocol will be enhanced and modified as pilot work is undertaken in other countries and more is learned in this area. The cohort study described here is the design of choice and should be implemented in any country where it is feasible. Due to limitations of available data, other designs would have to be carefully evaluated and would be considered only if they could reasonably approximate the cohort study. This report describes the study protocol and presents results of pilot work conducted to date.

Keywords
Childhood Leukemia
Extremely Low Frequency Magnetic Fields (ELF-MF)
Electrical Transformers
TransExpo International Study
Epidemiology
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SUMMARY

Purpose of the Study

To evaluate the association between residential extremely-low frequency magnetic fields (ELF-MF) exposure and childhood leukemia incidence in an epidemiologic study of a highly exposed population where the potential for selection bias is minimized or eliminated.

Background

Since 1979 a large number of epidemiologic studies examining the potential effect of residential exposure to extremely-low frequency magnetic fields (ELF-MF) on childhood leukemia have been published. Two pooled analyses (Ahlbom et al., 2000; Greenland et al., 2000), which included the major epidemiologic studies of ELF-MF and childhood leukemia published prior to 2000, pointed to a consistent, roughly twofold increase in childhood leukemia risk in association with residential ELF-MF exposure above 0.3-0.4 μT. Based on “limited” epidemiologic evidence linking ELF-MF exposure to childhood leukemia (heavily influenced by the results of the two pooled analyses) and “inadequate evidence” for carcinogenicity of ELF-MF in rodent bioassays, the International Agency for Research on Cancer (IARC) classified ELF-MF as a possible human carcinogen (2B classification) in June 2001 (IARC, 2002). In the most recent evaluation WHO considered studies published since 2000 and concluded that IARC classification should not change (WHO, 2007). A pooled analysis of more recent studies of ELF-MF and childhood leukemia had findings in line with previous pooled analyses, but noted that these recent studies were small and lacked methodological improvements needed to resolve the apparent association (Kheifets et al 2010).

The possible carcinogen (2B) classification by IARC implies that a potential causal relationship between ELF-MF and childhood leukemia is not the only possible explanation for the observed epidemiologic association; based on available evidence, alternative explanations, such as confounding or bias, cannot be excluded. Control selection bias remains one of the most frequently mentioned non-causal possible explanations for the ELF-MF and childhood leukemia association. Control selection bias may develop in an epidemiologic study if the selection and participation probabilities of cases and controls are different based on their exposure status. Most of the published studies of ELF-MF and childhood leukemia had the potential for this type of error (Mezei, 2006). However, only very limited and indirect evidence is available in support of or against the selection bias hypothesis.

To reduce the scientific uncertainty surrounding the association between ELF-MF and childhood leukemia, new approaches are required. Childhood leukemia and high average exposures to ELF-MF are both quite rare, and retrospective assessment of ELF-MF exposure is prone to errors.
Something of an impasse has been reached in designing studies of ELF-MF magnetic fields and childhood leukemia. Only studies designed to minimize biases from different sources while maximizing the ability to detect an association, should one exist, would have a potential to contribute to our understanding. Novel approaches are needed, and it has been suggested that an international study of childhood leukemia among children living in apartment buildings with built-in medium to low voltage (MV-LV) transformers could provide important new information (Kheifets & Oksuzyan, 2008). The principle is that where a substation, transformer or an electrical room is within an apartment building, the inhabitants of apartments adjacent to the transformer (usually the apartment immediately above but possibly to one side as well) may be exposed to elevated magnetic fields whereas inhabitants of other apartments have similar socioeconomic characteristics but are not so exposed. The attraction of the study is the ability to select study subjects (affected or not by the disease of interest) from the similar environment, and then ascertain exposure status based on the location of the residence and without requiring subject participation, thereby avoiding some of the control selection and participation biases and problems that have plagued other ELF-MF studies.

This report describes such a study, identifies the data needed, presents various study designs, develops a detailed protocol and presents results of pilot work conducted so far.

Study Description

An International study of childhood leukemia and residences near electrical transformer rooms” (acronym: TransExpo) is currently being evaluated or piloted in several countries.

TransExpo aims to study the incidence of leukemia in a cohort of children who have lived in buildings with built-in transformers. The exposure of the study subjects to ELF-MF would be estimated based on the location of the child’s apartment in relation to the nearby transformer or electric room, and the characteristics of that room and the associated cables and wiring.

Provided that ELF-MF exposure can be reliably evaluated based on the relative location of the transformers and residences within the building, it may be possible to conduct a study which maximizes the selection of highly exposed individuals while minimizing or eliminating the potential for participation bias. The individual exposure assessment would not require contact with the study participants and would be carried out blind to the children’s health status and to a possible diagnosis of the disease of interest.

People living in buildings with transformers form a study population, which includes both exposed and unexposed individuals. Although there are few known risk factors for childhood leukemia and no substantive confounding has been identified in the previous studies, questions on the potential role of socioeconomic status (SES) and residential mobility on previous results remain. This study will have an additional advantage because distributions of confounding factors among building residents, such as other environmental exposures and SES, are likely to be more homogeneous than those of persons not living in such buildings.

Compared to previous case-control studies of childhood leukemia and ELF-MF exposure, the major advantages of TransExpo include the opportunity for objective exposure assessment conducted prior to the ascertainment of the outcome (i.e. a leukemia diagnosis) and
independently of knowledge of whether the person is a case or control, the enrollment of study subjects with a wider and less left-skewed distribution of exposure levels (i.e. more highly exposed subjects), control of unidentified confounding and the avoidance of selection bias due to differential participation of cases and controls in the study.

To be able to provide convincing results that might aid in the interpretation of the previous studies, it is important that the study include a sufficiently large number of highly exposed cases and centers that are able to perform studies of high quality.

**Challenges**

Childhood leukemia is a very rare disease and the number of MV-LV transformers located in residential buildings in individual countries is limited. Due to rarity of both the disease and the exposure of interest, an international study involving several countries is needed to achieve sufficient sample size for a meaningful study. Additionally, for each country or region, ELF- MF exposure assessment needs to be developed based on a quantitative assessment of actual and predicted (estimated) exposures in carefully selected apartments from a representative sample of buildings in which transformers are located.

Lack of control for possible risk or protective factors for childhood leukemia may be considered a weakness. However, for a factor to be a confounder it has to be related to both exposure and disease. In this case, any postulated factor would have to differ between children in apartments next and far away from transformer.

**Implementation**

Implementation of such a novel and complex study will require overall coordination and flexibility. In each country a team of epidemiologists and exposure assessment experts would need to be established. These teams would further need to gain access to and cooperation of various registries and electric power companies with information on transformer location and design. It is likely that completely identical design in each country would not be possible due to various limitations in the availability and quality of information. Thus, for each country, the most appropriate approach (cohort or case-control design; country wide or regional coverage etc.) would have to be developed. Each contributing country or region, however, will need to meet a minimum set of requirements for inclusion in the study.

To be considered for the study, any potential participating country or region must have: (1) a substantial number of transformers in residential buildings; (2) a high quality leukemia (or cancer) registry for a defined calendar period of time; and (3) a population registry or similar complete listing of the residents of the country or region that has reliable address information, including historical information on changes of address, for the defined calendar period. The population registry will be used to construct the study cohort or, if complete enumeration of the cohort is infeasible, to sample controls from a population of children who lived in buildings with transformers.
For each country we will begin with feasibility questions to determine whether the needed data exists in principle. For those countries where transformers are often located in residential buildings that have childhood leukemia registries and that have an ability to select participants (see Feasibility study below) we will proceed to a pilot study. The purpose of the pilot study would be to determine whether reasonably accurate exposure assessment, which does not require participation of subjects, could be developed (see Pilot study below). The pilot study will also need to evaluate epidemiologic procedures, information quality and access to data and will need to enable the researchers to select the appropriate study design. Once countries with pilot results indicating that a rigorous study is possible are identified, the main study could be implemented (see Figure 1-1).
Feasibility Studies

Prior to initiating the pilot study in any given country or geographic region, it is essential to assess its feasibility in that location. In addition to verifying availability of epidemiologic data from cancer registries and from population registries, it is essential to ascertain the availability of reliable exposure information at each participating location or country.

The pilot work can only be initiated if recorded information is available and accessible, at a local (e.g., city), regional or national level, for the following three main features during a specified calendar period:

1. Information on location and characteristics of Internal Transformer Stations;
2. Cancer registry: reliable personal data and diagnostic information on incident childhood leukemia cases; and
3. Population registry or similar (complete or nearly complete) listing of the general population (e.g., health insurance rolls, etc.) with reliable address information (which ideally also includes an apartment number) – for truly random selection of controls with known addresses from the general population.

For each country we need the following information:

Childhood Leukemia Registry
1. Area covered
2. Completeness
3. Years of data availability
4. Address availability

Source of control selection
1. Population Registry (or similar such as health insurance records)
2. Address availability
3. Years of data availability
Preliminary Studies

Transformers
1. Availability of addresses of buildings with transformers
2. Estimated number
3. Typical designs and their characteristics
4. Years of data availability and modifications over these years

Pilot Studies

Exposure Assessment

The basic assumption in the main epidemiologic study is that residents of apartments in close proximity (immediately above or adjacent) to transformer rooms are exposed to magnetic fields significantly higher than average residential exposure levels in other apartments in the same buildings and that these exposures can be reliably predicted without access to the residence. Although preliminary data suggests that this is the case it needs to be verified at each location/country, since exposure assessment in the main epidemiologic study will be based primarily on the location of the residences relative to the location of the transformer rooms and to the characteristics of transformers (such as location of LV cables) in the same building. The exposure assessment component needs to characterize magnetic field exposures in residences that are located both near to and distant from the transformer room, based upon their precise location relative to the transformer room and transformer characteristics such as rated/actual load, the number of transformers in the transformer room and the routing and configuration of their low voltage bus bars or associated cables. The goal is the development of a simple but yet reliable prediction model in which exposures can be estimated without making measurements inside an apartment. To achieve this, systematic measurements of magnetic field levels will be needed for residences immediately above (and next to) transformer rooms and for selected residences farther away in the same buildings.

An exposure assessment study would be performed within a sample of apartment buildings with built-in transformer rooms located throughout the country or region. It is anticipated that 10 to 30 different apartment buildings per country should be included in the measurement study. Ideally, these buildings should be selected by stratified (on transformer type or configuration) random sampling from a comprehensive list of buildings with transformers. This is the only way to ensure that the buildings selected for the exposure assessment study are representative of all buildings with transformers in the country or region. If this is not possible the procedure for building selection should be documented so that the possibility for bias can be assessed. The purpose of the exposure assessment study is to: (1) identify various standard and non-standard transformer room equipment configurations; (2) perform magnetic field measurements in residential apartments above or next to transformer room and in other apartments sampled from the building; and (3) analyze the data and develop a model for prediction of the measured fields based upon the proximity of the selected apartments to the transformer room and the characteristics of the transformer(s).
Information Needed from an Electric Company

Electric companies in countries or regions participating in the TransExpo Study would be asked to provide information related to the various types of transformer room equipment and associated electrical configurations which are located within residential apartment buildings. This information will enable an evaluation of the types and prevalence of standard transformer room equipment lay-outs, the prevalence of non-standard transformer room configurations, routing practices for primary and secondary transformer cabling, grounding practices, and other related equipment parameters.

The type of information which would be requested of the participating electric company would be divided into the following categories:

Standard Transformer Room Configurations

- Major types of standard transformer room configurations in use
- General diagram for each type of standard transformer room configuration
- Prevalence (approximate percentage) of each type of standard transformer room configuration
- Typical locations within apartment buildings (basement, 1st floor, corner of building, multiple locations, etc.) of transformers for each type of configuration.
- Historical changes in transformer room configurations
- Availability of transformer room configuration information from the electric company based on the address of the building.

Non-Standard Transformer Room Configuration

- Prevalence (approximate percentage) of non-standard transformer room configurations, i.e., those that cannot be classified by standard type, and for each of these configurations
- Location within apartment buildings (basement, 1st floor, corner of building, multiple locations, etc.)
- Historical changes in non-standard transformer room configurations
- Availability of transformer room configuration information from the electric company based on building addresses

Transformer Characteristics

- Typical sizes of transformer rooms and types of transformers located in apartment buildings
- An estimate of typical loadings (e.g. 60% of name plate rating)
- Power ratings (capacity such as 600kVA) and number as a function of building size
Preliminary Studies

- Primary (high voltage) voltage rating of transformers
- Secondary (low voltage) voltage rating of transformers
- Grounding practices

Power Buswork or Cabling

- Routing location of primary (high voltage) cables to the transformer (note routing location on floors, walls or ceilings and distance between the phases, along with any non-standard configurations such as cable trays)
- Primary (high voltage) cable size and configuration diagrams
- Routing location of secondary (low voltage) cables or rigid buswork from the transformer to the switchgear (note the routing location relative to floors or walls or ceilings, along with any non-standard configurations, such as use of cable trays or conduits,
- Secondary (low voltage) cable size and configuration diagrams
- Routing locations of low voltage cables to upper floors (vertical shafts, standardized or non-standard configurations, use of cable trays or conduits, cable configurations, routed near floors or walls or ceilings, etc.)

Main Switchgear Panels

- Location within an apartment building
- Electrical grounding practices
- Configuration and routing of main power cables from transformer to switchgear

It is anticipated that the electric company would be able to provide this type of general information for each standard type of transformer room configuration within their service area, and detailed transformer room layout information for the selected sample of residential apartment buildings. Based upon this information, it is anticipated that the characteristics of transformer room equipment and configurations may be identified that are most highly predictive of magnetic field levels measured in selected apartments, based on their proximity to the transformer room.

To demonstrate the usefulness of this information, consider the arrangement of the building transformer equipment as shown in Figure 2-1. The primary (high voltage) cables to the transformer are routed from the floor almost to the ceiling along the left sidewall. The cable is routed along the wall using stand-offs to provide some distance from the primary cable to the wall (and the potential residential apartment next door). Near the ceiling, the three phases of the primary cable separate and are routed down to the top of the transformer. The transformer is located towards the center of the room. The secondary (low voltage) cables are routed to the ceiling, where rigid conductors (buswork) are located along the ceiling and are routed to the right side wall. As shown in Figure 2-2, the secondary (low voltage) conductors remain separated and are located near the ceiling. This type of secondary configuration creates elevated magnetic fields on the floor above these conductors (potentially within a residential apartment).
Figure 2-1
Example of a Transformer Room Layout
The transformer room equipment characteristics identified to be predictive of ELF- MF levels, such as the routing of the secondary cables as shown in Figure 2-2, could then be used to develop a calculation model for this type of transformer room configuration. Magnetic field measurements in apartments on upper floor levels directly above the transformer room would establish a range of associated magnetic field levels for this particular type of transformer room equipment configuration. However, actual exposure assessment would be based primarily on the quantitative exposure prediction models discussed below.

**Measurement of Magnetic Fields**

Apartment buildings with transformer rooms will be selected for the Pilot Study measurement component by stratified random sampling based upon transformer room configuration. Since the number of apartments with measurements will be limited, it will be important to sample from configurations anticipated to generate both high and low levels of exposure. Since the more complex the exposure assessment protocol, the more likely that selected subjects will refuse to participate, we recommend a simple protocol which can be completed in 30 min. It is however very important to develop unbiased information; thus exactly the same procedures should be followed in all apartments regardless of their proximity to transformers.
Building and Apartment Selection

Approximately 10 to 30 different apartment buildings with inside transformers will be identified for the exposure assessment study in cooperation with the electric company. Buildings would be randomly sampled to provide a range of different transformer room configurations and types (small vs. large, standard vs. non-standard configurations, transformer room location within the building, etc.) for study. Detailed technical information regarding each transformer room and its configuration would be recorded in order to study the relationship between structural characteristics and measured magnetic field exposure levels and to develop a suitable prediction model.

In each building, apartments that have rooms directly above or adjacent to the transformer room will be selected as “exposed” apartments. One “unexposed” apartment is selected on the same floor as the “exposed” apartment, randomizing the “unexposed” apartment’s location on that particular floor. Another “unexposed” apartment is randomly selected among all apartments on other floors of the building. Some pilot studies suggest that ELF-MF at an apartment above the “exposed” apartment might also have somewhat elevated fields, and it along with an apartments on the same floor might represent an “intermediate” category.

Scheduling and Residential Appointments

Once the apartment buildings and specific apartments have been identified, contact needs to be made with their occupants to solicit their participation in the measurement part of the study. The occupant would be asked to provide access to the various rooms of the apartment to conduct field measurements. A schedule would have to be developed for each apartment building and apartment to be visited, in order ideally to coordinate measurement visits with the apartment residents on the same day. This schedule would need to be coordinated with the electric company to access the transformer room to confirm configuration details and perform field measurements within the room on the same day(s) on which field measurements were being made in the building’s residential apartments (see below). In some countries the transformers or electric rooms might belong to building owner rather than electric company and permission to access the room might need to be obtained from them.

Residents within each selected apartment would have to be contacted prior to the visit to solicit their participation in the measurement study. A letter would be prepared which would broadly describe the measurement survey, request access to the apartment on a particular date, describe the type of measurements to be performed within the apartment, and request a convenient time of day when the resident would be home to provide access for these measurements. Subsequent to receiving the letter, each resident would need to be called to confirm receipt of the letter and to set an appointment time for visiting the selected apartment on the scheduled day. Alternative “unexposed” apartments may also need to be selected in case some “unexposed” residents decline to participate in the study. If the “exposed” resident is unavailable on a specific date, then an alternate date should be selected. A follow-up telephone call to each participating resident should be made the day before each scheduled visit as a reminder to the residents. The selected residents would be asked if a recording magnetic field meter could be left in the apartment for a 24-hour period to record variations in the magnetic field over time and a return appointment time for the next day would also have to be scheduled to retrieve the 24-hour recording meter. The
return time to retrieve the meter should be confirmed with the resident prior to completing the measurement visit.

_Residential Measurements*

An effort will be made so that measurements within each residential apartment will take no more than 15 to 30 minutes to complete and will utilize these measurement methods:

1. Spot magnetic measurement at front door of apartment and location (x,y,z coordinates) of that measurement. These coordinates shall be with respect to a common origin such as the external door to the transformer room. Another site-specific origin could be used if it better facilitates locating other points for the study measurements.

2. Spot magnetic field measurements will be taken in every commonly occupied room of the residence (using an EMDEX II magnetic field meter full frequency range 40-800Hz including harmonics). One spot measurement will be taken at the center of the room and four spot measurements at 1.4 meters away from the corners of the room, at the height of 0.5 and 1 meter above the floor. In the each bedroom, an additional measurement will be taken at the center of each bed.

3. A magnetic field meter (EMDEX II) will be placed at a convenient, unobtrusive location in the usual bedroom of the youngest resident of the apartment (preferably a child) to record field levels over a 24-hour measurement period. The meter will be located at a height of 0.5 meter above the floor level and record magnetic field levels every 5 seconds. The precise location (x,y,z coordinates) of the meter will be recorded for calculation of the distance to the meter used to make similar measurements in the transformer room (see below).

4. Optional: To assess the potential for contact currents in the residences, the voltages between the faucet (or spout) and drain will be measured in the kitchen and in the bathroom.

5. Optional: To assess the potential for SES differences by floor within a building a short questionnaire (country specific) that asks about education, income, number of residents in the apartment (total and number less than 15 years of age) can be administered at the end of the measurement visit.

_Transformer and Residence Characteristics_

Information about the characteristics of each transformer room, including equipment layout and specifications, will also be collected during the site visit. This will require the cooperation of the electric utility company or building owner to provide access. The locations (x,y,z coordinates) of the transformer and associated primary and secondary cabling and switchgear will be recorded. Additional sources of exposure apart from the transformer will be assessed if found significant. Transformer technical details and specifications will be requested from the electric company. Drawings and sketches of the transformer room layout with respect to equipment locations and photographs may also be conducted.

Drawing and sketches of the entire residential building and the location of the apartments within the building should also be prepared. Photos of the building to confirm location of apartments and measurements of distances between apartments and transformer rooms should be taken when possible.
If possible, a recording magnetic field meter will also be placed in each building transformer room to record variations in the magnetic field for a 24-hour period. The meter would be placed on a plastic pedestal in the vicinity of the secondary low voltage buswork and the precise location (x,y,z coordinates) of the meter recorded for comparison with the locations of meters placed in the selected apartments. This meter would be the first meter to be deployed upon arriving at the apartment building, so that subsequent magnetic field measurements within any residential apartment or elsewhere in the building would be made concurrently with the meter in the transformer room (which would already be recording magnetic field data). If several visits to the building on different days were needed to take measurements in all the selected apartments, the meter in the transformer room should also be in place for simultaneous recording on at least 2-3 of these days.

A return visit the day following each meter placement would have to be scheduled to retrieve the 24-hour recording meters left in the transformer room and in the selected apartments.

The purpose of the 24 hour measurement is to characterize the magnetic field fluctuations within the apartment bedroom and to confirm that the magnetic field variations in the apartment correlate with the magnetic field variations as measured in the building transformer room. The 24 hour measurement also serves the purpose of developing quantitative prediction models for the most important exposure characteristics and of evaluating the measurement error associated with those predictions for apartments of cases and controls in the main study. For these apartments the only exposure information available to make the predictions will be the transformer room characteristics, the location of the apartment relative to the transformer room and the spot measurement taken at the apartment entrance.

Analyzing Exposure Assessment Results

The results will be analyzed to characterize the exposure distributions in different types of residences (above transformer or electric room, first floor, elsewhere in building, dependence on the type of transformer station). The main exposure metric from the 24-h measurements will be time weighted average (TWA), but also percentages of time spent above selected ELF-MF thresholds will be described. The measurement error associated with dichotomous classification to "exposed" and "unexposed" will be analyzed by calculating specificity and sensitivity. Three alternative TWA values (0.2, 0.4 and 0.8 µT) will be used as cut off points between "exposed" and "unexposed" in these analyses.

The measured TWA values and spot measurement averages will also be modeled as a function of transformer and residence characteristics to investigate how well such models predict magnetic field exposure. The database for such modeling is described below.
Figure 2-3
Example of Building Transformers

Database to Facilitate Prediction of Magnetic Fields Within Apartment(s) of Interest.

The results will be analyzed to develop quantitative prediction models to estimate various exposure metrics adjusting by country as necessary. They will also serve to characterize the exposure distributions in different types of residences (above transformer or electric room, first floor, elsewhere in building, dependence on the type of transformer station). By comparing the actual quantitative exposures measured in the Exposure Assessment Study with the corresponding predicted values it will be possible to evaluate the misclassification probabilities (specificity and sensitivity) associated with any desired classification of exposures in the main study. It will also be possible to assess the misclassification probabilities associated with more ad-hoc classification schemes that might combine, for example, a 2 level classification of transformer room configuration with a 5 level classification of apartment location (see below).

The objective of this database is to compile key engineering factors that affect the magnetic field level in residences located above electric transformer rooms. These parameters could then be used to predict (calculate, estimate) magnetic field exposure in residences without visiting the residence for measurements. The following information is anticipated as necessary to create a 3-D computer model of an electric power transformer room and the low voltage supply cables that...
feed the building switchgear room. The computer model could be used to calculate magnetic field levels in apartments located above the transformer room. The EPRI EMF Workstation software could be used to create the 3-D model for each of the major transformer room configurations within the participant’s service area (see Figure 2-4). In addition statistical models would be developed to improve predictions and evaluate misclassification.

![Figure 2-4](image)

**Figure 2-4**

*Example of Transformer Room Model Used for Magnetic Field Calculations.*

Calculated magnetic field levels can be provided as contour maps of field strength for a variety of conditions. The most dominant source creating magnetic fields in residences above transformer rooms is the low voltage cables or buswork and not the transformer itself. This is because the low voltage conductors always carry many more amperes than high voltage cables and transformers generally act as point sources so that the field due only to the windings of a transformer attenuate as one over the distance cubed. The magnetic field level is affected primarily by low voltage circuit loading, location/routing of the low voltage cables or buswork (e.g. mounted on ceiling, wall, or floor), and distance away. The needed variables are described in Table 2-1. At this time the best methodology to estimate spatial coordinates at internal building locations has not been evaluated. It is possible that x,y,z coordinates could be directly measured using a laser distance tool and some common exterior reference locations. However, this is labor intensive and would require relatively free access to the apartment building. The accuracy and feasibility of various emerging applications that augment GPS for use internal to buildings is untested for this study. It offers promising but unproven technology.
<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XFMR id</td>
<td>character, max. length = 20</td>
<td>the unique identifier for each transformer - a serial number that can be used to determine location and general specifications</td>
</tr>
<tr>
<td>XFMR rating</td>
<td>number, format ##</td>
<td>an identifier for the transformer nameplate rating in KVA</td>
</tr>
<tr>
<td>XFMR volt</td>
<td>number, format ## / ####/</td>
<td>an identifier for the transformer primary and secondary voltages in kV - used to convert KVA rating to amperes for buswork loading</td>
</tr>
<tr>
<td>XFMR nom</td>
<td>number, format ##</td>
<td>Nominal/typical loading expressed as percent of transformer nameplate rating (e.g. 60% of xxx KVA)</td>
</tr>
<tr>
<td>Buswork id</td>
<td>character, max. length = 20</td>
<td>the unique identifier used to identify the type of buswork (rigid, flexible cable) and link to transformer information</td>
</tr>
<tr>
<td>Buswork loc</td>
<td>numeric, values of 1, 2 or 3</td>
<td>Integer used to generally describe low voltage/secondary location: 1- ceiling, 2- wall, 3-floor</td>
</tr>
<tr>
<td>Prim bus spac</td>
<td>number, format ##</td>
<td>Distance between primary bus phases</td>
</tr>
<tr>
<td>Sec bus spac</td>
<td>number, format ##</td>
<td>Distance between primary bus phases</td>
</tr>
<tr>
<td>XRoom dim</td>
<td>number, format ## .##</td>
<td>Transformer room dimensions of length, width</td>
</tr>
<tr>
<td>XRoom Ht</td>
<td>number, format ##</td>
<td>Transformer room height - floor to ceiling</td>
</tr>
<tr>
<td>Pr-Bus length</td>
<td>number, format ##</td>
<td>Primary buswork length</td>
</tr>
<tr>
<td>Sc-Bus length</td>
<td>number, format ##</td>
<td>Secondary buswork length</td>
</tr>
<tr>
<td>ScBus vector</td>
<td>number, format ##,## ,##</td>
<td>X, Y, Z coordinates of centroid of apartment</td>
</tr>
<tr>
<td>Apt size</td>
<td>number, format ## ,##</td>
<td>Length and width of apartment</td>
</tr>
<tr>
<td>Calc ht</td>
<td>number, format ##</td>
<td>The height above apartment floor calculations are to be performed</td>
</tr>
<tr>
<td>PrBus-# start</td>
<td>number, format ## ,## ,##</td>
<td>X, Y, Z coordinates at start of primary buswork with reference to origin at 0,0,0 at transformer base center</td>
</tr>
<tr>
<td>PrBus-# end</td>
<td>number, format ## ,## ,##</td>
<td>X, Y, Z coordinates at end of primary buswork with reference to origin at 0,0,0 at transformer base center</td>
</tr>
<tr>
<td>ScBus-# start</td>
<td>number, format ## ,## ,##</td>
<td>X, Y, Z coordinates at start of secondary buswork with reference to origin at 0,0,0 at transformer base center</td>
</tr>
<tr>
<td>ScBus-# end</td>
<td>number, format ## ,## ,##</td>
<td>X, Y, Z coordinates of start of secondary buswork with reference to origin at 0,0,0 at transformer base center</td>
</tr>
</tbody>
</table>

Note: buswork starting/ending coordinates are used to compute a centroid. Attempts to directly measure the central points of energized buswork is not recommended due to electrical hazard and access concerns.
**Piloting Epidemiologic Procedures**

Another objective of the pilot study is to assess availability and quality of the data required for the identification and enrolment of study subjects so that the most important component of the main study can be designed. It is desirable to evaluate quality and completeness of the information and test the assumptions as much as possible.

**Defining Source for the Cohort Enumeration or Control Selection**

Develop information on the completeness of available Population Registry (or alternative sources of population listings, e.g., health insurance rolls for countries with national health coverage), how regularly it is updated, when birth of the child is added to the registry, whether notification of changes in the place of residence is compulsory, whether historical addresses are also available or only the current address is kept on the records, and whether address includes an apartment number or at least a floor. It should be assessed whether data on residential history can be obtained for a given person, and whether residents at a given address at a given time can be identified. Completeness of additional information such as vital status should also be assessed. Identification of a linkage-key such as personal identifier or family code is required. Years for which information is complete and accurate must be determined.

**Evaluating Tumor or Leukemia Registries**

In many countries well-established tumor registries exist and can serve as a source for identification of leukemia diagnosis. In others, good childhood leukemia registries are established. The pilot should evaluate coverage, year when reliable registration has been achieved, completeness, accuracy and availability of address information including floor and/or apartment numbers. Feasibility of linking leukemia cases to population registries should also be assessed.

If these are not available, although not ideal, ascertainment of leukemia cases through hospitals can be evaluated. This would be acceptable only if all the cases in a given region are referred to limited number of hospitals and if completeness, accuracy and availability of information can be ascertained. In addition, retrospective information should be available for a substantial number of years. Additional checks (for example assuring that there is only one record per child) might be needed.

**Pilot Study Deliverable**

To determine the viability of the main study and ability for a given country/region to be included, the pilot study from each country/region should provide:
**Preliminary Studies**

**Exposure**

1. Estimated number of buildings with transformers
2. Specificity and sensitivity of TWA prediction with cutpoint 0.4 μT based on the crude classification of apartments as exposed or nonexposed based on adjacency to Transformer room.
3. Distributions of actual measurements in apartments (1) above or next to transformers; (2) on the same floor as an apartment in (1); (3) apartments on other floors of the building
4. Data for the development of a prediction model for measured TWA

**Epidemiologic Design**

1. Availability of data in cancer and population registries, including coverage in time and space
2. Proposed main study design
3. Projected number of cases during study period who resided in apartments above or adjacent to a transformer room.
4. Estimated costs to conduct main study
The preferred approach of TransExpo is a cohort study, where the cohort is defined as all children who ever lived in a building with built-in transformer during a specified study period. If data for a full cohort approach is not available, a nested case-control, a population based case-control (population here is children who have lived in transformer buildings) or a neighborhood matched case-control design can be considered (the latter can be viewed as approximations to the cohort design). For each country the most appropriate study design would be used depending on the information available. The cohort is the best design, followed by the population based case-control and neighborhood matched case-control design. When cohort is not feasible, other designs would be evaluated to allow for methodological comparison.

Considerations Applicable to All Study Designs

**Institutional Review Board (IRB)**

An IRB approval (or equivalent depending on the country/region) should be obtained for each participating center.

**Case definition**

Childhood leukemias are defined primarily as: acute lymphocytic leukemia (ALL) and acute myelogenous leukemia (AML) (ICD-9 204–205 or ICD-10 C91–C92) diagnosed before age 15.

**Case ascertainment**

For completeness of case-ascertainment, cases diagnosed during the specified study period will be identified from the cancer or leukemia registry if one is available. In regions where no cancer registry is available, cases would be identified by contacting the local hospitals where pediatric leukemia patients are commonly referred – this method can be used only if one or few (≤5) hospitals serve a country or a well defined region with a well defined catchment area.

**Case Confirmation**

All childhood leukemia diagnoses identified either though the registry or through the hospital’s roster should be reviewed and their eligibility confirmed. Ideally, pathology records would be collected for all incident cases of the index disease.
Training for all study personnel

All personnel conducting exposure assessment shall be trained in EMF measurement and exposure protocol. In addition, personnel sent to the field will be trained on drawing sketches of apartment buildings. All personnel involved in data analysis will have prior experience in data management and analysis.

Data collection

Participant countries shall describe procedures used for linking and analysis and perform data cleaning.

Minimum Set of Variables to be collected by each center and location for the main study:

1. Comprehensive list of buildings with transformers.

We will need information on all the transformer-buildings located in the study area within the study time-frame where the children eligible for inclusion in the cohort study have been residing during the individual observation period.

- Location: exact address (and geocoding, and location within building if available)
- Transformer type
  - Standard or non-standard transformer room configuration
  - transformer characteristics
  - power bus work or cabling (floor, ceiling, wall)
  - main switchgear panels
- Date of installation/changes/remodeling/removal

2. A list of residents of the buildings of interest (depending on design):

- First name
- Last name
- Sex
- Date of birth
- Individual ID for each subject (depending on the country this could be parent or child identification number)
- Residential history or address at time of diagnosis of an index case (depending on design).

3. Cancer registry

- First name
- Last name
- Sex
- Date of birth
- Date of diagnosis
Main Study Designs

- Address at time of diagnosis including floor and/or apartment number (and geocoding, if available)
- Diagnosis, preferably with histological subtypes

Data Management

Countries shall use information and management software available to them. However, this software should be documented along with any software code used for linking. Each subject will have the unique study ID created for this study which will incorporate country code and, if data is collected in more than one location within given country, region code.

Response to new or unexpected findings and to changes in the study environment

If investigators encounter any difficulties with situations not addressed by the study protocol, they should contact: Leeka Kheifets, PhD.

Cohort Study

The cohort study design is the preferred type of design for the TransExpo study, but requires several key pieces of information. The ability to identify and enumerate the entire cohort from the population would be a requirement as well as the ability to properly assess the exposure history of each cohort member and completely identify cases of childhood leukemia occurring among the cohort members. Researchers will need to be able to fully describe the population as exposed versus unexposed (based on distance of residence to transformer room) and also cases as opposed to non cases. The link between the population register and the cancer register that would allow for this is a unique identification number or a suitable set of personal identifiers (name, surname, sex, date and place of birth, unique ID).

To ascribe exposure status to the full population, the apartment buildings with built-in transformers must first be identified. The population registry could then be searched by the addresses of these relevant buildings to identify children living in the buildings with transformers during the study period. Apartments of all children in these buildings would be categorized provisionally as exposed (if directly above or adjacent to transformer), possibly exposed (if on the same floor or directly above the exposed apartment) and unexposed (all other apartments in the building). The linkage to the cancer registry would identify childhood leukemia cases.

Cohort is the preferred type of design for TransExpo because it has the lowest likelihood for bias.

Study population

The cohort study would include all residents (ages 0-14 years) who ever lived in the buildings with built-in transformers within the boundaries of the study region during the specified study period. A child will enter into the cohort at birth or when moved into the building with transformer (whichever is later) and will be followed to age 15, the end of the study, departure
from the study area or to the date of diagnosis (whichever is earlier). Only time lived in the building (or buildings) with transformers would contribute to exposure estimate.

**Inclusion criteria**

Living in a building with a transformer at any time up to but excluding 15th birthday.

**Protocol**

Create a dataset of children ages 0-14 living in buildings with transformers.
1. Develop a comprehensive list of addresses of buildings with transformers.
2. Select a historical population registry file, possibly including changes of address within the municipality of residence.
3. To link the population registry with historic addresses to the comprehensive list of buildings with built-in transformers, create a variable to match on if a unique identifier (preferred) or other linking method does not exist. The created variable could contain the full street address (Street Number + Street) and/or district/region that are in both the comprehensive building list and population registry.
4. Link comprehensive list of buildings with built-in transformers to population registry by location (Street Number + Street) or other appropriate linking variable.
5. Addresses with known transformers not matching any residential building should be examined to verify whether they are located in residential buildings or not. Beside the problem of incomplete address, it is also possible that a number of transformers with unmatched address are indeed located in residential buildings but their entrance is from a different street or at a different street number of the same street. Evaluate the possibility of using geocodes of transformers to identify some that might have a different address (e.g. side street).
6. If new addresses are identified, link the updated subset of buildings with built-in transformers to population registry by new location (Street Number + Street).
7. If Street name is not exactly spelled the same, partial matches can be examined and assigned a quality code.
8. Systematically go through and ascertain partial matches. This step may require multiple iterations

At this stage, a dataset will be created containing children (ages 0-14 years) who ever lived in buildings with transformers and their complete residential history (including periods spent at non-transformer building addresses). If an index or indices of socio-economic status (e.g. deprivation score) are available for the location of the residence, a socioeconomic level (SES) may be assigned using this measure. Documentation of measure should be provided if used.

**Assign preliminary exposure status for each child in the dataset created above**

Exposure status should be assigned before ascribing disease status. In addition, exposure assignment should be done blind to the disease status (i.e. individuals involved in exposure assessment should not know which address belongs to a case and which to a control). If the exact
apartment number of each cohort member is not readily available from the population file, the availability of alternative sources of information should be explored. If the information on the precise location of the apartment is not available from any existing file (e.g. building files) and can only be collected through site-visits, a nested case-control design may be considered in order to decrease the exposure assessment cost per subject (see § III. B). Only if the historic address and/or apartment information is not available other designs can be considered (see § III. C).

To assign exposure:

1. If feasible, a map for each apartment building should be created specifying the location of the transformer. Drawings of the buildings might be available from local municipalities.
2. In the map, the transformer room and all apartments in the dataset should be marked.
3. Record the total number of apartments in the building and number of floors.
4. For each apartment in the dataset estimate distance to transformer room:
   - 1 = above the transformer room; 2 = sharing a wall with the transformer room; 3 = same floor as an apartment in 1 or 2; 4 = right above an apartment in 1; 5 = other.
5. To assign exposure, each apartment building created in the matched list might need to be visited. If this step is needed and can be done at a reasonable time and cost, the cohort design will remain the preferred option. If the cohort can be completely enumerated but it is not feasible to visit each apartment building in the matched list, visits can be made and exposures assigned only for cases and for controls selected in a nested case-control study (see below). Otherwise, a population-based or matched neighborhood case-control should be considered. During the visit the precise locations (x,y,z coordinates) of the entries to the apartments in the dataset would be recorded for purposes of making quantitative exposure predictions. Estimates of the coordinates of the midpoint of the apartment should also be made.
6. Finally, the dataset created above will be updated with exposure information collected in 1-5.

**Refine Exposure Assessment**

If possible collect information for the transformer rooms in the buildings where the cohort members resided. This information will most likely come from an electric utility, or could be collected while visiting the building.

1. General diagram of transformer room
2. An estimate of typical loading (e.g. 60% of name plate rating) transformer room configuration
3. Power ratings (capacity such as 600kV/A) and quantity as a function of building size
4. Routing location of primary (high voltage) cables to the transformer (floors, walls or ceilings)
5. Routing location of secondary (low voltage) cables or rigid buswork from the transformer to the switchgear (routed near floors, walls or ceilings, etc.)
6. Location (x,y,z coordinates) of the secondary buswork.
Main Study Designs

7. Main switchgear panels: Configuration and routing of main power cables from transformer to switchgear

8. Historical changes to transformer room configurations, including date of change

This information can be used to refine exposure assessment based on the distance of an apartment of interest to the transformer room and characteristics of that room based on findings from the measurement study. One goal is quantitative prediction of the exposure in the interior of the apartment. Another is to revise the preliminary exposure status assigned based on the 5 level code of “distance to transformer room” made in step 2. E.g., in some countries, the apartments located immediately above the transformer room can only be considered “exposed” if the secondary cables are located on the ceiling of the transformer room; if the secondary cables are located on the floor of the transformer room, the apartments immediately above the transformer rooms are considered “unexposed”.

Linking to the cancer registry

1. Link the data file, i.e. the list of children (ages 0-14 years) living in buildings containing transformers, to the cancer registry by unique linking identifier - (personal identifiers of the cohort members to be used are: name and surname, sex, date and place of birth, and personal identification code. The residence address should NOT be used for linkage.

2. Create a new variable CASE and mark records in the final data set that have childhood leukemia as 1. All other matches (non-leukemia cancer cases) should be coded as 2. All other records should be 0. Partial or questionable matches should be documented if they cannot be resolved.

3. Add relevant diagnostic information to the database (or create a diagnostic database including the subject ID code to be used for merging it with the main database).

Nested Case-Control Study

The nested case-control study design may be considered when it is possible to completely enumerate the study cohort but if is not feasible to conduct visits to the apartment buildings of every cohort member for purposes of exposure assessment. With this design the “risk set” corresponding to each leukemia case is identified as the set of cohort members born in the same year as the case who are known to be in the cohort and still alive at the age that the case had when he/she was diagnosed. Four (or another small number) controls are randomly sampled from each risk set, and visits to the apartment buildings of the case and the controls are conducted. It some settings, the risk sets may be further restricted to cohort members who live in apartment buildings that are “similar” to those of the case, e.g. by virtue of having been constructed during the same general time frame or having the same general electrical configuration in their transformer rooms.

Study population

The nested case-control study would include all children diagnosed with leukemia (ages 0-14 years) who ever lived in the buildings with built-in transformers within the boundaries of the
study region during the specified study period and a matched (on birth year and age at the reference date) random sample of children without leukemia who lived in similar buildings with built-in transformers.

**Inclusion criteria**

Living in a building with a transformer at any time up to but excluding 15th birthday.

**Protocol**

Identify cases

1. Create a dataset of children ages 0-14 living in buildings with transformers.

Follow the same procedures described for cohort studies (§ III. B. 1)

2. Linking to the cancer registry

Follow the same procedures described for cohort studies (§ III. B. 4)

3. Select controls

Select four controls per case from the set of cohort members born in the same year as the case who are known to be in the cohort and still alive at the age that the case had when he/she was diagnosed. Four (or another small number) controls are randomly sampled from each risk set, and visits to the apartment buildings of the case and the controls are conducted. In some settings, the risk sets may be further restricted to cohort members who live in apartment buildings that are “similar” to those of the case, e.g. by virtue of having been constructed during the same general time frame or having the same general electrical configuration in their transformer rooms.

**Assign preliminary exposure status for each child in the dataset created above**

Follow the same procedures described for cohort studies (§ III. B. 2)

Exposure assignment should be done blind to the disease status (i.e. individuals involved in exposure assessment should not know which address belongs to a case and which to a control).

**Refine Exposure Assessment**

Follow the same procedures described for cohort studies (§ III. B. 3)

If possible collect information for the transformer rooms in the buildings where the cohort members resided. If possible collect information for the transformer rooms in the buildings with cases and controls. This information will most likely come from an electric utility, or could be collected while visiting the building.

1. General diagram of transformer room

2. An estimate of typical loading (e.g. 60% of name plate rating) transformer room configuration

3. Power ratings (capacity such as 600kV/A) and quantity as a function of building size
Main Study Designs

4. Routing location of primary (high voltage) cables to the transformer (floors, walls or ceilings)
5. Routing location of secondary (low voltage) cables or rigid buswork from the transformer to the switchgear (routed near floors, walls or ceilings, etc.)
6. Location (x,y,z coordinates) of the secondary buswork.
7. Main switchgear panels: Configuration and routing of main power cables from transformer to switchgear
8. Historical changes to transformer room configurations, including date of change

This information can be used to refine exposure assessment based on the distance of an apartment of interest to the transformer room and characteristics of that room based on findings from the measurement study. One goal is quantitative prediction of the exposure in the interior of the apartment. Another is to revise the preliminary exposure status assigned based on the 5 level code of “distance to transformer room” made in step 2. E.g., in some countries, the apartments located immediately above the transformer room can only be considered “exposed” if the secondary cables are located on the ceiling of the transformer room; if the secondary cables are located on the floor of the transformer room, the apartments immediately above the transformer rooms are considered “unexposed”.

Population-Based Case-Control Study

The population-based case-control study should be considered only if complete enumeration of the study cohort is not feasible. The choice between the population-based case-control study and the cohort or nested case-control study will usually depend on the amount of address information recorded by the population registry (or other readily accessible existing building files). It will be the choice of study design if no historical data is readily available, but residential history could be reconstructed from the population registry for a limited number of children.

In this approach, for each case who lived in a building with a built-in transformer and identified through the cancer registry we would randomly select controls from the population of children born in the same year who were known to be living in the same or similar buildings with built-in transformers at the age the case was diagnosed. Here “similar” could mean a cluster of apartment buildings with internal transformers that were built in the same neighborhood at approximately the same time. We would find these children by cross-referencing the matched and selected potential controls from the population registry with a list of buildings with built-in transformers. The controls will have lived in buildings with internal substations, but not necessarily the same buildings as the corresponding cases. We would then identify the apartment within the building where each case or control lived to get accurate exposure information.

Population-based case-control studies have a smaller problem with the issue of selection bias than traditional case-control studies because the controls are drawn at random from the full matched set of potential population controls for each case.


**Study population**

The population case-control study would include all children diagnosed with leukemia (age 0-14) who ever lived in the buildings with built-in transformers and a matched (on birth year and age) random sample of children without leukemia (age 0-14) who lived in the same or similar buildings with built-in transformers.

**Inclusion criteria**

Living in a building with a transformer at any time up to but excluding 15th birthday.

**Protocol**

*Develop a comprehensive list of addresses of buildings with transformers.*

Develop a comprehensive list of addresses of buildings with transformers. Addresses with known transformers not matching any residential building should be examined to verify whether they are located in residential buildings or not. Beside the problem of incomplete address, it is also possible that a number of transformers with un-matched address are indeed located in residential buildings but their entrance is from a different street or at a different street number of the same street. Evaluate a possibility of using GIS of transformers to identify some that might have a different address (e.g. side street).

**Identify cases**

1. Link all leukemia cases ages 0-14 yrs from the tumor registry, to the population registry and re-construct their complete residential history.

2. Link to the complete list of buildings with built-in transformers And retain only cases who ever lived in the building with transformer.

3. Match should be based on several variables created from the addresses of a leukemia case and the addresses of a building with transformers.

4. Some cases may have non-existing addresses because of misspelling in an address. In such situation, each address should be inspected manually and misspellings should be corrected, if possible. After that matching with the list of the building with transformers should be performed again.

5. Close but non-exact matches because of misspelling in an address or similar spelling of street or any other information in an address should be examined. In such situation, matches should be inspected manually.

6. Extract all relevant diagnostic information.

**Select controls**

1. Select a random sample of potential controls for each case, matched on year of birth. When possible select 4 controls per case. To have 4 controls per case, a much larger number of potential controls will need to be selected (depending on the fraction of the population that lives in apartment buildings with T-rooms, but, based on experience in some countries, it is probably on the order of 100 potential controls).
Main Study Designs

2. Re-construct the complete residential history for all potential controls.

3. Link the list of addresses of selected potential controls to list of addresses in the same or similar buildings with built-in transformers to identify actual controls that had lived in a building with built-in transformers at some point PRIOR to the age at which the corresponding case was diagnosed. In some countries Steps 1 and 2 can be combined. Step 1 might need to be repeated if not enough controls were initially selected. If this happens it needs to be documented.

4. All controls selected will be merged again with tumor registry to make sure that they have not been diagnosed with cancer by the date of leukemia diagnosis of a case. Children diagnosed after the diagnosis of the index case will be retained as controls.

5. Merge case and control data sets. Create a new variable CASE and mark records in the final data set that have childhood leukemia as 1. Mark controls as 0. Add additional column for control number (1-4) and another to identify the case for which the controls were drawn.

**Assign preliminary exposure status to the records in the dataset created above.**

Exposure assignment should be done blind to the disease status (i.e. individuals involved in exposure assessment should not know which address belongs to a case and which to a control.

To assign exposure, each apartment building of a case or matched control must be visited.

1. If feasible, a map for each apartment building should be created specifying the location of the transformer. Drawings of the buildings might be available from local municipalities.

2. In the map, the transformer room and all apartments in the dataset should be marked.

3. Record the total number of apartments in the building and number of floors.

4. For each apartment in the dataset assign a code for distance to transformer room:

   1. 1 = above the transformer room; 2 = sharing a wall with the transformer room; 3 = same floor as an apartment in 1 or 2; 4 = right above an apartment in 1; 5 = other.

5. If feasible make a spot measurement in front of the door of each apartment in the dataset and record the precise location (x,y,z coordinate) where the measurement was made. Also estimate the location of the approximate midpoint of the apartment.

6. Finally, the dataset created above will be updated with a refined exposure estimate.

**Refine Exposure Assessment**

If possible collect information for the transformer rooms in the buildings with cases and controls. This information will most likely come from an electric utility, or could be collected while visiting the building.

1. General diagram of transformer room

2. An estimate of typical loading (e.g. 60% of name plate rating) transformer room configuration

3. Power ratings (capacity such as 600kV/A ) and quantity as a function of building size
4. Routing location of primary (high voltage) cables to the transformer (floors, walls or ceilings)
5. Routing location of secondary (low voltage) cables or rigid buswork from the transformer to the switchgear (routed near floors, walls or ceilings, etc.)
6. Location (x,y,z coordinates) of the secondary buswork.
7. Main switchgear panels: Configuration and routing of main power cables from transformer to switchgear
8. Historical changes to transformer room configurations, including date of change

This information can be used to refine exposure assessment based on the distance of an apartment of interest to the transformer room and characteristics of that room based on findings from the measurement study. One goal is quantitative prediction of the exposure in the interior of the apartment. Another is to revise the preliminary exposure status assigned based on the 5 level code of “distance to transformer room” made in step 3. E.g., in some countries, the apartments located immediately above the transformer room can only be considered “exposed” if the secondary cables are located on the ceiling of the transformer room; if the secondary cables are located on the floor of the transformer room, the apartments immediately above the transformer rooms are considered “unexposed”.

**Neighborhood Matched Case-Control Study**

This type of case-control study design is less desirable than both the cohort and the population-based case-control study designs and should be used for TransExp only in the event that a cancer registry was available, but there is no population registry or there is no way to link the cancer registry to a population registry. A list of residents of the buildings relevant to the study from the same year as the case diagnosis must be available or can be constructed for this study design, as well as a list of relevant apartment buildings with internal substations.

In this situation, cases who lived in an apartment building with transformer at a time of diagnosis would be ascertained from the tumor registry and matched controls would be all children born in the same year who lived in the apartment building where the case lived in the year of diagnosis, or in similar nearby buildings. For this purpose a list of residents of the buildings where a case lived in the same year as case diagnosis will need to be created.

The number of potential controls in this study design will be dependent on the number of apartments per transformer building. For the smaller buildings, the fewer apartments are located in a building the more likely a given apartment will be positioned closer to the transformer room and thus be exposed. In the most extreme case of a transformer building with one apartment, the apartment has to be exposed by definition. When using this neighborhood matched case-control design, this apartment would be selected for the study only if a case has occurred in it but it would not be selected if only healthy children have lived there. This may results in an overrepresentation of cases from buildings with few apartments and a deficit of controls from such buildings. As a consequence, cases will be (on average) from smaller buildings than controls and thus are more likely to be exposed than controls, even if there is no true association. Selection of controls from a large building with many apartments, to a case from a small building...
with fewer apartment, may also be inadequate potentially resulting in selection bias since in such situation very few apartments may be located near a transformer room (i.e. be exposed), thus any given control (even randomly chosen from the list of controls available in a given building) has a lower likelihood to be exposed. Thus we propose that all available controls born in the same year and living in the identified buildings at the time of the diagnosis of the index case be used – this should not present a difficulty since the list of all potential controls would have to be developed and estimation of exposure once the building is visited would be straightforward. In addition we can control for the number of apartments in a building in the analysis.

The neighborhood case-control study design is less desirable than both the cohort and the population case-control study designs. Control selection in a typical case control study often invokes the possibility of selection bias. Cohort and nested case-control studies are less prone to this type of bias. Because the controls for this study are drawn from the same buildings as the cases, and because they need not be actively recruited into the study to estimate their exposure, there may be less issue of selection bias. In our case, as long as possible confounders such as SES seem to be evenly distributed across all of the floors of the buildings of our study selection bias will likely not be too large of a factor.

This study design has a great advantage that the entire control population need not be enumerated - you only need to determine the resident children and their birthdates for buildings with transformers in which a case occurs or similar buildings. Therefore this may be the only feasible design in some locations. In addition, matching on the building may reduce potential confounding making cases and controls more similar by factors that are associated with neighborhood (socio-economic status, environmental factors and other). This design will be used only if we can find enough centers that can undertake cohort approach.

**Study population**

The case-control study would include all children (age 0-14) who lived in buildings with built-in transformers where cases occurred on the date of the case diagnosis. The controls constitute a sample of the cohort of children who lived in these buildings at the time of index case diagnosis.

**Inclusion criteria**

Living in the same building as the case on the date of case diagnosis and the same age as the case at some point during the year in which the case was diagnosed.

**Protocol**

**Develop a comprehensive list of addresses of buildings with transformers.**

Develop a comprehensive list of addresses of buildings with transformers. Addresses with known transformers not matching any residential building should be examined to verify whether they are located in residential buildings or not. Beside the problem of incomplete address, it is also possible that a number of transformers with un-matched address are indeed located in residential buildings but their entrance is from a different street or at a different street number of the same street. Evaluate a possibility of using GIS of transformers to identify some that might have a different address (e.g. side street).
**Main Study Designs**

**Identify cases**
1. Select from the tumor registry all leukemia cases ages 0-14 yrs
2. Link all leukemia cases to list of buildings with built-in transformers to determine which cases lived at the time of diagnosis in a building with built-in transformer.
3. Data linking should be based on several variables created from the address of a leukemia case and the address of a building with transformers.
4. Some cases may have non-existing addresses because of misspelling in an address. In such situation, each address should be inspected manually and misspellings should be corrected, if possible. After that matching with the list of the building with transformers should be performed again.
5. Close but non-exact matches because of misspelling in an address or similar spelling of street or any other information in an address should be examined. In such situation, matches should be inspected manually.
6. Extract all relevant diagnostic information.

**Select controls**
1. From municipal or building records for each building identified in step II develop a list of children who were born in the same year and lived in the building at the time of case diagnosis.
2. All controls selected will be checked again with the tumor registry to make sure that they have not been diagnosed with cancer by the date of leukemia diagnosis of the corresponding case. (Children diagnosed after the date of diagnosis of the index case will be retained as controls.) Majority of siblings would have the same exposures but would not be born in the correct year. As they would not provide useful independent information and their inclusion would complicate analysis, they would not be included.
3. Merge case and control data sets. Create a new variable CASE and mark records in the final data set that have childhood leukemia as 1. Mark controls as 2. Add additional column for building number or otherwise identify which controls go with which cases.
4. Assign preliminary exposure status to the records in the dataset created above.

Exposure assignment should be done blind to the disease status (i.e. individuals involved in exposure assessment should not know which address belongs to a case and which to a control.

**To assign exposure, each apartment building created in the matched list must be visited.**
1. If feasible, a map for each apartment building should be created specifying the location of the transformer. Drawings of the buildings might be available from local municipalities.
2. In the map, the transformer room and the apartments of case and controls should be marked.
3. Record the total number of apartments in the building and number of floors.
4. For each apartment in the dataset assign code for distance to transformer room:
5. 1 = above the transformer room; 2 = sharing a wall with the transformer room; 3 = same floor as an apartment in 1 or 2; 4 = right above an apartment in 1; 5 = other.
6. If feasible make a spot measurement in front of the door of each apartment in the dataset.
7. Finally, the dataset created above will be updated with a refined exposure estimate.

**Refine Exposure Assessment**

If possible collect information for the transformer rooms in the buildings with cases and controls. This information will most likely come from an electric utility, or could be collected while visiting the building.

1. General Diagram of transformer room
2. An estimate of typical loading (e.g. 60% of name plate rating) transformer room configuration
3. Power ratings (capacity such as 600kV/A ) and quantity as a function of building size
4. Routing location of primary (high voltage) cables to the transformer (floors, walls or ceilings)
5. Routing location of secondary (low voltage) cables or rigid buswork from the transformer to the switchgear (routed near floors, walls or ceilings, etc.)
6. Main Switchgear Panels: Configuration and routing of main power cables from transformer to switchgear
7. Historical changes to transformer room configurations, including date of change

This information can be used to refine exposure assessment based on the distance of an apartment of interest to the transformer room and based on findings from the measurement study. E.g., in some countries, the apartments located immediately above the transformer room can only be considered “exposed” if the secondary cables are located on the ceiling of the transformer room; if the secondary cables are located on the floor of the transformer room, the apartments immediately above the transformer rooms are considered “unexposed”.

**Preparation of Final Data File**

All final data will be sent to a central location, at UCLA, for aggregation. After data has been collected and cleaned, countries will ensure that ID/information used for linkage have been removed before sending it to coordinators for the main study for the final pooling of data. Below is a minimum set of variables (see Table 3-1), additional variables will vary depending on the study design – e.g. additional addresses for cohort study, or control number for case-control study.
### Table 3-1
Minimum Set of Variables for the Main Study:

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projno</td>
<td>character, format ## / ####/ ##</td>
<td>project number - an identifier for use within the TRANSEXPO, indicating the supplying Country, Region,</td>
</tr>
<tr>
<td>Study type</td>
<td>Description of study</td>
<td>1=cohort, 2=nested case-control, 3=population case-control, 4=neighborhood matched case-control</td>
</tr>
<tr>
<td>Id</td>
<td>character, max. length = 20</td>
<td>the unique identifier, used by the study in its internal records to identify this individual alone - included as a check if data will need to be re-sent, etc.</td>
</tr>
<tr>
<td>Building id</td>
<td>character, max. length = 20</td>
<td>the unique identifier, used by the study to identify a building, will be used to link to transformer information</td>
</tr>
<tr>
<td>Building size - 1</td>
<td>numeric, values of 1 to N</td>
<td>Number of floors</td>
</tr>
<tr>
<td>Building size-2</td>
<td>numeric, values of 1 to N</td>
<td>Number of apartments</td>
</tr>
<tr>
<td>case status</td>
<td>numeric, values of 0, 1 or 2</td>
<td>1= Childhood leukemia; 2 = control</td>
</tr>
<tr>
<td>Sex</td>
<td>numeric, values of 1 or 2</td>
<td>1=male, 2=female</td>
</tr>
<tr>
<td>birthdate</td>
<td>date, format dd/mm/yy</td>
<td>date of birth</td>
</tr>
<tr>
<td>Diagdate</td>
<td>date, format dd/mm/yy</td>
<td>date of diagnosis, or corresponding date for controls</td>
</tr>
<tr>
<td>Diag</td>
<td>ICD</td>
<td>Use ICD 10; include ICD for other childhood cancers</td>
</tr>
<tr>
<td>Ses</td>
<td>numeric</td>
<td>socio-economic status - it was agreed that this should be the most accurate categorization available from each study; details to be supplied of number of levels and their definitions.</td>
</tr>
<tr>
<td>preliminary exposure status</td>
<td>numeric, values of 1 upwards</td>
<td>1 = above the transformer room; 2= sharing a wall with the transformer room; 3 = same floor as an apartment in 1 or 2; 4 = right above an apartment in 1; 5 = other.</td>
</tr>
<tr>
<td>refined exposure status</td>
<td>numeric, values of 1 upwards</td>
<td>TBD by each study depending on pilot work</td>
</tr>
</tbody>
</table>
Data Analysis and Statistical Methods

Due to expected small sample size in each location the expectation is that individual country analysis would not be meaningful. Therefore only a joint analysis is planned. This analysis, in part, will depend on the balance of study designs used by various countries. One possibility is to analyze the data as a set of matched case-control studies. For the actual cohort studies, the cohort would be stratified on year of birth. The matched controls for each case would consist of all members of the cohort who were born in the same year as the case and who were resident in an apartment with an internal substation at the time the case was diagnosed. This stratification could usefully be refined to select controls only from “similar” apartment buildings, whether similarity was defined based on the type of transformer configuration or on the basis of construction in the same neighborhood at approximately the same time. In fact this is precisely how hazard ratios are estimated in stratified cohort studies, ignoring the overlap between the matched controls for different cases. For the nested case-control study, the only difference in the analysis would be that the matched controls would be a small sample of members of the cohort who were born in the same year as the case and who were resident in an apartment with an internal substation at the time the case was diagnosed. For the population-based case-control studies the matched controls would consist of cohort members selected for each case using the criteria specified in Section D above that did not require complete enumeration of the cohort. For the neighborhood matched case-control studies, there would be a further restriction to controls from the same apartment building as the case, or from a small number of nearby apartment buildings. Alternatively, new methods might be developed to most efficiently combine various study designs, such as various meta-analytic approaches that can take into considerations possible biases. Analyses methods would be further developed as the study proceeds.

Strengths and Limitations

This study has a potential to shed a light on ELF- MF and childhood leukemia association through several features. Compared to previous case-control studies of childhood leukemia and ELF- MF exposure, the major advantages of TransExpo include the opportunity for objective exposure assessment (conducted prior to the ascertainment of the outcome (i.e. a leukemia diagnosis) in the cohort design and independently of knowledge of whether the person is a case or control, the enrollment of study subjects with a wider and less left-skewed distribution of exposure levels (i.e. more highly exposed subjects), control of unidentified confounding and the avoidance of selection bias due to differential participation of cases and controls in the study.

The major challenge would be to include a large number of countries to ascertain sufficient number of highly exposed cases. In addition, centers should be able to perform studies of high quality.

Any study, no matter how carefully conducted will have limitations. We have identified several potential biases that need to be considered. In a population based case-control approach we might have a potential for bias if cases are identified through the registry that has much better address information than our control sampling frame. Such situation is probably not uncommon – thus a child could be included if it was a case but would be missed as a control. This will only be a problem if exposure is also related to such a selection (e.g. through SES). This is possible, if for example, apartments above transformers tend to be of low SES. To address this possibility
once the case who lived in a transformer building is identified his/her residential history would be ascertained through population registry and that information (which will be of the same quality/completeness as that of a control) would be used in the analysis. Cases that are identified solely based on tumor registry addresses and that would be missed based on population registry addresses would be retained for a sensitivity analysis.

In a neighborhood case-control approach, we are excluding buildings where there were no cases and years with no cases. It can be a problem if mobility is related to exposure (say people move more from apartments above transformers because they are noisy) and mobility is related to leukemia. We might be able to evaluate this using case-control analysis of the cohort data, if the study is of sufficient size.

Despite success in treatment, the causes of childhood leukemia remain elusive. From twin studies and the use of neonatal blood spots it has been possible to back track the first initiating genetic events within critical haemopoietic cells to foetal development in utero for most precursor B cell acute lymphoblastic leukemia (ALL) and some cases of acute myeloid leukemia (AML). These events may occur as part of normal fetal development. Whether other factors (environmental or inherited) increase the chance of these first genetic changes is unclear. For some leukemias (e.g. infant MLL positive ALL) the first event appears adequate to create a malignant clone but for the majority of ALL and AML further changes are required, probably postnatal. Several environmental factors have been proposed for the second hit, but only ionizing irradiation and certain chemicals, e.g. benzene and cytotoxics (alkylators and topoisomerase II inhibitors) have been confirmed and then principally for AML. There is some evidence suggested that delayed, dysregulated responses to common infectious agents play a major part in the conversion of pre-leukemic clones into overt pre-B cell ALL, the most common form of childhood leukemia.

There is no single cause for childhood leukemia and for most individuals a combination of factors appears to be necessary; all involving gene–environment interactions (Greaves, 2006; Eden, 2010). To date few clear preventative measures have emerged, except the complete avoidance of first trimester X-rays in pregnancy; a healthy diet with adequate oral folic acid intake both preconception and early in pregnancy; and the early exposure of children to other children outside the home to facilitate stimulation and maturation of the natural immune system (Mezei 2002).

As the study develops, appropriate investigations of occurrence of bias and impact on the study findings, would be considered during feasibility phase. For example, we plan to evaluate whether there is an SES gradient by floor within buildings with transformers.
An additional component of the study might include an attempt to enroll individuals for additional measurements inside their apartments. The intend of this component is not to evaluate an association between leukemia and magnetic fields, as these measurements will be prone to the biases that plagued previous studies, but rather to allow for an examination of the selection bias hypothesis. By comparing observed effect estimates among participants in the measurement component of the study and effect estimates among all study subjects based on the exposure assessment of the main study as discussed above (see Table 4-1 below) we might be able to infer to what extent the participation bias can explain previously observed associations. If similar association is found in the main study and the measurement component, selection bias would be an unlikely explanation. If the association is limited to the participants in the measurement study only, then selection bias would be a likely explanation for the observed association. This scenario would also provide support for the argument that selection bias may explain the association found in previous studies. If no association is found in the measurement component of TransExpo our ability to shed light on selection bias issue would be limited.

Table 4-1
Comparison of Possible Results of TransExpo Study Components
Measurement Component of the Study

Participation in the measurement component by each country is optional and will depend on the country specific IRB requirements.

Protocol

Enrollment in the measurement component

For each child from the main study who currently lives in the same building where he or she was ascertained (a building with a built-in transformer), a letter will be sent to the identified address with information about the study. The letter will have a statement that the family will be contacted by the study about their participation. Additionally, the letter will have contact information for the study, so that interested family may directly contact the country representative of the study about the participation.

In 3-4 weeks each family that has not already agreed to participate will be contacted by phone, if available, or by another letter. This second letter, or a follow-up letter for those contacted by phone, will include a contact form for the family to fill out and return. The form will ask the family to provide a contact phone number (if none was available from the registry or the roster), or an additional phone number, as well as alternative contact information such as email address, cell phone number. The form will have additional questions about the best time to contact the family.

In case the family refuses to participate, it will be asked to fill the short questionnaire (over the phone or by mail) about the reasons for refusal. The prepaid and addressed return envelope should be provided with the second mail.

Interview and exposure assessment of cases and controls

If a family agrees to participate, then a personal interview and measurement can be scheduled at their residence. The informed consent could be presented to the family and signed at the time of the interview or can be mailed to the family in advanced, so they can sign it prior to the interview. No interview should be conducted before the family signs the informed consent form.

An attempt to blind interviewers to a case or control status should be made. Therefore, the status of the case or control will not be disclosed to the interviewer. However, it may be hard to prevent the interviewer from not recognizing the status of a case or a control, as they will be going to their place of the residence to conduct the interview and measurement. Thus interviewers need to be trained, interview should be structured and measurement protocol followed. The measurement protocol for this component would be the same as in Pilot study (see section I.B.1.b).
RESULTS OF COUNTRY SPECIFIC PILOT STUDIES

So far we have identified 37 countries for possible participation (Figure 5-1).

The pilot work has been completed in 5 countries (Finland, Hungary, Israel, Switzerland and Bulgaria). Additionally, studies appear feasible in Canada and Italy. Pilot work is beginning in Italy. In several countries the study does not appear feasible. In some countries (e.g. Sweden, Switzerland and UK) the study might be possible, but the number of buildings with transformers appears to be too small to make it worthwhile, as they are likely to contribute less than 1 exposed case. Assessment of the feasibility in other countries is underway (e.g. China, Spain).

<table>
<thead>
<tr>
<th>Pilot Finished</th>
<th>Interested/ Maybe</th>
<th>Contacted</th>
<th>To be Explored</th>
<th>Not Feasible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finland</td>
<td>Portugal</td>
<td>France</td>
<td>Ukraine</td>
<td>Brazil</td>
</tr>
<tr>
<td>Hungary</td>
<td>China</td>
<td>Greece</td>
<td>Former East Germany</td>
<td>Belgium</td>
</tr>
<tr>
<td>Israel</td>
<td>Canada</td>
<td>Denmark</td>
<td>US</td>
<td>Austria</td>
</tr>
<tr>
<td>Switzerland</td>
<td></td>
<td>Russia</td>
<td></td>
<td>Australia</td>
</tr>
<tr>
<td>Bulgaria</td>
<td></td>
<td>Spain</td>
<td></td>
<td>Australia</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pilot Started</th>
<th>Data Quality Issues</th>
<th>No Response yet</th>
<th># of Transformers Too Small</th>
</tr>
</thead>
<tbody>
<tr>
<td>Netherlands</td>
<td>Turkey</td>
<td>Romania</td>
<td>Croatia</td>
</tr>
<tr>
<td>Korea</td>
<td>Mexico</td>
<td>Norway</td>
<td>Slovenia</td>
</tr>
<tr>
<td>Italy</td>
<td></td>
<td>Poland</td>
<td>Sweden</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Japan</td>
<td>Armenia</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>UK</td>
</tr>
</tbody>
</table>

Results of pilot studies have resulted so far in three publications (see Appendix A) with a fourth manuscript being currently under review. Results are very encouraging (see e.g. Figure 5-2) and confirm that classification of ELF-MF exposure based on apartment location is feasible with remarkable specificity and sensitivity (see Hareuveny et.al., 2010).
In all countries average fields in the apartments located above transformers are 4-10 times higher than average fields in unexposed apartments (Table 5-1) and can be classified as “highly exposed”, relative to all other apartments located on the other floors of the same buildings. In most countries, an additional “intermediate category” can be developed which might consist of other apartments on the same floor as a “highly exposed” apartment. In some countries an apartment directly above “highly exposed” apartment might also belong in the “intermediate category”.

**Figure 5-2**
Typical Exposures by Apartment Type

A. Apartment above transformer
B. On the same floor as a “highly exposed” apartment
C. Apartment on another floor of the same buildings.
Results of Country Specific Pilot Studies

Table 5-1

Comparison of Average Exposures (in μT) in the Apartments Above Transformers and Other Apartments in the Same Building by Country

<table>
<thead>
<tr>
<th>Country</th>
<th>Above transformer</th>
<th>N</th>
<th>First floor</th>
<th>N</th>
<th>Other floors</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finland</td>
<td>0.56 (0.17-1.55)</td>
<td>30</td>
<td>0.21 (0.03-0.62)</td>
<td>28</td>
<td>0.10 (0.02-0.70)</td>
<td>30</td>
</tr>
<tr>
<td>Switzerland</td>
<td>0.59 (0.16-1.30)</td>
<td>8</td>
<td>0.14 (0.03-0.44)</td>
<td>10</td>
<td>0.07 (0.02-0.20)</td>
<td>3</td>
</tr>
<tr>
<td>Hungary</td>
<td>0.98 (0.18-3.68)</td>
<td>31</td>
<td>0.13 (0.04-0.31)</td>
<td>27</td>
<td>0.10 (0.01-0.39)</td>
<td>30</td>
</tr>
<tr>
<td>Israel</td>
<td>0.40 ± 0.20</td>
<td>8</td>
<td>0.080 ±0.040</td>
<td>8</td>
<td>0.066 ± 0.036</td>
<td>8</td>
</tr>
<tr>
<td>Bulgaria*</td>
<td>0.40 (0.05-2.04)</td>
<td>20</td>
<td>0.23 (0.03-1.13)</td>
<td>17</td>
<td>0.10 (0.01- 0.62)</td>
<td>20</td>
</tr>
</tbody>
</table>

* Min and max values are given in parentheses

All the pilot work so far shows that since the location of an apartment relative to the transformer can be easily determined, an exposure assessment can reliably be performed without obtaining access to residences. Based on results to date, it also appears that TransExpo will be able to identify and study a highly exposed population.
6
SAMPLE SIZE CONSIDERATIONS

To evaluate potential informativeness of the international TransExpo study of childhood leukemia and residences near electrical transformer rooms, we calculated estimates of the number of exposed cases we can expect to find in each participating country and for the study overall. Unfortunately, much of the information needed for such calculations is not available. We collected data from the web and individual country reports when possible. Parameters for which information was particularly scant were varied to develop a range of possible numbers of exposed cases.

In summary, the following data sources and assumptions were used:

- Total population of the country and number of children in the country
  - For Russia, only Moscow and St. Petersburg were included due to limited cancer registry coverage in other areas. Population information for St. Petersburg was obtained from http://www.state.gov/r/pa/ei/bgn/3183.htm.
  - For China, only Hunan Province was included, due to limited cancer registry coverage in other areas. Population information for Hunan Province was obtained from http://www.chinamaps.org/china/provincemaps/hunan.html.
  - For Italy, only Rome and Milan were included, due to limited cancer registry coverage in other areas. Population information for Rome was obtained from http://www.rome.info/facts. Population information for Milan was obtained from http://www.aboutmilan.com/the-city-of-milan.html.

- Coverage/completeness of cancer registry
  - Number of years cancer registry has been available and percent of cases in the registry vary for each country.
  - This information was taken from cancer registry for each country, when available.
  - For countries where registry websites did not contain this information, information was taken from the IARC Cancer Registry List and compared with other sources.
  - Other sources of information included published research articles that described the cancer registry, estimates from research partners in the respective countries, and in the case of Mexico, a public health newspaper.

Information used to estimate coverage, completeness, and years of availability of cancer registries were extracted from the following sources:
Sample Size Considerations

- **Austria**: Statistik Austria presentation (http://www.youngdemography.org/docs/pres_NZ.pdf)
- **Canada**: StatCan (http://www.statcan.gc.ca/cgi-bin/imdb/p2SV.pl?Function=getSurvey&SDDS=3207&lang=en&db=imdb&adm=8&dis=2)
- **China**: Personal Communication
- **Finland**: Finland Cancer Registry (http://www.cancerregistry.fi/eng/statistics/)
- **France**:
  - IARC - CI5-i-ix: Cancer Registry List. (http://ci5.iarc.fr/CI5I-IX/CI5i-ix.htm)
- **Israel**: Levav, I. Cancer risk among parents and siblings of patients with schizophrenia. The British Journal of Psychiatry (2007) 190:156-161. (http://bjp.rcpspsych.org/cgi/content/full/190/2/156#REF13)
- **Japan**:
  - IARC - CI5-i-ix: Cancer Registry List. (http://ci5.iarc.fr/CI5I-IX/CI5i-ix.htm)
  - Matsuda, Tomohiro. Do the Japanese feel more suspicious about cancer registration than the British? Cancer Epidemiology. Volume 34, Issue 2, April 2010, Pages 122-130
- **Korea**:
Sample Size Considerations


- **Netherlands**: The Netherlands Cancer Registry (http://www.ikcnet.nl/page.php?id=225&nav_id=97)
- **Russia**: IARC - CI5-i-ix: Cancer Registry List. (http://ci5.iarc.fr/C15I-IX/C15i-ix.htm)
- **Spain**:
  - IARC - CI5-i-ix: Cancer Registry List. (http://ci5.iarc.fr/C15I-IX/C15i-ix.htm)
- **Sweden**: The Swedish Cancer Registry (http://www.socialstyrelsen.se/register/hapsodateregister/cancerregistret/inenglish)
- **Switzerland**: Swiss Childhood Cancer Registry (http://www.childhoodcancerregistry.ch/index.php?id=1995)
- **UK**:
  - IARC - CI5-i-ix: Cancer Registry List. (http://ci5.iarc.fr/C15I-IX/C15i-ix.htm)
  - United Kingdom Association of Cancer Registries (UKACR) (http://82.110.76.19/about/history.asp)
- **Ukraine**: Ukraine Cancer Registry (http://users.i.com.ua/~ucr/eng/bcr_e.htm)
  - In countries where reasonable estimates of the registry’s start date and coverage could not be made, these factors were varied in the calculation.
  - At present, this factor is only varied for countries where duration of registry is very unclear (Mexico) and for countries where high-quality registration began prior to 1980 (Denmark, Finland, Hungary, Sweden). For the latter countries we used the actual start year of the registries as well as 1980 to calculate number of years registries were available.

- **Number of apartment buildings with internal transformer and address information**
  - The number of apartment buildings with internal transformer and address information was unknown for most countries.
  - Attempts to find information to inform estimates of these numbers were made by searching Google with terms like “apartment transformers”, “apartment substations”,

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“apartment internal electric supply”, “apartment internal electric distribution” as general terms and referring to Europe, Asia, and specific countries. Websites for electric companies, countries, and cities were also browsed in search of information related to this. Overall, no useful information to inform these estimates was found.

- The final calculations used estimates available for Finland, Hungary, Israel, France, and Sweden. The estimates provided for Finland, Hungary, Israel, and France ranged from approximately 0.00027 to 0.00057 of the total population. These two proportions were used in all other countries to estimate the number of apartment buildings with transformers, resulting in 2 values for each country. In Sweden, the available value was 120 which is less than 0.000014 of the total population. This value was used in the calculation after the calculated values using the other proportions resulted in estimates of exposed cases that seemed too high.

- For the UK, number of transformers was varied between 2,000 and 4,000. This was based on the UK feasibility study report which indicated that there are likely to be a small number of buildings with transformers relative to the UK population.

- For Italy, calculations were based only on information from Rome and Milan. The Italian TransExpo feasibility study report suggested that there are approximately 5,600 transformers in Milan and 3,000 in Rome. Therefore, we assumed 8,600 transformers for Italy.

- Number of exposed apartments per building
  - Assumed 1 exposed apartment per building
  - We expect most buildings to have only one exposed apartment, while a few may have two, and very few are likely to have more than that.

- Number of children in exposed apartments
  - We assumed proportions of exposed apartments in which children reside are: 0.3, 0.5, and 0.75.

- Annual rate of childhood leukemia
  - We assumed 4/100,000/year although it might be 5/100,000/year in some countries.

Based on this we calculated:

- The number of exposed children per year:
  - Number of exposed apartments per building) x (Number of children per apartment) x (Number of apartment buildings with transformer)

- Total number of exposed cases expected (over entire study period):
  - (Number of exposed children per year) x (Number of years of registry) x (Annual rate of childhood leukemia) x (Proportion of cases in registry)

The results are summarized in Table 6-1.
### Projected Number of Exposed Cases by Country

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of children&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Number years of follow-up&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Percent of cases in registry</th>
<th>Total number of exposed cases over total study period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>1,172,600</td>
<td>27</td>
<td>100</td>
<td>0.72-3.79</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>979,800</td>
<td>17</td>
<td>100</td>
<td>0.39-0.98</td>
</tr>
<tr>
<td>Canada</td>
<td>5,374,200</td>
<td>18</td>
<td>100</td>
<td>1.97-10.40</td>
</tr>
<tr>
<td>China&lt;sup&gt;c&lt;/sup&gt;</td>
<td>11,814,000</td>
<td>10</td>
<td>100</td>
<td>1.80-4.50</td>
</tr>
<tr>
<td>Denmark</td>
<td>984,500</td>
<td>23-67</td>
<td>100</td>
<td>0.41-6.50</td>
</tr>
<tr>
<td>Finland</td>
<td>858,600</td>
<td>30-57</td>
<td>100</td>
<td>1.08-5.13</td>
</tr>
<tr>
<td>France</td>
<td>11,922,600</td>
<td>15</td>
<td>50</td>
<td>2.70-6.75</td>
</tr>
<tr>
<td>Hungary</td>
<td>1,465,200</td>
<td>30-35</td>
<td>100</td>
<td>1.44-4.20</td>
</tr>
<tr>
<td>Israel</td>
<td>2,057,200</td>
<td>28</td>
<td>100</td>
<td>0.67-1.68</td>
</tr>
<tr>
<td>Italy&lt;sup&gt;c&lt;/sup&gt;</td>
<td>549,400</td>
<td>15</td>
<td>87</td>
<td>1.35-3.37</td>
</tr>
<tr>
<td>Japan</td>
<td>16,864,400</td>
<td>26</td>
<td>50</td>
<td>5.34-28.19</td>
</tr>
<tr>
<td>Korea</td>
<td>7,873,200</td>
<td>30</td>
<td>75</td>
<td>3.54-18.70</td>
</tr>
<tr>
<td>Mexico</td>
<td>32,287,500</td>
<td>7-15</td>
<td>10-25</td>
<td>0.26-7.21</td>
</tr>
<tr>
<td>Netherlands</td>
<td>2,889,600</td>
<td>21</td>
<td>100</td>
<td>1.14-6.03</td>
</tr>
<tr>
<td>Poland</td>
<td>5,698,000</td>
<td>22</td>
<td>50-75</td>
<td>1.37-10.86</td>
</tr>
<tr>
<td>Portugal</td>
<td>1,744,100</td>
<td>22</td>
<td>50-75</td>
<td>0.38-3.02</td>
</tr>
<tr>
<td>Russia&lt;sup&gt;e&lt;/sup&gt;</td>
<td>2,250,000</td>
<td>27</td>
<td>100</td>
<td>1.31-6.93</td>
</tr>
<tr>
<td>Spain</td>
<td>5,872,500</td>
<td>17</td>
<td>50-75</td>
<td>1.12-8.83</td>
</tr>
<tr>
<td>Sweden</td>
<td>1,410,500</td>
<td>30-52</td>
<td>100</td>
<td>0.04-0.19</td>
</tr>
<tr>
<td>Switzerland</td>
<td>1,170,400</td>
<td>29</td>
<td>100</td>
<td>0.71-3.77</td>
</tr>
<tr>
<td>UK</td>
<td>10,114,500</td>
<td>18</td>
<td>100</td>
<td>0.43-2.16</td>
</tr>
<tr>
<td>Ukraine</td>
<td>6,219,800</td>
<td>14</td>
<td>50-100</td>
<td>1.10-11.65</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>29.28-154.63</td>
</tr>
</tbody>
</table>

A. Country's population under 15 years of age
B. Number of years of follow-up based on start of registry; Year of start of registry varied for those countries in which registry information was unclear or missing (Mexico). For countries that are known to have a high quality registry in place prior to 1980 (Denmark, Finland, Hungary, Sweden), year of start of registry was varied as 1) 1980 and 2) actual year of start of registry.
C. Part of the country only: China - Hunan Province; Italy – Rome and Milan; Russia - Moscow and St. Petersburg;
Sample Size Considerations

We performed an analysis using a slightly different approach in which we estimated number of apartments per building with a transformer and number of children per building.

- Assumed average of 35 apartments per building with a transformer
- This number was varied several times from 10 to 60 apartments. We were not able to find enough information on building size in any country to use real data. Rather, 35 is a “best guess” that resulted in the most reasonable results given the variation among the other factors.

Number of children per apartment

- Number of children per apartment was dependent on several other factors:
  - The number of children in the country that lived in apartments
  - The number of children per building
  - The number of apartments per building
- For the number of children in the country that lived in apartments, we did extensive searching on Google, WHO, WorldBank, and other International and Country-specific data sites. The only information available was for Sweden, stating that 30% of children in the country live in apartments. Therefore, the proportion of children living in apartments was varied for all countries at 0.3 and 0.5 to provide a low and a high estimate.
- The number of children per building was unknown for all countries. The number of children per building was simply varied as 5, 15, and 25.

Calculations based on these assumptions resulted in similar numbers that ranged from 15 to 180 cases in the high exposure category.

It should be emphasized that all these numbers are just best guesses. More importantly, countries that were included might or might not participate in the study. On the other hand, other countries with large number of transformers might be identified and enrolled in the study.
7
ORGANIZATION OF THE STUDY

Study Protocol
The current document represents the core protocol for the TransExpo Study.

The Study Group
A collaborative group of scientists (the Study Group), consisting of Principal Investigator from each country, a PI from UCLA and a PI from EPRI. UCLA will serve as coordinator. The Study Group as a whole will be responsible for the progress of the study, the choice of analyses to be conducted, and the interpretation and preparation of publications of results. All the decisions about the study will rest on the Study Group, which will decide on a consensus basis.

Co-ordination
UCLA will:

- Take the responsibility for the co-ordination of the International Study;
- In collaboration with Study Group members, to provide guidelines on the collection of data from the required sources in the various countries;
- To assist participating countries with methodologic decisions where necessary;
- In consultation with participating countries, to provide guidelines for checking the accuracy and completeness of the data collected and of the case ascertainment procedures;
- To maintain the international database;
- To take responsibility for carrying out the statistical analyses of the combined data in consultation with the Study Group;
- To organize meetings of the Study Group to discuss on-going problems of the study, results, preparation of reports and publications;
- To select further countries to participate in the study and provide a link among the participating countries between the meetings of the Study Group
- To co-ordinate the publication of results of the international study;
Organization of the Study

Meetings
Meetings of the Study Group will be held as necessary, to discuss its developments, approaches to the analysis and interpretation of results, as well as to prepare publications.

Use of Data
The use of the combined data is the prerogative of the Study Group. The numbers are likely to be small and insufficient for the publication of individual country specific estimates. Access to the combined data set for further analyses may be provided to a national investigator or a third party for a well-described and specified purpose, only if written consent is obtained from all Study Group members. Analyses by such third parties will be performed at UCLA (no data will be sent out) in collaboration with the Study Group, and the interpretation of results will be discussed before any result is published. Such analyses will be permitted only if they do not pre-empt or duplicate work to be done by the Study Group.

Publications
UCLA will be responsible for preparing a paper of results from the epidemiological analyses. Authorship will include the study group, including a PI from each country.

Financial Aspects
Initial funding for pilot work might be available from EPRI. Obtaining funds from local or national level is highly encouraged.
REFERENCES


APPENDIX - PUBLICATIONS

The following publications have resulted from TransExpo pilot studies so far. Abstracts are reproduced here – see full articles for complete details.


Indoor transformer stations as predictors of residential ELF magnetic field exposure.

Ilonen K, Markkanen A, Mezei G, Juutilainen J.

Department of Environmental Science, University of Kuopio, Kuopio, Finland.

Abstract

Transformer stations in apartment buildings may offer a possibility to conduct epidemiological studies that involve high exposure to extremely low frequency magnetic fields (MF), avoid selection bias and minimize confounding factors. To validate exposure assessment based on transformer stations, measurements were performed in thirty buildings in three Finnish cities. In each building, spot measurements in all rooms and a 24-h recording in a bedroom were performed in one apartment above a transformer station (AAT), in one first floor (FF) reference apartment, and one reference apartment on upper floors (UF). The apartment mean of spot measurements was 0.62 microT in the AATs, 0.21 microT in the FF and 0.11 microT in the UF reference apartments. The 24-h apartment mean (estimated from the spot measurements and the bedroom 24-h recording) was 0.2 microT or higher in 29 (97%) AATs, in 7 (25%) FF and in 3 (10%) UF reference apartments. The corresponding numbers for the 0.4 microT cut-off point were 19 (63%), 4 (14%), and 1 (3.3%). The higher MF level in the FF reference apartments indicates that they should not be considered "unexposed" in epidemiological studies. If such apartments are excluded, a transformer station under the floor predicts 24-h apartment mean MF with a sensitivity of 0.41 (or 0.58) and a specificity of 0.997 (or 0.97), depending on the MF cut-off point (0.2 or 0.4 microT). The results indicate that apartments can be reliably classified as high and low MF field categories based on the known location of transformer stations.

Reprinted from Bioelectromagnetics; Vol 29 (3); 2008; Pages 213-218; Ilonen K; et al; Indoor transformer stations as predictors of residential ELF magnetic field exposure; Abstract of the article.

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Exposure to 50 Hz magnetic field in apartment buildings with built-in transformer stations in Hungary.


Frédéric Joliot-Curie National Research Institute for Radiobiology and Radiohygiene, H-1221 Budapest Anna u.5, Hungary. thuroczy@hp.osski.hu

Abstract

Exposure to 50 Hz magnetic field (MF) was evaluated in 31 multi-level apartment buildings with built-in step-down transformer stations. In each building, three apartments were selected: one apartment located immediately above the transformer room (index apartment), one located on the same floor and one on a higher floor. The mean value of measured MFs was 0.98 microT in apartments above transformers, 0.13 microT on the same floor, and 0.1 microT in on higher floors. The mean measured MF value was higher than 0.2 microT in 30 (97%) index apartments, 4 (14%) on the same floor as the index apartments and 4 (13%) on higher floors. The corresponding numbers were 25 (81%), 0 and 0, respectively, when 0.4 microT was used as cut-point. It is concluded that apartments in building with built-in transformers can be reliably classified into high and low-exposure categories based on their location in relation to transformers.

Reprinted from Radiation Protection Dosimetry; Vol 131 (4); 2008; Pages 469-73; Exposure to 50 Hz magnetic field in apartment buildings with built-in transformer stations in Hungary; Thuróczy G; et al; Abstract of the article.

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Exposure to 50 Hz magnetic fields in apartment buildings with indoor transformer stations in Israel.

Hareuveny R, Kandel S, Yitzhak NM, Kheifets L, Mezei G.

Radiation Safety Division, Soreq NRC, Yavne, Israel.

**Abstract**

To advance our understanding of an association between exposure to power frequency magnetic fields (MFs) and the risk of childhood leukemia, we should conduct a study that is convincingly free of selection and response bias, with highly accurate exposure assessment and a large number of highly exposed individuals. Previous measurements revealed that MF in apartments located above internal transformer stations (ITSs) are higher than in other apartments in the same building. An international epidemiologic study of childhood leukemia, TransExpo, was designed to take advantage of this scenario. This article presents the results of an exposure assessment study performed in apartment buildings with ITS in Israel. Measurements were performed in 41 apartments within 10 buildings. Average MF at the height of 0.5 m was 0.40 μT in apartments above the ITS and 0.06-0.12 μT in all other apartments. These results confirm that classification of MF exposure based on apartment location is feasible with remarkable specificity (0.98 and 0.96 for cutoff points of 0.2 and 0.4 μT, respectively) and sensitivity (1.00 for both cutoff points). Because the location of an apartment relative to the ITS can be easily determined, an exposure assessment can reliably be performed without obtaining access to residences. *Journal of Exposure Science and Environmental Epidemiology* advance online publication, 21 April 2010; doi:10.1038/jes.2010.20.

Reprinted from *Journal of Exposure Science and Environmental Epidemiology*; Epub 4/21/10; Hareuveny R; Kandel S; et al; Exposure to 50 Hz magnetic fields in apartment buildings with indoor transformer stations in Israel. Abstract of the article.

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APPENDIX - REPORTS

The following progress or final reports have resulted from TransExpo feasibility and pilot studies:

1. TransExpo pilot study in Bulgaria. 2010
   Principal investigator: Prof Michel Israel
   Institution: National Centre of Public Health Protection, Bulgaria

2. Feasibility study for the Dutch contribution to an international study of childhood leukemia and residences near electrical transformer rooms (TransExpo); Progress report EMF&H projects September 2010
   Principal investigator: Prof H Kromhout
   Institution: Utrecht University, Netherlands

3. TransExpo feasibility study in Italy. Results of the pre-feasibility assessment
   Principal Investigator: Susanna Lagorio
   Institution: National Centre for Epidemiology – National Institute of Health (CNESPS – ISS)

4. Transexpo: pilot study in Switzerland. September 2009
   Principal Investigator: Martin Roosli
   Institution: Swiss Tropical and Public Health Institute, Basel
1. TransExpo Pilot Study in Bulgaria

National Center of Public Health Protection

Sofia, 2010

PROJECT TEAM

Project leader: Prof. Michel Israel, Ph.D

Team: National Center of Public Health Protection, Victoria Zaryabova, MS, Res. Ass.
Tsvetelina Shalamanova, PhD, Res. Ass. Mihaela Ivanova, Eng. Petia Ivanova, Eng. Hristina Petkova, Magdalena Dimitrova, Rumiana Petrova,

Consultants: Prof. Zdravka Valerianova, MD, PhD - National Oncological Hospital, Prof.
Mircho Vukov, PhD - Center for Health Information, Jordan Kalchev, PhD - National Statistical Institute, Bojidar Gatev - Sofia Electrical Company

Funding: This study was funded by the Electric Power Research Institute (EPRI Contract EP-P29958/C14066

Introduction

The problem with public exposure to electric (EF) and magnetic fields (MF) from built-in dwellings transformer stations was set by the general public during 80's in last century.

Then there were about 200 built-in transformer stations in Sofia. The rest ones were placed in separate small buildings situated outside the dwellings. The fears among the population that the "old" built-in transformer stations could emit dangerous levels of EF and MF led to the necessity of conducting a pilot study. It was performed in the period 1995-1996. There were investigated 36 transformer stations all over the territory of Sofia. A group of them (15) were built-in the period 1990-1995. Transformer stations were classified as follows:

Basement (underground) type - placed in a premise that is a part of the building and is under the ground level;

Ground floor type - situated in a premise that is a part of the building and is on the ground level or little above it;

Contiguous type - situated add to the building (there is a common wall) and it is situated on or little above the ground level.

The results of this pilot study show that the magnetic field values exceed the "limit" of 3 mG in living rooms situated just next to the transformer stations. This is more valid for the Ground floor transformers type. There, the measured values are several times higher that for the other transformer types.
In this case, we proposed the transformers build in dwellings to be preferably of **Basement** and **Contiguous** types. Most of the literature data for the typical magnetic field values due to electrical appliances for one "typical living apartment" are between 0.5 and 4 mG.

The big raise of the price of the land in our country especially in the capital, also the huge construction of new buildings after 1996 led to the practice all transformers to be build within the dwellings. Our data show that only on the territory of the "wide capital" there are more than 8,000 built-in transformers. This will enlarge the public concern about the health effects caused by the EMF emission.

The conclusion of this first study in Bulgaria concerning transformers in dwelling was that more data of measurements are needed, in more living rooms with different consumption of electric current and power of the transformers. All measurements should be performed under standard conditions, and using standardized method of measurement. Furthermore, according to IARC statement "extremely low frequency magnetic fields are possibly carcinogenic to humans (Group 2B)" requires more research to answer the question if there is any relationship between magnetic fields values and cancer especially childhood leukemia.

In 2008, Bulgaria through the National Centre of Public Health Protection (NCPHP) joined the International TRANSEXPO Project, with pilot study. At this first stage of the project our investigation was directed to performing measurements in dwellings with built-in transformer stations, collecting data of population and cancer registry, choosing the epidemiology design feasible for continuing the project.

**Electrical Distribution system in Bulgaria**

In Bulgaria the supply of population with electricity is performed by a well-balanced electricity system built in the 50's and 60's of last century. At this time most of the transformers have been built-in the dwellings. After 60's up to 90's it was allowed the transformers to be situated only outside the buildings. The reason that the land and electricity system is state property gives the opportunity to place the transformers in small buildings among the dwellings. After 1990 this practice became impossible, and the most of the new transformer stations were located in or next to the buildings. In the past Bulgaria plays an important role in the production and distribution of electricity in the Balkans. Till 90's electricity distribution network is owned and is a priority of the State, then it was sold to three private companies: CEZ, EVN, EON. These companies are currently committed to the management and maintenance of electrical distribution in the country and plans and investments for the construction of electric power distribution network and facilities. But this impedes specification of the total number of transformers in the country. The rapid developing process of investment in construction and continuous incorporation of new transformers in residential and administrative buildings made the task much more complicated, furthermore the construction of transformers is born by property investors.

**Built-in transformers**

In Bulgaria is common to built-in transformer stations in buildings. The built-in transformer provides electricity to residential, industrial and agricultural buildings. They are placed in the basement of a building or in separate premises depending on the ability of the terrain.
**Transformer station located in the basement of a residential building**

There are premises with built-in transformers where the transformers cells are located at elevation \(-3.30\) m, below the gangway from the street to the courtyard. In this case the adjoining areas are basements, garages, machine room, elevators and warehouses. This is the most appropriate method available to prevent exposure of the population living above the transformer, since the first floor is located at a distance of \(2.65\) m from the roof of transformer station. This type of location common occurs in newly built buildings.

In most cases basement type of transformers are adjacent to apartments (objects to this project), shops or residential care facilities. Access to them is carried out from the ground level via openable lid and a metal ladder. The rooms are insulated by thick concrete wall from the rest of the basement and the ceiling of the transformer station is a concrete slab with thickness depending on the construction design.

**Ground type transformer station**

Integrated (ground) type transformers are built mainly during 70's in Sofia, at the construction of residential units over 10 floors. They carry out electrical supply to several multi-storey residential buildings in the area (minimum two). This type of transformer could be located between two apartments on either side, and one above the premises of transformer station. In most cases there is one apartment next to the transformer station and above.

**Contiguous type**

Such transformers are widespread in the country. This type of transformer stations are mounted in a premise located next to the building. Sometimes there is a small air gap between the building and transformer room.

**Modular transformers**

This is a quite new transformer station type which is compact and can be embedded in buildings or to be placed individually. Hereafter a sketch of such type of transformer station is presented.
Main elements:

1. Concrete frame - monolithic
2. Distribution system - medium voltage (in Bulgaria voltages up to 20 kV are called medium; above 100 kV - high voltage); later for the purposes of the project voltages above 1 kV will be considered as "high voltage";
3. Low voltage panel
4. Transformer
5. Door
6. Cable ("high" voltage)
7. Cable connections 0.4 kV
8. Adaptor

Data from Sofia electrical company (CEZ)

According to information given by electrical company there are more than 2000 built-in transformers in Sofia.

Main types of the built-in transformer stations are underground and basement types.
They could be classified by several criteria:

Regarding to the used transformers we have dry and oil ones. Transformer station with oil transformer requires more than one premise which is the reason that more common types are those with dry transformer.

According to the number of transformers they could be with one, two, three or etc.

Main elements of transformer stations are:

- Distribution system - primary ("high") voltage;
- Distribution system for secondary (low) voltage;
- Transformer.

Distribution systems are two types. So called "old type" are with separate cells (open distribution system) with equipment and they require minimum 3.5 m height of the premise. The new ones are with closed distribution system and the height of the transformer room should be not less than 2.5 m.

![Open and Closed Distribution System](image)

**Figure B-2**
Open and Closed Distribution System

**Cables’ configurations**

Primary (high voltage) is rigid bus work to the transformer passing on different height from the ceiling of the transformer station;

Secondary (low voltage) could be realized as follows:

- With rigid bus work from the transformer to the switchgear, on different heights from the ceiling of the transformer station;
- With cables from the transformer to the switchgear which pass through floor, walls, or at different heights from the ceiling of the transformer station.
The modifications of transformer stations in Sofia were made mainly during the last two years in the following cases:

- Some have been modified in order to optimize the stations: change of equipment with closed complete distribution systems;
- Some of them after break down.

**Bulgarian National Cancer Registry (BNCR)**

A specialized cancer network was founded in Bulgaria in 1952. It consists of 13 Regional Oncological Centers (dispensaries) and a National Oncological Hospital in Sofia. There are three specialized children's oncohaematology hospitals in the biggest cities in Bulgaria - Sofia, Plovdiv and Varna. The Regional Cancer Registries are part of the structure of each Regional Oncological Center, and the Bulgarian National Cancer Registry - of the National Oncological Hospital [1]. In the country exists a compulsory registration of malignant neoplasm, regulated by the Ministry of Health [2,3,4]. According to the legislation every physician/medical worker is required to send a "rapid notification" to the Regional Oncological Center for each newly diagnosed cancer case, for a person suspected of having cancer or for those dying from a malignant neoplasm, and since 1975 for carcinoma in situ, as well, by the patient's permanent residence. The BNCR uses active and passive methods of data collection. The personnel of the Regional Cancer Registries periodically visits the regional health facilities, which provide service, as well as actively seek all cases of malignant neoplasm and carcinoma in situ, unknown to the certain registry. Another main source of information on cancer patients are death certificates. The BNCR receives information from all Regional Cancer Registries around the country. The data are verified for range and completeness, duplication, and consistency between clinical and morphological diagnosis. The most recent update of the rapid notification was introduced in 1992 [5]. For 1993 the cancer patients have been following up by type of treatment and date of death, as well. In January 2005 the Xth revision of the International Classification of Diseases (ICD), 1992 was introduced in Bulgaria. All cases of malignant neoplasm dated after 1993 (the initial year of cases identification by person) had to be recoded, according to the new classification requirements. The localization is coded according to the four-digit rubrics for all malignant neoplasm (C00 - C97), carcinoma in situ (D00 - D09) and for D39.0, D42, D43, D45, D46, D47.1, D47.3 which are changed from Borderline to Malignant according to ICD-O, Third edition, 2000.
A software product "Oncology - 2005", has been developed to serve the needs of registration of cancer cases and was implemented throughout the country in all Regional Oncological Centers at the beginning of 2005. The software meets all requirements of "Standards and Guidelines for Cancer Registration in Europe", IARC Technical Publication № 40, 2003, for coding of certain variables. It also allows additional information for cancer cases to be collected, for example: information for metastases localization; Clark and Breslow for the malignant melanoma of skin; estrogen and progesterone receptors of breast cancer; new information about the type of medical facility, where the initial treatment happened during the first year after cancer diagnoses, etc.

When determining the multiple primary cancers the rules of the European Network of Cancer Registries (ENCR) "Recommendations for coding Multiple Primaries", 2000 are followed.

A check of the Unified System for Civil Registration and Administrative Services to the Population (USCRASP) was made for all cancer cases died since 1998 in order to improve the malignant neoplasm registration system in accordance with IARC requirements. The National Statistical Institute provides population and mortality data for the registry needs.

All records are kept stored according to The Archives Law from 1974 and The Health Law from 2004.

The data on cancer incidence, as well as the included additional data, is appropriate for epidemiological studies, for public health administering, etc. This information is available to all individuals and institutions interested according to the legislation of the country for data confidentiality.

**Quality of the Registry's data**

The quality of the Registry's data is assessed in terms of comparability, completeness and accuracy. To evaluate the comparability of the data with other populations and periods of time, an analysis of the extent to which the register conforms to international guidelines and standards for cancer registration with regard to the coding of the site and morphology of primary tumours, incidence date, multiple primaries, etc. is performed. To assess the completeness the capture-recapture method is used. The estimated overall completeness of the data for 2007 is 92.5%.

The applied indicators for accuracy are as follows - the percentage of all registered cancer cases in 2007 that have been morphologically verified (MV %), and the percentage of death certificate only registrations (DCO%).
Figure B-4
Leukemia Cases by Year of Diagnosis for 0-14 Years in Sofia and Bulgaria

On the next table is presented the number of newly diagnosed cases of childhood leukemia in Sofia by age.

Table B-1
Number of Newly Diagnosed Cases of Childhood Leukemia in Sofia by Age

<table>
<thead>
<tr>
<th>Age(years)</th>
<th>Number</th>
<th>Per Cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>7</td>
<td>6,5</td>
</tr>
<tr>
<td>1</td>
<td>6</td>
<td>5,6</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>9,3</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td>10,3</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>14,0</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>9,3</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>5,6</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>5,6</td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>6,5</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>3,7</td>
</tr>
<tr>
<td>10</td>
<td>6</td>
<td>5,6</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>0,9</td>
</tr>
<tr>
<td>12</td>
<td>5</td>
<td>4,7</td>
</tr>
<tr>
<td>13</td>
<td>8</td>
<td>7,5</td>
</tr>
<tr>
<td>14</td>
<td>5</td>
<td>4,7</td>
</tr>
<tr>
<td>Total</td>
<td>107</td>
<td>100</td>
</tr>
</tbody>
</table>
In appendix I is given detailed information concerning the number of newly diagnosed cases of the whole population of Bulgaria and Sofia according to ICD-10. A sample is made for newly diagnosed cases of childhood leukemia (in the range 0-14 years) for both Bulgaria and Sofia, according to ICD-10. The classification is made for urban and rural areas for the age range 0-14 years.

**Population registry**

Unified System for Civil Registration and Administrative Services to the Population (USCRASP) was introduced in Bulgaria in 1979. The system covers all country citizens, including foreigners permanently staying in the county. Each person is identified by name and family names, as well as by a unique personal number (unified civil number -UCN). Records for persons are linked to their address registration. The address is an unique description of the place of residence or the postal address. Information on persons and their addresses is stored in registers - automated information funds.

According to the changes of the Law on Civil Registration in 1999, two addresses are used in civil registration of persons:

- "current address" - the address of usual residence;
- "permanent address" - the address of registration into the population register, which is the official postal address.

Classification of Roads and Classification of addresses within the country were created and regularly updated in order to maintain the address registration of population according to the above mentioned two addresses.

Records on persons and their address registration were created by the local administrative authorities. Information is transmitted to USCRASP. So created information funds (registers) are used for administrative service of population. Individual data is ensured to the National Statistical Institute (NSI) in order to maintain the statistical registers of population and demographic processes.

Register of persons is maintained at the NSI for statistical purposes. Each person is identified by names, ID and address according to the persons "current addresses". The address consists of:

- name and code of the settlement;
- name and code of the street according to the Classification of Roads;
- administrative number of the building according to the Classification of addresses;
- entrance;
- number of the apartment within the building.

The register of persons covers the whole country population. Based on the register, information could be derived on: sex, age (date and year of birth), citizenship, etc.
The NSI information system maintains personal registers on births, deaths, marriages, divorces and changes of address registration.

Information from the register on persons and their address registration is available since 2001 and on demographic events - since 1995. Register information is updated monthly based on the official certificates issued for registration of changes into the person's characteristics or addresses.

Additional data on persons is produced and namely on births, deaths and changes of addresses through linking the personal records from the register of persons with the demographic records.

**Assessment of the information quality**

In general, the system of statistical registers covers the whole country population and is regularly updated. There are some weaknesses existing, concerning the register information and namely in:

- reporting the international migration - part of the population does non report the leaving of the country;
- a part of the population does not report at the local administrations the changes of addresses and especially changes of addresses within the settlements.

Despite of the weaknesses pointed and taking into account their limited number, the available register information could be used for the purposes of further epidemiological study. More important is the problem related to provision of individual data on persons and the necessary procedures in this respect.

In appendix II is given a sample from the population registry concerning the annual average population in the range 0-14 years for the period 1993-2007.

**Selection of buildings and measurement campaign**

The built-in transformer stations were identified in cooperation with Sofia electrical distribution company. Four main divisions (East, West, North and South) of Sofia electrical distribution company are responsible for the separate regions of the city. Each one of them provided information concerning the addresses of built-in transformers on their territory 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.
Unfortunately, we could not manage to ensure three eligible apartments for each of visited buildings. In some of the buildings inhabitants were not found, in others they refused measurements in their property.

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.

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 - 320 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.

*Studied buildings*

The buildings were mainly of bricks except one which was monolithic in-situ cast concrete structure.
- Over 80% of them were built before 1975;
- Height of the rooms - 2.60 - 3.00 m;
- Floorage of the apartments - 42m² – 90m²;
- Number of rooms: 2 to 5.

*Measuremet procedure*

Measurements were performed according to the measuring procedure of TRANSEXPO project. Measurements were accomplished in summer - 2009: in the time intervals 9 a.m - 1 p.m and 4 p.m - 7 p.m.
- 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;
  - 24 h dosimetry in "exposed" and "unexposed" apartments.

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 station.

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.

**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).

**Results and discussion**

**Spot measurements**

We performed spot measurements in 23 exposed apartments, 21 unexposed on the first floor, 21 unexposed on 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 Tables B-2 and B-3 are presented mean values and range of the magnetic flux densities for different room types according to the apartment category on the two measuring heights.
Table B-2
Mean Values and Range of the Magnetic Flux Densities for Different Room Types on Height 0.5 m

<table>
<thead>
<tr>
<th>on 0.5 m</th>
<th>Apartment 1</th>
<th>Apartment 2</th>
<th>Apartment 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apartment</td>
<td>N=20</td>
<td>N=17</td>
<td>N=20</td>
</tr>
<tr>
<td>Average</td>
<td>0.40</td>
<td>0.23</td>
<td>0.10</td>
</tr>
<tr>
<td>(µT)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max mean</td>
<td>2.04</td>
<td>1.13</td>
<td>0.62</td>
</tr>
<tr>
<td>(µT)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min mean</td>
<td>0.05</td>
<td>0.03</td>
<td>0.01</td>
</tr>
<tr>
<td>(µT)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kitchen</td>
<td>N=17</td>
<td>N=15</td>
<td>N=15</td>
</tr>
<tr>
<td>Average</td>
<td>0.41</td>
<td>0.20</td>
<td>0.11</td>
</tr>
<tr>
<td>(µT)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max mean</td>
<td>0.50</td>
<td>0.23</td>
<td>0.14</td>
</tr>
<tr>
<td>(µT)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min mean</td>
<td>0.32</td>
<td>0.17</td>
<td>0.09</td>
</tr>
<tr>
<td>(µT)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bedroom</td>
<td>N=20</td>
<td>N=17</td>
<td>N=20</td>
</tr>
<tr>
<td>Average</td>
<td>0.47</td>
<td>0.26</td>
<td>0.18</td>
</tr>
<tr>
<td>(µT)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max mean</td>
<td>0.76</td>
<td>0.33</td>
<td>0.26</td>
</tr>
<tr>
<td>(µT)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min mean</td>
<td>0.29</td>
<td>0.18</td>
<td>0.13</td>
</tr>
<tr>
<td>(µT)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Living room</td>
<td>N=19</td>
<td>N=16</td>
<td>N=15</td>
</tr>
<tr>
<td>Average</td>
<td>0.36</td>
<td>0.18</td>
<td>0.10</td>
</tr>
<tr>
<td>(µT)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max mean</td>
<td>0.53</td>
<td>0.26</td>
<td>0.11</td>
</tr>
<tr>
<td>(µT)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min mean</td>
<td>0.24</td>
<td>0.13</td>
<td>0.08</td>
</tr>
<tr>
<td>(µT)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other room</td>
<td>N=11</td>
<td>N=7</td>
<td>N=6</td>
</tr>
<tr>
<td>Average</td>
<td>0.33</td>
<td>0.26</td>
<td>0.10</td>
</tr>
<tr>
<td>(µT)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max mean</td>
<td>0.49</td>
<td>0.36</td>
<td>0.14</td>
</tr>
<tr>
<td>(µT)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min mean</td>
<td>0.16</td>
<td>0.17</td>
<td>0.08</td>
</tr>
<tr>
<td>(µT)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table B-3
Mean Values and Range of the Magnetic Flux Dimensions for Different Room Types on Height 1.0 m

<table>
<thead>
<tr>
<th>on 1.0 m</th>
<th>Apartment 1</th>
<th>Apartment 2</th>
<th>Apartment 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apartment</td>
<td>N=20</td>
<td>N=17</td>
<td>N=20</td>
</tr>
<tr>
<td>Average ($\mu$ T)</td>
<td>0.33</td>
<td>0.20</td>
<td>0.10</td>
</tr>
<tr>
<td>Max mean ($\mu$ T)</td>
<td>1.52</td>
<td>0.71</td>
<td>0.60</td>
</tr>
<tr>
<td>Min mean ($\mu$ T)</td>
<td>0.05</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>Kitchen</td>
<td>N=17</td>
<td>N=15</td>
<td>N=15</td>
</tr>
<tr>
<td>Average ($\mu$ T)</td>
<td>0.38</td>
<td>0.19</td>
<td>0.11</td>
</tr>
<tr>
<td>Max mean ($\mu$ T)</td>
<td>0.47</td>
<td>0.22</td>
<td>0.14</td>
</tr>
<tr>
<td>Min mean ($\mu$ T)</td>
<td>0.30</td>
<td>0.16</td>
<td>0.09</td>
</tr>
<tr>
<td>Bedroom</td>
<td>N=20</td>
<td>N=17</td>
<td>N=20</td>
</tr>
<tr>
<td>Average ($\mu$ T)</td>
<td>0.35</td>
<td>0.21</td>
<td>0.09</td>
</tr>
<tr>
<td>Max mean ($\mu$ T)</td>
<td>0.52</td>
<td>0.25</td>
<td>0.11</td>
</tr>
<tr>
<td>Min mean ($\mu$ T)</td>
<td>0.24</td>
<td>0.16</td>
<td>0.08</td>
</tr>
<tr>
<td>Living room</td>
<td>N=19</td>
<td>N=16</td>
<td>N=15</td>
</tr>
<tr>
<td>Average ($\mu$ T)</td>
<td>0.30</td>
<td>0.17</td>
<td>0.09</td>
</tr>
<tr>
<td>Max mean ($\mu$ T)</td>
<td>0.41</td>
<td>0.23</td>
<td>0.11</td>
</tr>
<tr>
<td>Min mean ($\mu$ T)</td>
<td>0.21</td>
<td>0.13</td>
<td>0.07</td>
</tr>
<tr>
<td>Other room</td>
<td>N=11</td>
<td>N=7</td>
<td>N=6</td>
</tr>
<tr>
<td>Average ($\mu$ T)</td>
<td>0.29</td>
<td>0.23</td>
<td>0.10</td>
</tr>
<tr>
<td>Max mean ($\mu$ T)</td>
<td>0.39</td>
<td>0.29</td>
<td>0.13</td>
</tr>
<tr>
<td>Min mean ($\mu$ T)</td>
<td>0.13</td>
<td>0.17</td>
<td>0.07</td>
</tr>
</tbody>
</table>
Table B-4
Mean Values by Buildings for Different Apartment Category on Height 0.5 m

<table>
<thead>
<tr>
<th>Buildings</th>
<th>Apartment 1</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&quot;exposed&quot;</td>
<td>&quot;on the same floor&quot;</td>
<td>&quot;unexposed&quot;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>on 0.5 m</td>
<td>average</td>
<td>min</td>
<td>max</td>
<td>average</td>
<td>min</td>
<td>max</td>
<td>average</td>
<td>min</td>
<td>max</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building 1</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>0,06</td>
<td>0,05</td>
<td>0,08</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building 2</td>
<td>0,60</td>
<td>0,29</td>
<td>0,87</td>
<td>0,40</td>
<td>0,23</td>
<td>0,58</td>
<td>0,28</td>
<td>0,24</td>
<td>0,32</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building 3</td>
<td>0,57</td>
<td>0,12</td>
<td>1,36</td>
<td>0,41</td>
<td>0,35</td>
<td>0,48</td>
<td>0,14</td>
<td>0,12</td>
<td>0,16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building 4</td>
<td>0,16</td>
<td>0,08</td>
<td>0,45</td>
<td>0,13</td>
<td>0,06</td>
<td>0,26</td>
<td>0,04</td>
<td>0,03</td>
<td>0,05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building 5</td>
<td>0,38</td>
<td>0,20</td>
<td>1,59</td>
<td>0,30</td>
<td>0,07</td>
<td>0,86</td>
<td>0,08</td>
<td>0,01</td>
<td>0,21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building 6</td>
<td>0,35</td>
<td>0,17</td>
<td>0,61</td>
<td>0,23</td>
<td>0,13</td>
<td>0,60</td>
<td>0,25</td>
<td>0,09</td>
<td>0,62</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>0,09</td>
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<td>0,03</td>
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<td>1,13</td>
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<td>0,14</td>
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<td>additional app</td>
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</tbody>
</table>

* - these apartments were not for living purposes and therefore excluded from the study
### Table B-5
Mean Values by Buildings for Different Apartment Category on Height 1.0 m

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<thead>
<tr>
<th>Buildings</th>
<th>Apartment 1</th>
<th></th>
<th>Apartment 2</th>
<th></th>
<th>Apartment 3</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&quot;exposed&quot;</td>
<td>---</td>
<td>&quot;on the same floor&quot;</td>
<td>---</td>
<td>&quot;unexposed&quot;</td>
<td>---</td>
</tr>
<tr>
<td>on 1.0 m</td>
<td>average</td>
<td>min</td>
<td>max</td>
<td>average</td>
<td>min</td>
<td>max</td>
</tr>
<tr>
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<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
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<td>*</td>
<td>*</td>
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</tr>
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<td>0.82</td>
<td>0.41</td>
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<td>0.57</td>
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<td>0.30</td>
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<td>0.13</td>
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<td>0.53</td>
<td>0.04</td>
<td>0.02</td>
<td>0.08</td>
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<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
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<td>0.15</td>
<td>0.08</td>
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<tr>
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<td>0.07</td>
<td>0.41</td>
<td>0.07</td>
<td>0.04</td>
<td>0.15</td>
</tr>
<tr>
<td>Building 14</td>
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<td>1.52</td>
<td>0.23</td>
<td>0.10</td>
<td>0.35</td>
</tr>
<tr>
<td>Building 15</td>
<td>0.12</td>
<td>0.09</td>
<td>0.19</td>
<td>0.18</td>
<td>0.06</td>
<td>0.35</td>
</tr>
<tr>
<td>Building 16</td>
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<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Building 17</td>
<td>0.33</td>
<td>0.06</td>
<td>1.24</td>
<td>0.06</td>
<td>0.03</td>
<td>0.09</td>
</tr>
<tr>
<td>Building 18</td>
<td>0.25</td>
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<td>0.34</td>
<td>0.14</td>
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<td>1.20</td>
<td>0.05</td>
<td>0.03</td>
<td>0.13</td>
</tr>
<tr>
<td>Building 20</td>
<td>0.10</td>
<td>0.07</td>
<td>0.15</td>
<td>0.10</td>
<td>0.04</td>
<td>0.16</td>
</tr>
<tr>
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<tr>
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<td>1.10</td>
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<tr>
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<td>0.33</td>
<td>0.05</td>
<td>1.08</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* - these apartments where not for living purposes and therefore excluded from the study
On the following graphs are presented apartment averages for the three types of apartments on height 0.5 m and 1.0 m.

Figure B-6
Apartment Averages for the Three Apartments on Height 0.5 m

Figure B-7
Apartment Averages for the Three Apartments on Height 1.0 m
Appendix - Reports

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.

Figure B-8
Bedroom Averages for the Three Types of Apartments on Height 0.5 m
Additionally mean and maximum values on the centre of the beds are presented on the next figure.
Appendix - Reports

Figure B-10
Mean and Maximum Values on the Center of the Beds.

Red lines correspond to cut-off points of 0.2 $\mu$ T and 0.4 $\mu$ T

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.

24-hour 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>
<thead>
<tr>
<th>Code of Building</th>
<th>Minimum ($\mu$ T)</th>
<th>Maximum ($\mu$ T)</th>
<th>Mean ($\mu$ T)</th>
<th>Standard deviation ($\mu$ T)</th>
<th>Median ($\mu$ T)</th>
<th>Geometric mean($\mu$ T)</th>
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</thead>
<tbody>
<tr>
<td>Building 17</td>
<td>0.15</td>
<td>5.23</td>
<td>1.37</td>
<td>0.44</td>
<td>1.32</td>
<td>1.30</td>
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<td>0.09</td>
<td>0.56</td>
<td>0.41</td>
<td>0.06</td>
<td>0.43</td>
<td>0.41</td>
</tr>
<tr>
<td>Building 7</td>
<td>0.10</td>
<td>1.63</td>
<td>0.62</td>
<td>0.23</td>
<td>0.57</td>
<td>0.57</td>
</tr>
<tr>
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<td>0.49</td>
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<td>0.027</td>
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<tr>
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<td>0.18</td>
<td>0.07</td>
<td>0.18</td>
<td>0.16</td>
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<tr>
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<td>0.79</td>
<td>0.47</td>
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<td>0.47</td>
<td>0.46</td>
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</table>

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

Table B-7
Records of Magnetic Flux Density for Corresponding Bins and Data for the Exposure

<table>
<thead>
<tr>
<th>Total</th>
<th>Percent of Exposure</th>
<th>Percent of</th>
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</table>

B-22
### Bins ($\mu$ T)/building

<table>
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<th>Bins ($\mu$ T)/building</th>
<th>records</th>
<th>time</th>
<th>($\mu$ T.h)</th>
<th>total</th>
</tr>
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<td>0.00</td>
<td>0.0</td>
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<tr>
<td>0.2 - 0.4</td>
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<td>0.1</td>
<td>0.01</td>
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<td>145</td>
<td>0.7</td>
<td>0.09</td>
<td>0.3</td>
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<tr>
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<td>6.4</td>
<td>1.13</td>
<td>3.4</td>
</tr>
<tr>
<td>&gt; 0.8</td>
<td>20186</td>
<td>92.7</td>
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<tr>
<td><strong>Total exposure</strong></td>
<td></td>
<td></td>
<td></td>
<td>33.04 ($\mu$ T.h)</td>
</tr>
</tbody>
</table>

| **Building 4**          |         |      |             |       |
| < 0.20                  | 5       | 0.0  | 0.00        | 0.0   |
| 0.2 - 0.4               | 8345    | 38.3 | 3.27        | 32.7  |
| 0.4 - 0.6               | 13448   | 61.7 | 6.74        | 67.3  |
| 0.6 - 0.8               | 0       | 0.0  | 0.00        | 0.0   |
| > 0.8                   | 0       | 0.0  | 0.00        | 0.0   |
| **Total exposure**      |         |      |             | 10.01 ($\mu$ T.h) |

### Table B 7 (continued)

Records of Magnetic Flux Density for Corresponding Bins and Data for the Exposure

<table>
<thead>
<tr>
<th>Bins ($\mu$ T)/building</th>
<th>Total records</th>
<th>Percent of time</th>
<th>Exposure ($\mu$ T.h)</th>
<th>Percent of total</th>
</tr>
</thead>
<tbody>
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<tr>
<td><strong>Total exposure</strong></td>
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<td>14.83 ($\mu$ T.h)</td>
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</tbody>
</table>

| **Building 10**         |               |                 |                      |                 |
| < 0.20                  | 5879          | 27.1            | 1.15                 | 18.3            |
| 0.2 - 0.4               | 15749         | 72.7            | 5.1                  | 81.4            |
| 0.4 - 0.6               | 37            | 0.2             | 0.02                 | 0.3             |
| 0.6 - 0.8               | 0             | 0.0             | 0.0                  | 0.0             |
| > 0.8                   | 0             | 0.0             | 0.0                  | 0.0             |
### Total exposure

<table>
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<td>54.6</td>
<td>6.69</td>
</tr>
<tr>
<td></td>
<td>0.6 - 0.8</td>
<td>2890</td>
<td>13.3</td>
<td>2.03</td>
</tr>
<tr>
<td></td>
<td>&gt; 0.8</td>
<td>0</td>
<td>0.0</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Total exposure</td>
<td>11.45 ($\mu$ T.h)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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 2 dosimeties 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.
Additional measurements

The location of the transformer station in the building is of 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.

In figure is presented the vertical distribution of the magnetic field at the places with max values in the "exposed" apartments above and next to transformers.
Estimation of specificity and sensitivity

The specificity and sensitivity were estimated for cut-off point $0.4 \, \mu T$ for the two measurement heights $0.5 \, m$ and $1.0 \, m$. The results are as follows:

Values of $0.4 \, \mu T$ and above were measured in 18 out of 19 exposed apartments for height $0.5 \, m$ and in 17 out of 18 for height $1.0 \, m$.

The corresponding values for sensitivity and specificity are given in Table B-8.
Table B-8
Sensitivity and Specificity

<table>
<thead>
<tr>
<th>Height, m</th>
<th>Specificity, %</th>
<th>Sensitivity, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>90.47619</td>
<td>94.73684</td>
</tr>
<tr>
<td>1.0</td>
<td>86.36364</td>
<td>94.44444</td>
</tr>
</tbody>
</table>

Discussion of the measurement results

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 $\mu$T vs. 0.20 $\mu$T). 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 ($\mu$T.h) - 33.04 ($\mu$T.h). The difference in total exposure is due to the fact that not always the bedroom is the most exposed room in the apartment.

In conclusion, conducted measurements for the pilot Transexpo study, show a clear distinction between the magnetic field values in the 3 apartment categories.
Case identification

Efforts were made to perform a cross-section between data from the cancer registry and transformer station addresses. It was realized in collaboration with the Sofia electrical company. This pilot analysis showed three cases that could be an object of discussions:

1. Case - child with leukaemia living in Institution for children without parents - we found out the underground transformer located in the yard of the Institution;
2. Case - child with leukaemia living in a house - underground transformer located in the house yard;
3. Case - child with leukaemia living in a building next to another one with built-in transformer.

Additional efforts have to be made in order to ensure the full register of built-in transformer stations. Another problem is the information concerning the eventual change of the addresses of these children before the year of diagnosis. This is a challenge for a further study.

Final discussion and possibility for further research

The information that exists in the population and cancer registries is eligible for the purpose of the study. Quality of the data gives an opportunity for identification of cases and control groups for further epidemiological study.

The situation with the data of built-in transformer stations in Bulgaria is more complicated, because there is not unified register for the location of built-in transformer stations. This information is owned by three different companies. Nevertheless, it is possible to receive needed information in case it is necessary for further research.

The three proposed epidemiology designs for the Transexpo study were discussed by a working group on the project. Taking into account the available sources of information it found as the most appropriate epidemiology design - nested case-control study. The considerations of experts regarding the three types of epidemiology design are shown below:
**Table B-9**  
**Epidemiology Design**

<table>
<thead>
<tr>
<th>EPIDEMIOLOGY</th>
<th>AVAILABILITY/POSSIBILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DESIGN/REQUIREMENTS</strong></td>
<td><strong>AVAILABILITY/POSSIBILITY</strong></td>
</tr>
<tr>
<td><strong>COHORT STUDY</strong></td>
<td><strong>POSSIBILITY</strong></td>
</tr>
<tr>
<td>1. Identification from population registers all children who lived in relevant buildings;</td>
<td>Possible, but hard to be realized, because of the need to use several proven sources to gather the information. Since 1993 the connection between the house managers and municipality was interrupted. A part of the population does not report at the local administrations the changes of addresses and especially changes of addresses within the settlements</td>
</tr>
<tr>
<td>2. Identification all residents 0-14 ages of the buildings with built-in transformers;</td>
<td></td>
</tr>
<tr>
<td>3. Link the cohort to cancer registry;</td>
<td></td>
</tr>
<tr>
<td>4. Comparison of cancer incidence rate between &quot;exposed&quot; and &quot;non-exposed&quot; children.</td>
<td></td>
</tr>
<tr>
<td><strong>NESTED CASE-CONTROL STUDY</strong></td>
<td></td>
</tr>
<tr>
<td>1. Identification of children from cancer registry who lived in buildings with built-in transformers</td>
<td></td>
</tr>
<tr>
<td>2. Random selection of control children from children who lived in similar buildings (not necessarily the same as the corresponding case)</td>
<td></td>
</tr>
<tr>
<td>3. Identify which apartment within the building each case and control have lived</td>
<td>Taking into account availability of cancer registry, data from the population registry and the available information for transformer stations all epidemiology specialists consider this type of design as feasible for our country.</td>
</tr>
<tr>
<td><strong>CASE-CONTROL STUDY</strong></td>
<td></td>
</tr>
<tr>
<td>1. Screening for children from cancer registry who lived in buildings with built-in transformers</td>
<td></td>
</tr>
<tr>
<td>2. Random selection of control children from children who lived in the apartments with transformers</td>
<td></td>
</tr>
<tr>
<td>Controls are selected from all children living in the apartment buildings where the cases lived in the year of diagnosis, matching within one year of birth, sex, ethnicity, county of region (or matching on building instead)</td>
<td>For this type of design it is possible:</td>
</tr>
<tr>
<td>- it is hard but not impossible to identify who else lived in on the same year in the same building, and which flat within the building each child lived in.</td>
<td></td>
</tr>
<tr>
<td>But at this stage of discussion with epidemiologists and specialists in statistics (also epidemiologists) the case-control design of study is outcasted, because it will be very hard to find groups (exposed and control) matching by age (within 1 year of birth), ethnicity and other parameters needed.</td>
<td></td>
</tr>
<tr>
<td>Population registry does not contain information about ethnicity; in compliance with national laws where it is forbidden to classify such information except for the cases of taking the census of population (the last one in Bulgaria took place in 2001).</td>
<td></td>
</tr>
</tbody>
</table>
Appendix - Reports

As a conclusion, the information from different sources could be used for the aims of the further study in order to identify the dwellings close to transformers stations; to obtain information on persons living there; to identify children with leukaemia, etc.

Based on the cancer register of children, information could be derived on their personal identification and address registration. Based on these data, the buildings/dwellings of residence could be identified and the availability of a built-in transformer stations. Creation of control group will be not a problem.

The above mentioned approach could be modified in the course of the study in order to ensure achievement of the purposes of the study.

Acknowledgements

I want to thank to the team from section Physical Factors from the National Center of Public Health Protection for their entire work on the project, for organizing and conducting the measurement campaign.

I am grateful to Eng. B. Gatev from CEZ, for providing access to transformer stations and support during the measurement campaign and to Eng. E. Angelov from Company ELAM and to Eng. I. Iliev from Trafoelectroinvest (subcontractor of CEZ) for providing information on transformer stations in Sofia.

I would like to thank to Prof. Z. Valerianova, MD, PhD from the National Oncological Hospital for the help and valuable advices about the epidemiology of the study, to N. Dimitrova, MD from the National Cancer Registry for providing and proceeding the results from the cancer registry.

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Special thanks to Gabor Mezei from EPRI and Leeka Kheifets from the University of California for the permanent assistance and consulting.
References

2. Instruction № 858/ 05.03.1964
3. Ministry of Health Order № RD-09-451/ 29.06.1990
5. Nomenclature № 2 concerning medical forms, serial № 120A of the Ministry of Health
2. Feasibility Study for the Dutch Contribution to an International Study of Childhood Leukemia and Residences near Electrical Transformer Rooms (TransExpo)

Principal Investigator: Prof H Kromhout

Institution: Utrecht University, Netherlands

Summary of project goal:

The problem of differential selection bias remains one of the most frequently mentioned non-causal possible explanations for the exposure to extremely-low frequency (ELF) magnetic fields (MF) -childhood leukemia association. Differential selection bias may develop in an epidemiologic case-control study if the selection and participation probabilities of cases and controls are different based on their exposure status. Most of the published studies of ELF-MF and childhood leukemia had the potential for this type of error undermining the interpretation of these data and subsequently the regulatory inferences made based on these data.

Transformer stations located inside apartment buildings may offer a basis for designing epidemiological studies that avoid selection bias, minimize confounding factors and include people exposed to relatively strong ELF MFs. Exposure levels measured in apartments above transformer stations are often above 0.4 µT (~50%) while apartments on other than the first floor have rarely exposures higher than 0.1 µT. Thus, people living in these apartment buildings form a study population including both exposed and ‘unexposed’ individuals in which a very similar distribution of confounding factors such as other environmental exposures and socioeconomic status is likely.

As childhood leukemia is a very rare disease and the number of buildings in which transformers are located inside residential buildings and in which there are apartments right above or next to transformers will be small in each country, a multi-country study is needed. For participation in the multi-country study to be feasible the following information should be available in The Netherlands:

1. Information on location of transformers and configuration;
2. Cancer registry – Reliable information on incident childhood leukemia cases and their addresses at diagnosis;
3. Possibilities for truly random selection of controls with known addresses from the general population. This could be based on population registries or active follow-of residents of a building via municipalities’ registries.

In the feasibility study IRAS, RIVM and the Comprehensive Cancer Centres have clarified the situation for The Netherlands with respect to location of transformers, addresses at diagnosis of childhood leukemia cases and truly random selection of controls. In addition, the feasibility study has given insight which epidemiologic design (cohort, nested case-control or case-control) will be most suitable given the available information in The Netherlands.
Appendix - Reports

Progress up to August 2010:

1. Information on location and characteristics of transformers;

The Dutch three main electricity providers, Alliander, Stedin and Enexos, agreed to provide data of transformers built into buildings. Alliander provided a list of 24,000 transformers of which most likely many are not inside a building. A house-to-house check was performed in one area in Amsterdam Zuideramstel to assess accuracy of provided geo-coordinates. This check pointed to a high quality of geo-coordinates and the majority of the transformers could be located in the field. Stedin provided separate lists of transformers in Utrecht, Amersfoort and the rest of their coverage area with 450, 30 and 2,500 in-built transformers, respectively. Enexis provided a list of 1,500 in-built transformers.

Overall, typical power capacity of the transformers (information provided only by Enexis and Stedin) is 450 kA (about 25-35% of transformers), followed by 630 kA (about 25%) and 250 kA (about 15%), with a range from 10 to 1,600 kA. It seems to be a typical pattern that transformers are not built into cellars, but rather into the ground floor of apartment buildings, or attached to buildings or in separate buildings (very frequent).

2. Cancer registry – Reliable information on incident childhood leukemia cases and their addresses at diagnosis;

Childhood leukemia cases of the entire The Netherlands are included in the data base. Registration of cases started in the 1973. At SKION extensive records exist of children who have been diagnosed with cancer, including the addresses of childhood cancer. The parents have given consent for the use of those records for research. No re-contacting and re-consenting is necessary, but a medical ethical committee should test the project procedure. An extended analysis of the legal aspects of the TransExpo study has been made.

3. Possibilities for truly random selection of controls with known addresses from the general population.

The GBA provides the only possibility to draw truly random population controls. The GBA may be used for medical research for this kind of purpose. Within a municipality, it is technically possible to search for an address and house number of children who have lived during a specific time at an address. The possibility to search for the residential history of children might differ strongly between the municipalities. In Utrecht, for example, histories are saved and can be accessed at a later time point. However, this may not be the case in all municipalities.

Overall conclusion

It was concluded that performing the TransExpo study in The Netherlands is feasible in a case-control design.

Recommendations

The main recommendation is to actually perform the TransExpo study. For this, funding should be acquired and the following work steps should be performed:
While it is feasible to perform the necessary steps as required by the international TransExpo study protocol, an actual check of the numbers of cases might yield that there are no cases. For this analysis addresses of cancer cases need to be matched with the transformer registry to find out if there were any cases in apartment buildings with built-in transformers.

As required in the TransExpo protocol, the feasibility study should be followed by the pilot phase. In the pilot, magnetic field strength across distance to the transformer room should be assessed. This is necessary to evaluate whether persons can be assigned low, medium or high exposure levels based on location of apartment within the building.

While a transformer registry can be developed based on the provider data, it still needs considerable work on quality checks and correction of addresses and geo-coding.

Some of the municipalities charge a fee for accessing the GBA data base. This fee has to be budgeted for selecting controls accordingly.
3. TransExpo Feasibility Study in Italy: Results of the Pre-feasibility Assessment

Principal Investigator: Susanna Lagorio

Institution: National Centre for Epidemiology – National Institute of Health, Rome (Italy)

Background

The Italian power distribution network has been run for almost 40 years (1962-1999) by ENEL, in a monopole regime. The decree-law n° 79/1999 introduced the liberalization in the Italian power market, and more than 150 electricity distribution companies currently operate in the country. The power providers in the ten most populous Italian cities are listed in the following table.

<table>
<thead>
<tr>
<th>City</th>
<th>Total population (2009)</th>
<th>Children (0-14 years)</th>
<th>Power distribution company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rome</td>
<td>2,724,347</td>
<td>371,752</td>
<td>ACEA Distribuzione SpA</td>
</tr>
<tr>
<td>Milan</td>
<td>1,295,705</td>
<td>160,459</td>
<td>A2A Reti Elettriche SpA</td>
</tr>
<tr>
<td>Naples</td>
<td>963,661</td>
<td>154,707</td>
<td>ENEL</td>
</tr>
<tr>
<td>Turin</td>
<td>908,825</td>
<td>108,293</td>
<td>AEM Torino Distribuzione SpA</td>
</tr>
<tr>
<td>Palermo</td>
<td>659,433</td>
<td>103,845</td>
<td>ENEL</td>
</tr>
<tr>
<td>Genoa</td>
<td>611,171</td>
<td>68,944</td>
<td>ENEL</td>
</tr>
<tr>
<td>Bologna</td>
<td>374,944</td>
<td>39,858</td>
<td>HERA SpA</td>
</tr>
<tr>
<td>Florence</td>
<td>365,659</td>
<td>42,424</td>
<td>SIE srl</td>
</tr>
<tr>
<td>Bari</td>
<td>320,677</td>
<td>4,3320</td>
<td>ENEL</td>
</tr>
<tr>
<td>Catania</td>
<td>296,469</td>
<td>44,941</td>
<td>ENEL</td>
</tr>
<tr>
<td>Italy</td>
<td>60,045,068</td>
<td>8,428,708</td>
<td>~150 companies</td>
</tr>
</tbody>
</table>

A nationwide population registry exists in Italy only since 2001 (and it is still incomplete to date), whereas each Italian municipality manages a complete and regularly updated population file (Italy counts 8094 municipalities, aggregated into 110 provinces and 20 regions).

Only one third of Italian citizens lives in areas covered by population-based cancer registries (AIRTUM, http://www.registri-tumori.it). Moreover, the coverage is geographically heterogeneous, varying between 50% in Northern Italy and 18% in Southern Italy and the islands.
However, the Italian Association of Pediatric Hematology and Oncology (AIEOP) runs a childhood cancer registry, consisting of several disease-specific and protocol-oriented databases. The Operational Centre of the AIEOP Registry (Director Dr. A. Pession, data-base administrator Dr. R. Rondelli) is at the Sant’Orsola – Malpighi Hospital, Bologna (Italy). The AIEOP registry was launched in 1976, with the main aim of evaluating outcomes of treatment protocols, and it reached an almost nationwide coverage in 1989 (98% of the resident population). The degree of registration completeness varies depending on the neoplasm, but it is very high for childhood leukemia (97% in 2008).

Against this background, it is clear that the feasibility of TransExpo in Italy must necessarily be assessed at the local level, eventually planning a multicentre coordinated contribution to the international study.

The electric utility companies in Rome (ACEA Distribuzione SpA) and Milan (A2A Reti Elettriche SpA) showed a keen interest in the TransExpo international project, and local teams of interested epidemiologists and exposure assessment experts were present in these areas, which are the two most populous Italian cities. Thus, a preliminary feasibility assessment was carried out in Rome and Milan.

**Findings from the pre-feasibility assessment in Rome**

ACEA provided the local research team with the complete list of secondary (MV-LV) transformers operating in Rome by the end of 2006.

The pre-feasibility assessment was carried out by the National Institute of Health (Dr. Susanna Lagorio, Dr. Alessandro Polichetti) in collaboration with the Epidemiology Department of the Local Health Agency RM-E (Dr. Francesco Forastiere, Dr. Giulia Cesaroni), and ACEA technicians. The objective of this explorative enquiry was to verify whether the basic requirements for participation in the TransExpo international feasibility study were actually met.

**Rome - Transformers**

The ACEA secondary cabin files consisted of 11,803 records and included the following variables:

- Code
- Location
- Address toponymy (street /avenue /square)
- Street name
- Street number
- Postal code
- District (1-19)
- Urban zone (1-155)
- Type of entrance
- Engineering data
- N° transformers per cabin
- Power
- Installation date

There was no direct information on the type of hosting building (i.e. if it was residential or not).

The ACEA technicians suggested to use the “type of entrance” as a proxy indicator of type of building, on the ground that secondary cabins located in residential buildings would usually be accessible through a regular door, while entrances classified as trapdoor, kiosk or pole would denote isolated cabins. However, the variable “type of entrance” had too many missing data (46%) to be of practical use (Table B-11).

### Table B-11
**Distribution of Secondary Cabins in the ACEA File (updated to 2006)**

<table>
<thead>
<tr>
<th>Entrance</th>
<th>Building</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Door</td>
<td>Residential</td>
<td>3,985</td>
</tr>
<tr>
<td>Trapdoor</td>
<td>Non residential</td>
<td>1,538</td>
</tr>
<tr>
<td>Kiosk</td>
<td></td>
<td>305</td>
</tr>
<tr>
<td>Pole</td>
<td></td>
<td>173</td>
</tr>
<tr>
<td>Missing</td>
<td>?</td>
<td>5,082</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>11,083</strong></td>
</tr>
</tbody>
</table>

The date of installation was characterized by an even higher proportion of missing data (Table B-12).

### Table B-12
**Distribution of Secondary Cabins in the ACEA File by Installation Date**

<table>
<thead>
<tr>
<th>Installation date</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1920 (missing?)</td>
<td>7,844</td>
</tr>
<tr>
<td>1920-1949</td>
<td>98</td>
</tr>
<tr>
<td>1950-1969</td>
<td>492</td>
</tr>
<tr>
<td>1970-1989</td>
<td>169</td>
</tr>
<tr>
<td>1990-1996</td>
<td>73</td>
</tr>
<tr>
<td>1997-2006</td>
<td>2,407</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>11,083</strong></td>
</tr>
</tbody>
</table>

Most records in the ACEA cabin file related to transformer rooms actually located in Rome (10,907; 99%), while a few were secondary cabins located out of Rome or auxiliary services (Table B-13).
Table B-13
Distribution of Secondary Cabins in the ACEA File by Location

<table>
<thead>
<tr>
<th>Facility</th>
<th>Location</th>
<th>N°</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secondary cabins</td>
<td>Rome</td>
<td>10,907</td>
<td>99%</td>
</tr>
<tr>
<td></td>
<td>Out of Rome</td>
<td>104</td>
<td>0.9%</td>
</tr>
<tr>
<td>Auxiliary services</td>
<td></td>
<td>72</td>
<td>0.6%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>11,083</td>
<td>100%</td>
</tr>
</tbody>
</table>

The available technical characteristics of the transformers were limited to the number of transformers and the total power (kVA), but were available for all records (Tables B-14 and B-15).

Table B-14
Secondary Cabins in the ACEA File by Number of Transformers

<table>
<thead>
<tr>
<th>Transformers (#)</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10,015</td>
</tr>
<tr>
<td>2</td>
<td>1,008</td>
</tr>
<tr>
<td>3-6</td>
<td>60</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>11,083</td>
</tr>
</tbody>
</table>

Table B-15
Secondary Cabins in the ACEA File by Rated Power

<table>
<thead>
<tr>
<th>Power (kVA)</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>25-199</td>
<td>1,086</td>
</tr>
<tr>
<td>200-399</td>
<td>2,981</td>
</tr>
<tr>
<td>400-499</td>
<td>3,919</td>
</tr>
<tr>
<td>500-699</td>
<td>2,276</td>
</tr>
<tr>
<td>700-999</td>
<td>431</td>
</tr>
<tr>
<td>1000-3780</td>
<td>390</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>11,083</td>
</tr>
</tbody>
</table>

The address of around one third of Rome buildings hosting transformer rooms, however, was incomplete, mainly due to missing street number (Table B-16).
Table B-16
Secondary Cabins in Rome by Completeness of Information on the Address

<table>
<thead>
<tr>
<th>Address</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete</td>
<td>7,487</td>
</tr>
<tr>
<td>Incomplete</td>
<td>3,420</td>
</tr>
<tr>
<td>Total</td>
<td>10,907</td>
</tr>
</tbody>
</table>

Relevant pieces of information not recorded in the ACEA cabin file included the within-building location of the transformer room and its orientation, the secondary cable route (ceiling vs floor), switchgear features, and type and date of technical change (if any).

The municipality of Rome covers an area of 1,285 km$^2$ with a population size of 2,747,689 people in 2006. Based on the ACEA cabin files, in 2006 there were 7 secondary cabins per km$^2$, and 4 MV/LV transformers per 1000 inhabitants, on average (Table B-17).

Table B-17
Density of Secondary Cabins in Rome and Number of Cabins Per Inhabitant

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1,285 km$^2$</td>
<td>2,747,689</td>
<td>Address information</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Complete</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incomplete</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Overall</td>
</tr>
</tbody>
</table>

In summary:

- Based on the ACEA cabin file provided in 2008 and updated to December 2006, almost one third of the 10,907 records relating to MV/LV transformers located in Rome had an incomplete address, and the number of secondary cabins apparently localizable (assuming no typing errors) dropped to ~7,500.
- Information on the type of hosting building was not available, and it was not clear how many cabins with complete address were actually located in residential buildings.
- The number of secondary cabins with standard and non-standard configuration was unavailable from the cabin file.
- Likewise, structural changes over the years had not been recorded.

In January 2009 we discussed with our ACEA referents the possibility of carrying out a preliminary survey of the cabins with complete address, aimed at collecting and recording currently missing data on the characteristics of the hosting. Our ACEA referents, however, judged such an extensive survey unfeasible and, in February 2009, declined their co-operation in the study.
In May 2010 a second TransExpo meeting was held at the National Institute of Health in Rome, with the objectives to assess progresses in the pre-feasibility assessment of TransExpo in Italy, to discuss the possibility of coordinating and joining the efforts, and eventually to move on and figure out the foreseeable design of the Italian pilot study.

Eng. Emilio Zendri from ACEA Distribuzione SpA kindly agreed to take part in the meeting and to re-enter into negotiations with the Rome research team. He showed us that the ACEA cabin file had underwent substantial improvements in the completeness of information available (Figure B-13).

The date of installation is now completely recorded (Table B-18).
Table B-18
Secondary Cabins by Installation Date (E. Zendri, 18 May 2010)

<table>
<thead>
<tr>
<th>Date</th>
<th>N°</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1949</td>
<td>18</td>
<td>0.1%</td>
</tr>
<tr>
<td>1950-1969</td>
<td>347</td>
<td>3%</td>
</tr>
<tr>
<td>1970-1989</td>
<td>1,351</td>
<td>11%</td>
</tr>
<tr>
<td>1990-1996</td>
<td>2,717</td>
<td>21%</td>
</tr>
<tr>
<td>1997-2006</td>
<td>6,131</td>
<td>48%</td>
</tr>
<tr>
<td>2007-2009</td>
<td>2,054</td>
<td>16%</td>
</tr>
<tr>
<td>2010</td>
<td>184</td>
<td>1%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>12,802</td>
<td>100%</td>
</tr>
</tbody>
</table>

*Rome - Source of study subjects*

- A historical Population Registry is available in Rome, as well as in any other Italian municipality. These registries are virtually complete and regularly updated (every child born in Italy is automatically enlisted in the Registry Office files of the municipality where his/her mother resides; notification of changes in the place of residence is compulsory and required to subscribe with water, power, and telephone service providers; resident files are officially revised at censuses, every 10 ten years).

- The Italian municipal Registry Office files include reliable and complete information on the personal residential address.

- Moreover, a complete list of Rome residents during the period 1996-2007 (including stable residents as well as people born, deceased, immigrated and emigrated during the mentioned time period) is available at the Epidemiology Department of Local Health Agency “RM-E”. It has been developed based on the Rome Registry Office files regularly updated every 3 months. The personal data recorded include:
  - Municipal code
  - Name and Surname
  - Fiscal code
  - Gender
  - Place and date of birth
  - Date of start residence in Rome
  - Address at start residence and any change occurred since 1996
  - Building unit and apartment number (completeness to be checked)
Appendix - Reports

- Family code
- Vital status (including date and place of death)
- Emigration (including date and place of destination)

Personal data of the child’s parents and of any other member of the family may be retrieved using the family code as linkage-key.

The individual residential history from 1996 to 2007 is available in terms of change/s of address within the Rome municipality. However, the residential history of children born before January 1st, 1996 and residing (at this date or later, before reaching 15 years of age) in buildings hosting a secondary cabin, is not available from this population source. Thus, the possibility to retrieve the required information for this sub-sample of potentially eligible children through the Rome Registry Office needs to be verified.

Census data (education, occupation, etc.) are also available for 80% of residents in 2001.

In summary:

- Population Registry files are available in Rome, and include reliable and complete information on address;
- Furthermore, an “epidemiology-oriented” historical population file including all Rome residents from 1996 to 2007 and plenty of related personal data is available and accessible by the TransExpo local research team.

Rome - Childhood Leukemia Registry

No Cancer Registry is available in Rome. However, two different sources may be used to ascertain childhood leukemia cases eventually diagnosed among cohort members:

(a) the regional data-base of hospital discharges (available since 1996) and
(b) the AIEOP childhood leukemia registry.

The individual pieces of information available in the AIEOP registry are:

- Personal data (name, surname, date of birth, place of birth, place of residence, address)
- Date of diagnosis
- Disease
- Treatment
- Transfer between centers
- TMO
- Follow-up
Appendix - Reports

- Cytogenetic
- Immunophenotype

The AIEOP registry has an almost nationwide coverage (98%) since 1989, and a high degree of completeness for childhood leukemia (97% in 2008).

The regional data-base of hospital discharges may contain multiple records per child, which need to be screened in order to find the hospitalization when the diagnosis was first made. It does not include hospitalizations sustained by resident in the region which took place out of the regional borders.

The AIEOP registry has the main advantages to include only incident cases of pediatric leukemia, and to allow tracing of cases diagnosed in children who moved from Rome to other Italian cities before the diagnosis.

Conclusions concerning the pre-feasibility assessment carried out in Rome

On the whole, all the basic requirements for moving on to the pilot study seem to be met in Rome. There is an interdisciplinary research team willing to join the TransExpo international research group. There are over 5,000 MV/LV transformers located in residential buildings, with a minimum set of related information recorded in electronic format, including the address. Both population and disease registries are available and accessible.

Pre-feasibility assessment in Milan

A pre-feasibility assessment of the TransExpo study in Milan was carried out during the period November 2009 – March 2010 by the Director of the Epidemiologic Unit at the Milan Local Health Agency (Dr. Luigi Bisanti) in collaboration with Dr. Susanna Lagorio (National Institute of Health) and technicians from the Milan electricity distribution company A2A Reti Elettriche SpA (Eng. Salvatore Pugliese and Eng. Massimo Samannà).

As in the case of Rome, the objectives of this explorative enquiry were to check the willingness of the local electricity distribution company to co-operate, and to verify whether the basic requirements for participation in the TransExpo international feasibility study were actually met.

On November 20th, 2009 a first meeting was held at the A2A headquarters. There was large consensus about the scientific relevance of the TransExpo study. A2A, however, was reluctant to accept the measurement-based exposure validation survey, being certain that it will endanger a wave of alarmism. It was also made clear that these worries were shared by all other Italian electricity distribution companies, including ACEA Distribuzione SpA in Rome, and ENEL.

The rationale of the side exposure validation study was, thus, discussed in detail and it was acknowledged that the validity of the assumption that in a transformer building the transformer itself is the main source of the between-flat variability in indoor magnetic induction levels, all other ELF-MF sources contributing just background noise, had to be field-checked.
In a second meeting, held on 23 March 2010, the pending reserves on the exposure validation survey were solved. The Milan distribution company accepted to carry it out on a convenience samples of 10-20 residential buildings, following the design suggested by the TransExpo international protocol, and assured its full co-operation to the TransExpo feasibility study.

**Milan-Transformers**

Around 5,600 transformer rooms exist in Milan, mainly located in residential buildings (following a municipal prohibition, dating back to last century, to place electrical cabins outdoor).

The Milan cabin data-base includes the following pieces of information:

- Unequivocal ID number;
- Address (street and street number) of the building within which the cabin is located;
- Level of the transformer room within the building (basement or ground floor);
- Number and power of transformers installed;
- Installment date;
- Maximum current load per transformer;
- Number of LV lines;
- Number of subscribers served (residing in the same or in other buildings).

For around 3,000 cabins, information about the kind of adjoining apartment is also available (i.e. office, shop, residential flat, cellar, etc.).

Moreover, A2A serves also the municipality of Brescia, with other 1,500 secondary cabins.

**Milan - Source of study subjects**

A Population Registry is available in Milan, as well as in any other Italian municipality (see § 3.1.1.B.). Thus, historical population files are available from the Milan Registry Office, and contain personal data and detailed information about the addresses, including a geo-code.

Based on preliminary checks, the apartment floor and number seem not available from the Milan population files.

**Milan - Childhood Leukemia Registry**

Outcome data relating to each cohort member could be retrieved through the Milan cause of death file, the Milan Cancer Registry, and the AIEOP childhood leukemia registry.

The Milan population-based Cancer Registry covers the period from 1999 to 2006.
A population-based Cancer Registry exists in Brescia as well, and its Director (Prof. Francesco Donato) is willing to collaborate in TransExpo.

The AIEOP childhood leukemia registry has complete data on cases resident in Milan diagnosed since 1976, while it reached an almost complete nationwide coverage in 1989.

Using the AIEOP data-base as the first source of case-ascertainment, and setting the cohort inception date at 1 January 1989, would allow to trace childhood leukemia cases diagnosed among Milan cohort members even if they emigrated before reaching 14 years of age.

**Conclusions concerning the pre-feasibility assessment carried out in Milan**

All the basic requirements for a successful pre-feasibility assessment seem thus to be met in Milan.

**References:**


4. TRANSEXPO: Feasibility Study in Switzerland

Principal Investigator: Martin Röösli

Institution: Institute Of Social And Preventive Medicine At Swiss Tropical Institute

Associated Institute of the University of Basel

Funding

This study was funded by the Electric Power Research Institute (EPRI Contract EP-P30619/C14246). The Federal Office of Environment (FOEN) covered the costs for the calibration of 10 EMDEX II measurement devices.

Summary

Regarding the still unresolved association between childhood leukemia and exposure to extremely low frequency magnetic fields (ELF-MF), it has been suggested that an international study focusing on populations living in apartment buildings with built-in transformers holds a strong potential to provide new data by focusing on the population with high exposure and an added ability to evaluate selection bias. Currently, in the framework of TransExpo several countries evaluate or pilot the feasibility of such a study. Basic requirements for countries eligible for participation in TransExpo are a childhood cancer registry, transformers that are built in apartment buildings and the possibility to select an representative (unbiased) control population (including information about their apartment and/or floor number).

In Switzerland, feasibility of case and control identification was tested and a measurement campaign evaluated the ELF-MF exposure distribution in 18 apartment buildings with built-in transformers. To test the planned exposure assessment method of TransExpo, we defined three exposure categories: highly exposed apartments are attached to a transformer room either directly above, wall-to-wall, edge-to-edge or corner-to-corner. Medium exposed apartments were either located on the same floor or directly above the exposed apartment. All other apartments in a building with transformers were low exposed.

It was found that case identification works well in Switzerland. But control selection is a major challenge, in particular identification of apartment and/or floor number. Nevertheless, a combination of information obtained from electric utility companies and communal population registries should work in most of the cases.

Our measurement campaign found a distinct exposure gradient between the three exposure categories. However, exposure values were relatively low in the highest exposure category (mean: 0.34 µT). If the analysis was restricted to eight buildings where the transformer was directly below or attached to the exposed apartment (omitting those apartments which faced the transformer only at a corner or edge), magnetic flux density levels were considerably higher in exposed apartments (mean: 0.59 µT). We found that exposure modeling on the data specification
The report sheet provides useful information for further refinement of the exposure assessment without the need to contact study participants.

The overall conclusion is that Switzerland will be an eligible country for the main study. However, the number of eligible cases will be only about 10 for the period between 1980 and 2007. This results in 1-2 highly exposed cases under the null hypothesis. As this estimate is subject to uncertainty a future participation of Switzerland in the main study should be done in a two-step procedure. First, with relative little effort, number of eligible cases can be determined by linking coordinates of study participants with the ones of transformers. Further activities may only be taken, if such a comparison yields a reasonable number of eligible cases.

**Introduction**

Since the publication of the Wertheimer study in 1979 several studies reported an association between childhood leukemia and exposure to magnetic fields from power lines (Ahlbom et al., 2000; Greenland et al., 2000). Based on this “limited” epidemiologic evidence and “inadequate evidence” for carcinogenicity of ELF-MF in rodent bioassays, the International Agency for Research on Cancer (IARC) classified ELF-MF as a possible human carcinogen (2B classification) in June 2001 (IARC, 2002). This classification was confirmed in the most recent evaluation WHO (WHO, 2007). With respect to the still unsolved causality, control selection bias remains one of the most frequently mentioned non-causal possible explanations for the MF-childhood leukemia association. It has been suggested that an international study of childhood leukemia focusing on populations living in apartment buildings with built-in transformers holds a strong potential to provide new data by focusing on the population with high exposure and an added ability to evaluate selection bias (Kheifets and Oksuzyan, 2008). Buildings with built-in transformers are expected to have a substantial exposure variability because ELF-MF from transformers decreases rapidly with distance. If this can be verified with measurement campaign in a given study area, exposure assessment can be done without measurement based only on the location of an apartment within a building and does not need contact with study participants. Thus, selection bias is avoided.

Currently, in several countries the feasibility of such a study is evaluated or piloted. The acronym for this international study is TransExpo. Basic requirements for countries eligible for participation in TransExpo are a childhood cancer registry, transformers that are built in apartment buildings and the possibility to select an representative (unbiased) control population sample (including information about their apartment and/or floor number).

In Switzerland we have a nationwide childhood cancer registry since 1976 and occasionally transformers are built within or attached to apartment buildings. Thus, Switzerland seems to be an interesting area for TransExpo. However, there are also limitations for the conduct of the study. We do not have a population registry, which is a problem for control selection. Cantonal or communal population registries collect only address information but not apartment identification in multi dwelling buildings. Moreover, little is known about actual exposure occurring in apartment buildings with transformers. Thus, the following three issues have to be clarified before the feasibility of TransExpo in Switzerland can be assured:
- How can we identify cases that lived in a building with a transformer?
- Regarding selection of controls: How can we identify all inhabitants of a transformer building at a given point in time? And in particular, how can we figure out in which apartment they lived?
- What are the levels of exposure in transformer buildings and what kind of data sources and models for exposure assessment from transformers are available in Switzerland?
- Does the planned exposure assessment method of TransExpo work in Switzerland, i.e. are ELF-MF levels in apartments facing a transformer room distinctly higher than in other apartments in the same building?

**Overview About Data Sources in Switzerland**

**Swiss Childhood Cancer registry (SCCR)**

In Switzerland, data on childhood cancer patients are collected nationwide by the Swiss Childhood Cancer Registry (SCCR). Information on all children aged <16 years, living in Switzerland, who are diagnosed with leukemia (including myelodysplastic syndrome), malignant solid tumors, brain tumors (including benign tumors) and histiocytoses are collected. The SCCR was set up in 1976 by the Swiss Pediatric Oncology Group for patients participating in clinical trials, with non-study patients having been registered since 1980. In January 2004, the central data office of the registry moved to Institute of Social and Preventive Medicine (ISPM) at the University of Bern, where the database structure and procedures were updated to meet international standards.

Table B-19 shows the number of cases that are diagnosed between 1985 and 2008 aged less than 15 years. Detailed information about the SCCR including childhood leukemia incidence data are published in Michel et al., 2007.
**Table B-19**

Childhood Cancer Cases Diagnosed Between 1985 and 2008 in the Age Group 0-14 years Registered in the SCCR.

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<td>46</td>
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<td>(b) Acute myeloid leukemias</td>
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<td>6</td>
<td>3</td>
<td>6</td>
<td>16</td>
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<td>2</td>
<td>0</td>
<td>14</td>
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<td>(d) Myelodysplastic syndrome and other</td>
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<td>0</td>
<td>1</td>
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<td>(e) Unspecified and other specified leukemias</td>
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</table>

For childhood cancer patients diagnosed between 1980 and 2008 address data including Swiss grid geo coordinates are available for the place of residency at time of diagnosis. Of note, within the framework of the CANUPIS study (Childhood Cancer and Nuclear Power Plants in Switzerland) address history of all cases born between 1985 and 2007 and diagnosed between 1985 and 2007 will be collected backwards from time of diagnosis up to birth. This information is collected from the community and thus will unlikely be subject to selection bias. This additional information may be useful for sensitivity analysis because place of residency prior to diagnosis is biologically more relevant than after the diagnosis.

**Transformer database**

The new Ordinance for Non-Ionizing Radiation (ONIR) was introduced in 2001. For transformers a precautionary value of 1 µT was determined and a standard limit of 100 µT. The standard limit had to be fulfilled everywhere, where a person can have access (apart from occupational exposure, which is regulated separately). The precautionary limit has only to be fulfilled in sensitive areas which is defined as places where people stay for a substantial amount of time during the day (e.g. at home or in school). The precautionary limit becomes only relevant when transformers are reconstructed or when a new transformer is built. The standard and the precautionary limit have to be fulfilled under worst case scenarios, i.e. during transmission of maximum current. In order to check compliance a two step calculation process is done. First, for each transformer distance to the closest sensitive area is compared with a transformer-type specific distance file. If distance is larger than stated, compliance is guaranteed. If not, a more elaborate modeling of the field is needed and has to be documented in a transformer specification sheet. This calculation is based on more input data such as exact position of the wires etc (see example in Figure B-14). But still, the calculation is conservative and rather overestimates the magnetic flux density than underestimate it. Thus, if this calculation indicates problems with standard limits, a measurement has to be conducted to check it. However, the exact measurement procedure has not yet defined and thus, measurements are rarely done so far.
Since the introduction of ONIR, information about transformers for whole Switzerland are stored in a database at the Federal Inspectorate for Heavy Current Installations (ESTI), which is responsible for the compliance of transformers with the standard limits. In the database of ESTI about 60,000 transformers are registered. According to D. Marty (head of the ESTI) about 10,000 transformers are built within or attached to a living building. This concerns mainly apartment building in urban or suburban areas. It is very unlikely that transformers are built or attached to single family buildings. In the Swiss transformer database the following information is stored:

- identification number for the electric utilities companies
- Swiss grid geo coordinates (missing for about 20% of older transformers)
- power, tension
- community, address
- type of construction: within building or not within building
- Year of license
- Relevance for standard limits (4 categories): not applicable, crude evaluation, specification sheet, measurement

With respect to the database entry *relevance for standard limits* the categories “not applicable” and “crude evaluation” imply that these transformers are not in the vicinity of any apartments or office spaces and thus not thorough evaluation of the standard limits was needed. Thus, only transformers where measurements have been conducted or a specification data sheet has been filled out, may be sited close or within an apartment building and are of interest for the purpose of TransExpo.
**Population registry**

We do not have a nationwide population registry but only communal or occasionally cantonal population registry. In these registries the apartment or floor number are usually not registered.

**Additional data sources**

The Swiss National Cohort (SNC) is a long-term, census-based, multipurpose cohort and research platform. It is based on the linkage of individual data from the census 1990 to the census 2000. This basic database has been enhanced with information from the mortality records from 1991 up to 2005 and with migration records since 1990, and with data from the building registry (type of building, age). We will also have information whether a person lived in the basement or in any other floor. For TransExpo this data source may be useful for sensitivity analyses. For instances we could consider not only living place at diagnosis but included the whole lifetime residency history. This result in 40-60 eligible cases based on the rough estimate that the average number of moving per child is one to two. In addition, the CANUPIS study will provide accurate spatial distribution of the childhood population in 1990 and 2000. This would allow checking us how many individuals lived in a specific building in 1990 or 2000. The database can also be used for simulation of a cohort or case-control study with a rough exposure assessment considering individuals as exposed that lived 1990 or 2000 in the basement of a transformer building.

**Case Identification**

**Methods**

In order to identify eligible cases that lived in a building with a transformer (eligible transformer buildings), geo-coordinates of study participants have to be linked to the coordinates of transformer sites. The feasibility of this approach was practically tested using a list with geo-coordinates and address of all (2867) transformers in the Basel area from the ESTI. We linked this list with geo-coordinates of a random population sample of 4000 residents of Basel and 5 surrounding suburban communities. We did not use geo-coordinates from real cancer patients due to legal reasons. In a first step we identified participants living less than 50 m from a transformer. Subsequently we plotted the coordinates of these participants and the next transformer in a geographic information system (GIS) and visually inspected whether study participants and transformer were located in the same building.

**Results**

For 185 out of the 2867 transformers in the Basel area, a specification data sheets has been filled out. They are of particular interest for our study. From the remaining transformers 1715 were crudely evaluated, 303 are not relevant for standard limit (see Table B-20 Overview about the number of transformers in the Basel area with information about coordinates and their relevance in terms of standard limits.) and 684 had missing information regarding ONIR status.
### Table B-20
Overview About the Number of Transformers in the Basel Area with Information About Coordinates and Their Relevance in Terms of Standard Limits.

<table>
<thead>
<tr>
<th>Relevance for standard limits</th>
<th>Total</th>
<th>With coordinates</th>
<th>Without coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>not applicable</td>
<td>303</td>
<td>81</td>
<td>222</td>
</tr>
<tr>
<td>crude evaluation</td>
<td>1715</td>
<td>615</td>
<td>1100</td>
</tr>
<tr>
<td>specification data sheet</td>
<td>185</td>
<td>177</td>
<td>8</td>
</tr>
<tr>
<td>measurements</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Missing</td>
<td>684</td>
<td>214</td>
<td>470</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2887</strong></td>
<td><strong>1087</strong></td>
<td><strong>1800</strong></td>
</tr>
</tbody>
</table>

Although, according to the ESTI, only 20% of coordinates should be missing in the transformer database, only 1087 (38%) of the transformers from the Basel area had valid geo-coded coordinates. At least, from the 185 most relevant transformers with a specification data sheet, 177 had a valid geo-code.

From our exemplary study population of 4,000 residents of the Basel area we identified 281 individuals who lived within 50 m of a transformer (2). From a visual inspection of all these places, we concluded that transformers are unlikely to be in the same building (or in immediate vicinity of the building) if distance between transformer coordinates and residency coordinates is larger than 20m (see examples in Figure B-16 Three examples of residency coordinates (green) and transformer coordinates (red) that are less than 20 m apart from each other.). This resulted in 48 participants out of 4000 that are likely to live in a building with a transformer. In terms of the ONIR status, 17 participants lived close to a transformer with a data specification sheet, 19 close to a broadly evaluated transformer, 3 close to a transformer where ONIR is not applicable and 9 close to a transformer with a missing ONIR status. This means that only 17 or about 0.5% of our study population is likely to live in a building with increased magnetic field levels from a transformer.
Figure B-15
Distribution of Distance Between Study Participants and Transformers for 48 Participants Who Lived Closer Than 50m from a Transformer.
Figure B-16
Three Examples of Residency Coordinates (green) and Transformer Coordinates (red) that Are Less Than 20 m Apart from Each Other.

One problem, we identified during the pilot study are missing coordinates. In the Basel area only a few coordinates were missing from the most relevant transformer with a data specification sheet. However, we learned from our collaboration with the Zurich electricity company (see chapter 0) that this may not be the case for the whole country. In Zurich the coordinates in the data specification sheet was not filled in. Thus, alternative approaches have to be considered for identification of eligible transformer buildings without coordinates. If only a few coordinates are missing (as in Basel) they can be retrieved for the relevant transformers from address information or by an enquiry at the responsible company. Otherwise the most feasible approach is to determine relevant buildings by the distribution line grid of the electric utility company which for Zurich would be available as a layer in GIS. This data can be provided by the electric utility company or by the community. Subsequently, place of transformers and place of residency have to be plotted and to be visually identified. Figure B-17 shows an example of such a distribution line grid. Distribution lines are drawn in red. Transformers are located at the end of distribution lines or as red rectangular.
Discussion of case identification

In our transformer database of the Basel area, we found 185 with a specification sheet out of 2203 transformer with any standard limit classification. These transformers may potentially cause a magnetic flux density $>1 \mu T$ in an apartment or an office space under worst case condition and thus, are relevant for TransExpo. Our pilot analysis showed that it is feasible to identify individuals living closer than 50 m from a transformer based on the coordinates. Visual inspection of the coordinates in GIS showed that the coordinates are accurate and allow identification of relevant buildings. It seems that visual inspection is the most accurate way to identify eligible transformer buildings. Although it needs considerable effort for each individual, the total effort is not too costly, because only a relative small proportion of individuals lived in the vicinity of a transformer. In our sample 281 out of 4000 individuals lived closer than 50 m of a transformer.

If a large amount of coordinates of transformers are missing for a certain area, considerable more effort is needed to link cases with transformer sites. But the example of Zurich showed that it is feasible, in principle. Only a few areas with missing coordinates are expected, because eligible transformer buildings are only expected in urban and suburban areas. In principle, the number of such areas can be determined prior to the start of TransExpo. At the moment the information in
the transformer database is rapidly evolving due to the implementation of the ONIR. And thus, in
the near future coordinates may be available for more transformers than to date.

**Expected number of eligible cases for TransExpo**

According to Table 3-1 in chapter 3 about 1,300 leukemia cases were diagnosed between 1985
and 2008 in children aged less than 15 years. We aim to include all cases that occurred since
1980, thus expecting to include about 1,600 leukemia cases. Eligible cases living in a building
with a transformer are only expected from urban and suburban areas. According to the Swiss
population statistics about 60% of the population is living in urban or suburban areas. We found
in our pilot analysis in the Basel area (see chapter 0) that about 0.5 percent of the population is
living in a building with increased magnetic field from a transformer. Thus, we expect about 5
eligible cases for TransExpo in Switzerland (\(Ca_{el}\)):

\[
Ca_{el} = 1600 \cdot 0.6 \cdot 0.005 = 5
\]

In principle, the number of eligible cases could be roughly doubled in Switzerland if we include
all buildings where a leukemia case lived at any time in his/her life prior to diagnosis. Address
history will be available in 2010 for cases diagnosed between 1985 and 2007. Because number of
apartments is relatively low in general, number of exposed cases will be between 1-2 based on
the assumption that there is no association between ELF-MF and childhood leukemia.

**Control Identification**

**Methods**

For control selection identification we have tested different approaches.

1. We have selected 10 different communities and asked them what type of data they could
   provide about inhabitants of a specific building between 1980 and 2007.

2. In order to test the process of control person identification, we randomly selected 10
   apartments with transformers in the Zurich area and simulated control selection for the past.
   First, we wanted to obtain a list of all children living in this building at a specific, arbitrary,
   2000) from the communal population registry. Prior the start of the enquiry, we checked with
   the childhood cancer registry that no child with leukemia had been living there by chance.
   (This was not the case.) In a second step, we tried to figure out their apartment number from
   the building owner. If this works for date before 2000, control selection after 2000 should
   work as well.

**Results**

The community survey showed that type of data about inhabitants for a specific buildings differs
quite a lot. All communities could provide a list of all inhabitants from a specific building from
their computerized registries. However, computerized registries are only available since the mid
90ties in most of the communities. Prior to that, population registries are stored on paper and
microfiche and sorted by name. Thus, it would be very difficult to identify all inhabitants from a
specific building. Information about the apartment and/or floor number was only available in 1 out of 10 communities. Knowledge of the apartment and floor is essential for exposure assessment.

Regarding the control selection test in Zurich, the community registry could provide only inhabitant data for the period after 1995. For the period 1993-1995, the data are computerized and could be retrieved (in principle) but the system has changed and it would need a lot of effort and costs. Prior to 1993 data are only available on microfiches and sorted by name, which would make it very difficult to retrieve all inhabitants from a specific address. Information about apartment or floor number was not available. Thus, we tried three different approaches to identify controls.

1. Approach – building owners and notary’s offices: The address of a building owner would be available at the registry of deeds (“Grundbuchamt”), which every district of Zurich city has its own one (and each community in CH). So this information is easy to come by, but all property managements (“Liegenschaftsverwaltung”) that we contacted, stored their files for only about 10 years. So we only can get information about the actual situation or less than 10 years ago. Therefore we consider this a rather inefficient approach.

2. Approach – census of population: The Census would provide pretty much information about the buildings and who lives in on what floor and who owned the place at the time. Also we have access to the building ID and the coordinates. But a census of population is only performed every 10 years and therefore we have not got the data for all diagnosis dates as we need it. Therefore, we consider this as an unfeasible approach but it might provide useful information for plausibility checks and sensitivity analyses.

3. Approach – electric utility companies: In Zurich the EWZ can tell back to 1985 who has lived in a certain building in most of the cases but not always. Certainly, since 1994 (when a new system was introduced) the information should be available. The only problem is that only the name of the billing receiver is registered but no information about children is stored. Thus, one has to go back to the community and obtain all children from a given family. This should work, because paper records can be searched by name.

Discussion of control identification

Identification of the control population is the most difficult issue in Switzerland. Probably, identification of apartment and floor number is feasible by means of the electric utility company, but they can provide only the name of the person who got the bill. Thus, one has to go back to the communities and search for children for a given name. How well this actually will work has not been tested and is not worth to do so, because there are numerous electric utility companies and numerous communities which all have their own system. Given the limited number of cases such a feasibility study would be actually more extensive than doing the study itself. In any case, one has to face the possibility that not for all identified cases the control population in the same building can be identified. However, in our opinion there is no reason why such missings could be related to exposure and thus, introduce a bias in the study. One aspect that has to be considered, however, is the relative low number of apartments per building (in general). Thus, there might be no eligible controls in the same building and a cohort approach is to be preferred.
For Switzerland, control selection method 2 (identify all children who lived in a building with a transformer where a case occurred) is in principle more attractive than control selection method 1 (random sample of controls linked to transformer addresses) because fewer population registries have to be contacted (Details about control selection method 1 and 2 are given in the TransExpo study protocol). However, this may create a bias for small buildings, because in these buildings the likelihood to be exposed is high. If only one family lives in such a building, they will only enter into the study population if a case occurred but not a control resulting in a bias. Thus, in Switzerland a mixture of both methods is considered most appropriate for control selection. For buildings with many apartments control selection 2 is adequate. If a case is identified in a building with few apartments (e.g. <5), a control building will be selected from all transformer buildings in Switzerland. Subsequently a building will be selected randomly from this list and its inhabitants will be identified to be included in the study.

**Measurement Campaign**

**Methods**

For the measurement campaign we collaborated with the Zurich electric utility company (Elektrizitätswerk Zürich, EWZ). They have been very active in the measurements and modeling of ELF-EMF from transformers and collaborated with the corresponding Federal Department. They were willing to share their experiences with us and one employee accompanied and supported the conduct of most of the measurements.

**Selection of buildings**

The following criteria has been applied to select eligible buildings for conducting measurements:

- Transformer had to be located in or very close to an apartment building.
- The worst case predictions (according to data specification sheet) for the magnetic flux density in the closest apartment had to be around 1 µT or above.
- The transformer should not have been reconstructed since 2001, when the new ONIR was introduced. Thus, our aim was to select transformers that represent exposure conditions which were typical for the 80ties and 90ties. Although the most extreme cases (in terms of exposure) have been probably already reconstructed.
- Consent for conducting the measurements was obtained at least from the inhabitants of the most exposed apartment.

For the selection an employee of the EZW searched manually the ONIR data sheets and their database to identify eligible transformers. In a first step, he identified all 25 eligible locations that were not reconstructed and fulfilled the criteria above. Due to drop outs and refusals this was not sufficient and in a second step additional 7 buildings were considered for participation that already have been reconstructed. This resulted in 32 potentially eligible buildings. In a next step every building was inspected and the inhabitants have been identified based on the door plate. If this was not possible, the study assistant knocked or rang the bell of any apartment to ask if one can enter into the building to take a look inside (something you still can do in most places of Switzerland). In one case the management of the building ("Liegenschaftsverwaltung") provided
us with the necessary information about the residents. In total, we obtained consent for conduction the measurements from inhabitants of 18 eligible buildings. Table B-21 gives an overview about the selection process of the buildings. If apartments were located in the building, the most exposed apartment was identified together with the location of all eligible control apartments. The control apartments for the measurements were randomly selected from all unexposed apartments. Subsequently the residents of selected apartments where first contacted by mail – either simply a letter with our request to make an appointment or a letter with the request if they would participate in a study, depending whether a phone number was known (1st case) or not (2nd case).

Table B-21
Overview About the Selection of Buildings for Measurements.

<table>
<thead>
<tr>
<th>Description</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary selection (not reconstructed):</td>
<td>25</td>
</tr>
<tr>
<td>Not eligible:</td>
<td></td>
</tr>
<tr>
<td>refused by inhabitants:</td>
<td>6</td>
</tr>
<tr>
<td>no access/no identification of inhabitants:</td>
<td>1</td>
</tr>
<tr>
<td>no apartment in building:</td>
<td>4</td>
</tr>
<tr>
<td>Secondary selection (reconstructed):</td>
<td>7</td>
</tr>
<tr>
<td>Not eligible:</td>
<td></td>
</tr>
<tr>
<td>refused by inhabitants:</td>
<td>3</td>
</tr>
<tr>
<td>Total buildings included:</td>
<td>18</td>
</tr>
</tbody>
</table>

Measurement protocol

Our aim was to measure three differently exposed apartments in each building. The most exposed apartment was located closed to the transformer, either directly above, wall-to-wall, edge-to-edge or corner-to-corner (AP 1). A medium exposed category (AP2) included apartments that were either located on the same floor as the exposed apartment or directly above the exposed apartment. The latter case was only selected if the exposed apartment was located wall-to-wall to the transformer. Usually only one candidate was available for this middle category, because the number of apartments per floor was generally small (i.e. 1 or 2). The unexposed apartment was randomly selected from all other apartments.

For the measurements we used 10 EMDEX II devices. They have been calibrated in by the manufacturer, Enertech (USA) in December 2008. For all devices we received a calibration certificate according to the EU Directive 89/336/EEC, which corresponds to the norms EN 55022, EN 61000-4-2 und ENV 50140. The manufacturer states a typical measurement accuracy of +/- 1 % (http://www.enertech.net/html/EMDEXIISpecs.html)

We used a sampling rate of 3 seconds and measured the broadband (40-800 Hz) and the harmonics (100-800 Hz) separately. The display was set to battery in order to guarantee a unbiased selection of the measurement site.
Every measurement was taken after following protocol:

- 24h measurement in the transformer station room
- Spot-measurements in the apartments (about 10 minutes each)

The measurement always started on the left hand side of the entrance and ended on the right hand side of the apartment. In every room 5 EMDEX II devices have been placed; four devices in the 4 corners plus the middle of the room. Devices where positioned 0.5 m above ground on plastic tubes and about 1.4 m from the corners. In the bedroom we placed one device in the middle of the bed. Occasionally a sixth device was used for this bed measurement. In order to prevent confusion of the measurement devices, devices were always arranged in the same way, starting at the left and proceeding to the right, when entering in a room. In addition, a door measurement was taken at the entrance door. This measurement was also conducted if no access was obtained to a target apartment. We followed this protocol strictly except for the wishes of residents – as to measure the kitchen first so they could have lunch later or similar requests.

A very important part of measuring was the effort to minimize the influence of electrical gear or appliance on the measurement. If the employee of the EZW was present, he checked every measurement spot with his own Teslameter if it was influenced by electronic equipment or not. If he was not present, we made the precaution to add some distance from magnetic field sources such as cables or electrical devices, although this slightly may have altered the measurement place.

**Data management and analysis**

Data from EMDEX devices were imported into EMCALC and visually inspected for plausibility. Subsequently csv files were exported and data from different devices were combined to obtain a separate measurement file for each room. Three identifier variables were added to the data set for building, apartment and room. Then the files were imported into the statistical software R.

It was not possible to conduct all measurements from one building at the same time. Thus, in principle differences in the magnetic flux density between apartments may be due to change in the field emission of the transformer and not reflect true differences. (See example of a typical 24 hours exposure profile in a transformer station room in Figure B-18). In principle this could be corrected by normalizing the measurements against the transformer emissions during the measurement period or during 24 hours. Thus, in order to check the temporal variability of the magnetic flux density emission from the transformer during the measurement period, we plotted the continuous measurements taken at the transformer against the measurements taken in the building (Figure B-19). Except building number 11, we found little temporal variability during the measurement period and thus did not correct our measurements for this. For building number 11 measured value could be multiplied by a factor between 2 and 3 to obtain a typical daytime average but this was not done for the data presented in this report.
Figure B-18
Exemplary 24h Measurement in the Transformer Station Room (building 12).

Figure B-19
Example of an explorative plot of all measurements from one building. The continuous measurement was taken in the vicinity of the transformers (right hand scale). Occasionally, the 5 measurement devices from one room are identifiable.
We calculated arithmetic mean value of the broadband resultant for each room (or for the door measurement). Average apartment value was obtained from all available room averages of an apartment without the door measurements.

**Results**

We conducted measurements in 18 buildings thereof 4 buildings had reconstructed transformers (Table B-22).

**Table B-22**

Overview About the Buildings Where Measurements Were Conducted

<table>
<thead>
<tr>
<th>No</th>
<th>High (AP1)</th>
<th>Medium (AP2)</th>
<th>Reference (AP3)</th>
<th># of apartments in the building</th>
<th>Offices measured</th>
<th>Reconstruction</th>
<th>Date Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>yes</td>
<td>yes²</td>
<td>only door</td>
<td>~7</td>
<td>No</td>
<td>No</td>
<td>08.05.2009: 13:34-16:25</td>
</tr>
<tr>
<td>2</td>
<td>yes</td>
<td>only door</td>
<td>only door</td>
<td>6</td>
<td>No</td>
<td>No</td>
<td>11.05.2009: 09:51-11:07</td>
</tr>
<tr>
<td>3</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>&gt;20</td>
<td>AP1 &amp; AP2</td>
<td>No</td>
<td>03.07.2009: 09:30-12:30</td>
</tr>
<tr>
<td>4</td>
<td>yes</td>
<td>yes²</td>
<td>yes</td>
<td>&gt;20</td>
<td>AP1 &amp; AP2</td>
<td>No</td>
<td>01.07.2009: 07:00-09:15</td>
</tr>
<tr>
<td>5</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>8</td>
<td>No</td>
<td>No</td>
<td>30.04.2009: 13:39-17:04</td>
</tr>
<tr>
<td>6</td>
<td>yes</td>
<td>only door</td>
<td>only door</td>
<td>6</td>
<td>No</td>
<td>No</td>
<td>20.05.2009: 14:17-15:20</td>
</tr>
<tr>
<td>7</td>
<td>yes³</td>
<td>only door</td>
<td>yes</td>
<td>14</td>
<td>No</td>
<td>No</td>
<td>22.07.2009: 15:00-17:30</td>
</tr>
<tr>
<td>8</td>
<td>yes</td>
<td>inexistent¹</td>
<td>inexistent¹</td>
<td>1</td>
<td>No</td>
<td>No</td>
<td>06.05.2009: 13:39-15:16</td>
</tr>
<tr>
<td>9</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>6</td>
<td>No</td>
<td>No</td>
<td>14.05.2009: 10:06-12:59</td>
</tr>
<tr>
<td>10</td>
<td>yes</td>
<td>no access</td>
<td>yes</td>
<td>6</td>
<td>AP1</td>
<td>No</td>
<td>06.07.2009: 09:15-11:00</td>
</tr>
<tr>
<td>11</td>
<td>yes</td>
<td>only door</td>
<td>yes</td>
<td>7</td>
<td>No</td>
<td>No</td>
<td>05.08.2009: 17:30-20:20</td>
</tr>
<tr>
<td>12</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>8</td>
<td>No</td>
<td>No</td>
<td>24.06.2009: 16:00-19:00</td>
</tr>
<tr>
<td>13</td>
<td>yes</td>
<td>yes²</td>
<td>yes</td>
<td>13</td>
<td>No</td>
<td>No</td>
<td>28.07.2009: 8:30-9:20 and 15:10-17:25</td>
</tr>
<tr>
<td>14</td>
<td>yes</td>
<td>yes</td>
<td>only door</td>
<td>6</td>
<td>No</td>
<td>Yes</td>
<td>18.06.2009: 9:30-11:50</td>
</tr>
<tr>
<td>15</td>
<td>yes</td>
<td>yes</td>
<td>only door</td>
<td>12</td>
<td>No</td>
<td>Yes</td>
<td>09.07.2009: 13:30-14:40</td>
</tr>
<tr>
<td>16</td>
<td>yes</td>
<td>only door</td>
<td>yes</td>
<td>8</td>
<td>No</td>
<td>Yes</td>
<td>06.07.2009: 17:00-18:30</td>
</tr>
<tr>
<td>17</td>
<td>yes</td>
<td>yes</td>
<td>only door</td>
<td>7</td>
<td>No</td>
<td>Yes</td>
<td>12.08.2009: 10:00-12:15</td>
</tr>
<tr>
<td>18</td>
<td>yes</td>
<td>no access</td>
<td>yes</td>
<td>3</td>
<td>No</td>
<td>No</td>
<td>17.08.2009: 10:00-12:05</td>
</tr>
</tbody>
</table>

¹ Single family residency ² AP2 on 1st floor ³ AP1 is a restaurant
Not in every building three eligible apartments could be included. In total, we had access to 39 apartments. For additional 11 apartments we could measure the magnetic flux density at the door. In some of the buildings the current utilization was as office, although in principle this could have been used as apartment as well. The same holds for building 7 where the most exposed apartment was in fact a restaurant.

Figure B-19 depicts the mean exposure in the three exposure groups for different room types and for the averages of each apartment. The corresponding values are listed in Table B-23. There is considerable variability in the measurement which is shown by the blue lines indicating the range between minimum and maximum room average (see also Figure B-19). In exposed apartments highest magnetic flux density was measured in offices and parents’ bedroom (Table B-23). Highest room average for exposed apartments was 2.0 µT. Room averages above 1.0 µT were observed in 4 apartments. Highest room average in medium exposed apartments was 0.45 µT. In reference apartments highest room average was 0.26 µT.

![Figure B-20](image-url)

**Figure B-20**

Summary of the Measurements According to Exposure Categories (AP1=high; AP2=medium; AP3=reference). Blue Line Indicates Range.
Table B-23
Mean Values and Range of the Magnetic Flux Density Measurements for Several Room Types According to Exposure Category.

<table>
<thead>
<tr>
<th>Room Type</th>
<th>Most exposed apartment</th>
<th>Medium exposed apartment</th>
<th>Reference apartment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Apartment</strong></td>
<td>N=18</td>
<td>N=10</td>
<td>N=11</td>
</tr>
<tr>
<td>Apartment average (µT)</td>
<td>0.34</td>
<td>0.14</td>
<td>0.07</td>
</tr>
<tr>
<td>max. apartment mean (µT)</td>
<td>1.30</td>
<td>0.44</td>
<td>0.20</td>
</tr>
<tr>
<td>min. apartment mean (µT)</td>
<td>0.07</td>
<td>0.03</td>
<td>0.02</td>
</tr>
<tr>
<td><strong>Bedroom</strong></td>
<td>N=18</td>
<td>N=10</td>
<td>N=11</td>
</tr>
<tr>
<td>Room Mean (µT)</td>
<td>0.41</td>
<td>0.13</td>
<td>0.07</td>
</tr>
<tr>
<td>max. Room Mean(µT)</td>
<td>2.00</td>
<td>0.44</td>
<td>0.24</td>
</tr>
<tr>
<td>min. Room Mean (µT)</td>
<td>0.05</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Living room</strong></td>
<td>N=17</td>
<td>N=8</td>
<td>N=11</td>
</tr>
<tr>
<td>Room Mean (µT)</td>
<td>0.28</td>
<td>0.12</td>
<td>0.07</td>
</tr>
<tr>
<td>max. Room Mean(µT)</td>
<td>1.80</td>
<td>0.45</td>
<td>0.26</td>
</tr>
<tr>
<td>min. Room Mean (µT)</td>
<td>0.04</td>
<td>0.03</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Children’s Bedroom</strong></td>
<td>N=4</td>
<td>N=2</td>
<td>N=4</td>
</tr>
<tr>
<td>Room Mean (µT)</td>
<td>0.14</td>
<td>0.22</td>
<td>0.08</td>
</tr>
<tr>
<td>max. Room Mean(µT)</td>
<td>0.31</td>
<td>0.38</td>
<td>0.12</td>
</tr>
<tr>
<td>min. Room Mean (µT)</td>
<td>0.07</td>
<td>0.06</td>
<td>0.04</td>
</tr>
<tr>
<td><strong>Kitchen</strong></td>
<td>N=11</td>
<td>N=6</td>
<td>N=5</td>
</tr>
<tr>
<td>Room Mean (µT)</td>
<td>0.18</td>
<td>0.07</td>
<td>0.05</td>
</tr>
<tr>
<td>max. Room Mean(µT)</td>
<td>0.65</td>
<td>0.12</td>
<td>0.08</td>
</tr>
<tr>
<td>min. Room Mean (µT)</td>
<td>0.05</td>
<td>0.03</td>
<td>0.02</td>
</tr>
<tr>
<td><strong>Office</strong></td>
<td>N=4</td>
<td>N=2</td>
<td>N=2</td>
</tr>
<tr>
<td>Room Mean (µT)</td>
<td>0.69</td>
<td>0.09</td>
<td>0.05</td>
</tr>
<tr>
<td>max. Room Mean(µT)</td>
<td>1.61</td>
<td>0.12</td>
<td>0.06</td>
</tr>
<tr>
<td>min. Room Mean (µT)</td>
<td>0.15</td>
<td>0.06</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td>N=8</td>
<td>N=4</td>
<td>N=3</td>
</tr>
<tr>
<td>Room Mean (µT)</td>
<td>0.17</td>
<td>0.14</td>
<td>0.05</td>
</tr>
<tr>
<td>max. Room Mean(µT)</td>
<td>0.62</td>
<td>0.33</td>
<td>0.06</td>
</tr>
<tr>
<td>min. Room Mean (µT)</td>
<td>0.05</td>
<td>0.02</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>Door</strong></td>
<td>N=16</td>
<td>N=13</td>
<td>N=15</td>
</tr>
<tr>
<td>Room Mean (µT)</td>
<td>0.17</td>
<td>0.18</td>
<td>0.08</td>
</tr>
<tr>
<td>max. mean(µT)</td>
<td>0.47</td>
<td>0.56</td>
<td>0.25</td>
</tr>
<tr>
<td>min. mean (µT)</td>
<td>0.05</td>
<td>0.03</td>
<td>0.03</td>
</tr>
</tbody>
</table>
In general, there is an exposure gradient between highly exposed and reference apartments. One exception are the bedrooms of children, where higher magnetic flux density values occurred in the medium exposed apartments than in the highly exposed apartment. However, this is based on only 4 highly exposed and 2 medium exposed rooms. Interestingly, mean magnetic flux density of this four apartments was somewhat lower mean magnetic flux density of the two medium exposed apartments (0.20 vs. 0.22 µT). Thus, the magnetic flux density values of the children bedrooms just represent the average exposure of the corresponding apartments. Also for the door measurements we found only small differences between highly and medium exposed apartments. This probably just reflects the fact that both apartments were usually on the same floor and thus, doors are often quite close together.

**Figure B-21**
Overview about the exposure distribution in the three exposure categories for mean magnetic flux density per apartment, per parental bedroom, per living room and door measurements.

Table B-24 shows differently calculated averages of the magnetic flux density in the three exposure groups. Mean exposure in the exposed apartments was 0.34 µT, in the medium exposed apartments 0.14 µT and in the reference apartments 0.07 µT. Taking into account the door measurements for calculating average exposure in each apartment blurred the exposure differences between most exposed and medium exposed apartments. Average magnetic flux density in most exposed apartments that were directly above or adjacent to a transformer was
substantially higher (0.59 µT) than for apartments which faced the transformer only at a corner or edge.

Table B-24
Mean Values and Range of the Magnetic Flux Density Measurements for the Apartments According to Exposure Category

<table>
<thead>
<tr>
<th>Apartment¹</th>
<th>Most exposed apartment</th>
<th>Medium exposed apartment</th>
<th>Reference apartment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ap ¹</td>
<td>N=18</td>
<td>N=10</td>
<td>N=11</td>
</tr>
<tr>
<td></td>
<td>Apartment average (µT)</td>
<td>0.34</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td>max. apartment mean (µT)</td>
<td>1.30</td>
<td>0.44</td>
</tr>
<tr>
<td></td>
<td>min. apartment mean (µT)</td>
<td>0.07</td>
<td>0.03</td>
</tr>
<tr>
<td>Ap ²</td>
<td>N=18</td>
<td>N=15</td>
<td>N=17</td>
</tr>
<tr>
<td></td>
<td>Apartment average (µT)</td>
<td>0.29</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td>max. apartment mean (µT)</td>
<td>0.99</td>
<td>0.54</td>
</tr>
<tr>
<td></td>
<td>min. apartment mean (µT)</td>
<td>0.06</td>
<td>0.03</td>
</tr>
<tr>
<td>Ap ³</td>
<td>N=10</td>
<td>N=7</td>
<td>N=8</td>
</tr>
<tr>
<td></td>
<td>Apartment average (µT)</td>
<td>0.14</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>max. apartment mean (µT)</td>
<td>0.33</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>min. apartment mean (µT)</td>
<td>0.07</td>
<td>0.03</td>
</tr>
<tr>
<td>Ap ⁴</td>
<td>N=8</td>
<td>N=3</td>
<td>N=3</td>
</tr>
<tr>
<td></td>
<td>Apartment average (µT)</td>
<td>0.59</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>max. apartment mean (µT)</td>
<td>1.30</td>
<td>0.44</td>
</tr>
<tr>
<td></td>
<td>min. apartment mean (µT)</td>
<td>0.16</td>
<td>0.15</td>
</tr>
</tbody>
</table>

¹ without door measurements
² door measurements considered as additional room
³ most exposed apartment faces transformer at corner or edge
⁴ ideal cases with transformer below or adjacent to most exposed apartment
Average exposure for each apartment is listed in Table B-25.

**Table B-25**
Comparison of the apartments within one building. “Max. mean” and “min mean” refers to the maximum and minim room mean in the apartment (‘only door measurements available). All values in µT.

<table>
<thead>
<tr>
<th>Most exposed apartments</th>
<th>Reference apartments, same floor</th>
<th>Reference apartments, other floor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>Max. Mean</td>
<td>Min. Mean</td>
</tr>
<tr>
<td>Building 1</td>
<td>0.13</td>
<td>0.18</td>
</tr>
<tr>
<td>Building 2</td>
<td>0.79</td>
<td>2.00</td>
</tr>
<tr>
<td>Building 3</td>
<td>0.32</td>
<td>0.53</td>
</tr>
<tr>
<td>Building 4</td>
<td>0.13</td>
<td>0.29</td>
</tr>
<tr>
<td>Building 5</td>
<td>0.10</td>
<td>0.13</td>
</tr>
<tr>
<td>Building 6</td>
<td>0.27</td>
<td>0.62</td>
</tr>
<tr>
<td>Building 7</td>
<td>0.19</td>
<td>0.33</td>
</tr>
<tr>
<td>Building 8</td>
<td>0.43</td>
<td>1.32</td>
</tr>
<tr>
<td>Building 9</td>
<td>0.09</td>
<td>0.11</td>
</tr>
<tr>
<td>Building 10</td>
<td>1.05</td>
<td>1.61</td>
</tr>
<tr>
<td>Building 11</td>
<td>0.10</td>
<td>0.21</td>
</tr>
<tr>
<td>Building 12</td>
<td>0.07</td>
<td>0.10</td>
</tr>
<tr>
<td>Building 13</td>
<td>1.19</td>
<td>1.80</td>
</tr>
<tr>
<td>Building 14</td>
<td>0.15</td>
<td>0.25</td>
</tr>
<tr>
<td>Building 15</td>
<td>0.10</td>
<td>0.15</td>
</tr>
<tr>
<td>Building 16</td>
<td>0.27</td>
<td>0.63</td>
</tr>
<tr>
<td>Building 17</td>
<td>0.26</td>
<td>0.32</td>
</tr>
<tr>
<td>Building 18</td>
<td>0.10</td>
<td>0.09</td>
</tr>
</tbody>
</table>

With respect to the overall means of the apartments different cut-points were considered for comparisons: 0.2 µT, 0.4 µT and 0.8 µT. An overall mean of 0.8 µT was reached in 3 exposed apartments (~17% out of 18 apartments), none of the medium exposed apartments and in none of the reference apartments on other floors. A mean value of 0.4 µT was reached in 4 exposed apartments (~22%), 2 of the medium exposed apartments (out of 15 apartments with at least a door measurement) and in none of the reference apartments on other floors. A cut-point of 0.2 µT taken was exceeded in 8 (~44%) exposed apartments reached that level, 4 medium exposed apartments on the same floor (~20%) and 1 reference apartment on an other floor (out of 17...
apartments with at least a door measurements). The corresponding values for sensitivity and specificity are given in Table B-26.

<table>
<thead>
<tr>
<th>Cut-points</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Adj. sensitivity</th>
<th>Adj. specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;0.8 µT</td>
<td>100%</td>
<td>42%</td>
<td>100%</td>
<td>85%</td>
</tr>
<tr>
<td>&gt;0.4 µT</td>
<td>100%</td>
<td>44%</td>
<td>100%</td>
<td>86%</td>
</tr>
<tr>
<td>&gt;0.2 µT</td>
<td>89%</td>
<td>50%</td>
<td>50%</td>
<td>89%</td>
</tr>
</tbody>
</table>

Discussion of measurement results

Our measurement found on average a distinct exposure gradient between the three exposure categories, although there was some overlap between the three categories. Exposure values were relatively low and even in the highest exposure category mean exposure was only 0.34 µT. There is some uncertainty how representative these measurements are in terms of magnetic field exposure in transformer buildings between 1980 and 2007 in general. On the one hand, exposure values were probably higher prior to 2001 because the most extreme cases have been reconstructed after the implementation of the ONIR in 2001. On the other hand the Zurich electric utility company may have tended to select those buildings for this measurement campaign where most elevated magnetic field exposure values have to be expected.

Compared to transformer measurements in Hungary and Finland, we observed lower magnetic flux density levels in the most exposed apartment, whereas differences were minimal for the reference apartments. In Finland (Ilonen 2008), mean magnetic flux density in 30 highly exposed apartments from three cities was 0.62 µT compared to 0.34 µT in Zurich. In Hungary, mean exposure in 31 apartment was even higher, i.e. about 1 µT (Szabo et al. 2007, Thuróczy et al. 2008). However, if we restricted our analysis to eight buildings where the transformer was directly below attached (wall-to-wall) to the exposed apartment, our magnetic flux density levels were similar as in Finland (0.59 µT).

Exposure in children’s bedroom is considerable relevant in the context of this study. We found a higher average magnetic flux density in the children’s bedroom of medium exposed apartments than of highly exposed apartments. But this was based on only 2 medium exposed apartments and average exposure in these two apartments was higher than in other medium exposed apartments. Thus, we conclude that we did not find robust evidence that children’s bedrooms are systematically higher exposed in the medium exposed apartment category.

Conducting measurements at the door instead of conducting them in the apartment would be appealing because access is easier and it does not need consent of the owner. However, door measurements are likely to blur exposure differences between high and medium exposed apartment. The reason for this is that usually both apartments are on the same floor and the doors
are close together (facing each other). Other parts of the apartments are more far away: in the high exposed apartments closer to the transformer and in the medium exposed apartment more distant to the transformer.

A qualitative comparison of the measurement results with the prediction that are graphically depicted in the data specification sheet, indicates a relation between predictions and measurements Thus, worst case predictions, conducted in the process of approval of the transformers, contribute useful information about the exposure levels under every day conditions. Nevertheless, predictions are made for the most exposed part of the apartment and under worst case conditions with maximum current load. Thus, they considerable overestimate average ELF-MF in an apartment.

In summary, the measurement campaign could demonstrate a distinct exposure gradient between the three exposure categories. However, the effort that was needed to identify eligible buildings with highly exposed apartments, even in the most urban area of Switzerland, suggests that highly exposed apartments in buildings with transformers are not common. Thus, although transformers may be located within a building, distance to the closest apartment may be high because they are located in the very basement, e.g. below the parking slot.

**Overall Conclusions**

Overall the feasibility study showed that identification of childhood leukemia cases living in building with a transformer is possible based on coordinates, although other approaches has to be considered in particular regions such as Zurich. However, the number of eligible cases between 1980 and 2007 is relatively low: about 5-10 cases depending on whether residency history is taken into account or not. This is expected to result in 1-2 highly exposed cases under the null hypothesis of no association. This estimate is based on the situation in the Basel area and is thus, somewhat uncertain, because the situation may differ in other parts of Switzerland.

Control selection will be a challenge for the time prior to the mid 90ties when population data is only available on paper records or microfiche. This will be the most extensive work in a full study.

The measurement campaign showed that exposure assessment methods works and that the data specification sheets provide useful information for a more detailed exposure assessment that does not involve inhabitants of the buildings and thus prevents from selection bias.

The overall conclusion is that Switzerland will be an eligible country for the main study. However, the number of exposed cases will be small. In principle, participation of Switzerland in the main study could be done in a two-step procedure. First, with moderate effort, number of eligible cases can be determined by linking coordinates of study participants with the ones of transformers. If such a comparison yields too few eligible cases further activities may not be worth to pursuit.
Acknowledgements

I thank Daniela Jenni and Fabian Jähnig very much for organizing and conducting the measurements in an effective way. I am grateful that we could lend 10 EMDEX II devices from the Federal Office of Environment (FOEN) and for helpful technical support from Stefan Joss. Many thanks to Hansruedi Luternauer and Ricco Meier from the Electric Utility company in Zurich (EWZ), which provided useful insights into the exposure situation of transformers, provided data about transformers and supported the measurement campaign to a large extent. In particular, Ricco Meier dedicated substantial time to this project when accompanying our study assistants for most of the measurements. Many thanks also to Dario Marty and Urs Huber from the Federal Inspectorate for Heavy Current Installations (ESTI) who helped us with the Swiss transformer data base and provided data about transformers in the Basel area. I thank Miriam Pyrlík from the Swiss Childhood Registry for providing us all necessary data about childhood cancer incidence. Many thanks also to Gábor Mezei from EPRI and Leeka Kheifets from the University of California for helpful discussions at our TransExpo meeting in Jerusalem in September 2009. Last but not least, I am grateful for all study participants that allowed us to carry out measurements in their apartment.

References

Several workshops were held over the past several years to discuss study design and to evaluate feasibility in various countries. We list the workshops and participants below.

**Workshop I**

*Budapest, Hungary*

*April 14, 2005*

Jukka Juutilainen, *University of Kuopio, Finland*

Shaiela Kandel, *Soreq Nuclear Research Center, Isreal*

Rob Kavet, *Electric Power Research Institute, California, United States*

Leeka Kheifets, *University of California, Los Angeles, United States*

Gabor Mezei, *Electric Power Research Institute, California, United States; and National Research Institute for Radiobiology and Radiohygiene, Budapest, Hungary*

Paolo Ravazzani, *Technical University, Milan, Italy; and EMF-NET*

Mike Silva, *Electric Power Research Institute, California, United States*

Martine Souques, *Electricité de France, Paris, France*

Judit Szabo, *National Research Institute for Radiobiology and Radiohygiene, Budapest, Hungary*

Gyorgy Thuroczy, *National Research Institute for Radiobiology and Radiohygiene, Budapest, Hungary*
Appendix - Workshops

Workshop II

Budapest, Hungary

November 14-15, 2006

Bakos, Jozsef (National Research Institute for Radiobiology, Budapest, Hungary)
Barchana, Micha (National Cancer Registry, Israel)
Hareuveny, Ronen (Soreq, Nuclear Research Center, Israel)
Jakab, Zsuzsa (National Pediatric Cancer Registry, Budapest, Hungary)
Janossy, Gabor (National Research Institute for Radiobiology, Budapest, Hungary)
Juutilainen, Jukka (University of Kuopio, Kuopio, Finland)
Kandel, Shaiaela (Soreq, Nuclear Research Center, Israel)
Kheifets, Leeka (UCLA School of Public Health, Los Angeles, California)
Kirsh, Vicki (Cancer Care Ontario, Toronto, Canada)
Mezei, Gabor (Electric Power Research Institute, Palo Alto, California)
Pavic, Armin (Dept of Electrical Engineering, University of Zagreb, Zagreb, Croatia)
Silva, Michael (Electric Power Research Institute, Palo Alto, California)
Souques, Martine (EDF, Paris, France)
Szabo, Judit (National Research Institute for Radiobiology, Budapest, Hungary)
Thuroczy, Gyorgy (National Research Institute for Radiobiology, Budapest, Hungary)
Vincze, Janosne (ELMU, Electric Distribution Company, Budapest, Hungary)
Znaor, Ariana (Croatian National Institute of Public Health, Zagreb, Croatia)
**Workshop III**

_Varna, Bulgaria_

_April, 9-10, 2008_

Antoaneta Manolova (National Centre of Public Health Protection, Bulgaria)

Arzu Firlarler (GNRK, Gazi University)

Gabor Mezei, (Electric Power Research Institute, Palo Alto, California)

Gyorgy Thuroczy (National Research Institute for Radiobiology, Budapest, Hungary)

Iliya Iliev (National Centre of Public Health Protection, Bulgaria)

Jason Pole (POGO, Toronto, Canada)

Jukka Juutilainen (Univeristy of Kuopio, Kuopio, Finland)

Leeka Kheifets (UCLA School of Public Health, Los Angeles, California)

Maria Feychting (Karolinska Inst., Stockholm, Sweden)

Michel Israel (National Centre of Public Health Protection, Bulgaria)

Mihaela Ivanova) (National Centre of Public Health Protection, Bulgaria)

Mike Silva (Electric Power Research Institute, Palo Alto, California)

Nadia Dimitorva (National Centre of Public Health Protection, Bulgaria)

Nikolay Grigorov (National Centre of Public Health Protection, Bulgaria)

Ronen Hareuveny (Soreq, Nuclear Research Center, Israel)

Shaiela Kandel (Soreq, Nuclear Research Center, Israel)

Tsvetelina Shalamanova (National Centre of Public Health Protection, Bulgaria)

Victoria Zaryabova (National Centre of Public Health Protection, Bulgaria)

Zsuzsanna Jakab (National Pediatric Cancer Registry, Budapest, Hungary)
Appendix - Workshops

Workshop IV
Jerusalem, Israel

September 6-7, 2009

Micha Barchana, Israel Cancer Registry, Israel
Ronen Hareuveny, Soreq, Israel
Anke Huss, Utrecht University, Netherlands
Michel Israel, National Centre of Public Health Protection, Bulgaria
Mihaela Ivanova, National Centre of Public Health Protection, Bulgaria
Shai Izraeli, Tel Aviv University, Israel
Shaiela Kandel, Hebrew University, Israel
Leeka Kheifets, University of California, Los Angeles, USA
Susanna Lagorio, National Institute of Health, Italy
Jacques Lambrozo, Electricite de France, France
Gabor Mezei, Electric Power Research Institute, USA
Jason Pole, Pediatric Oncology Group of Ontario, Canada
Martin Roosli, University of Basel, Switzerland
Nir Yitzhak, Soreq, Israel
Viktorya Zaryabova, National Centre of Public Health Protection, Bulgaria
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