

Supplementary material for the paper entitled: A source-based measurement database for occupational exposure assessment of electromagnetic fields in the INTEROCC study: A literature review approach

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Annex I. INTERPHONE occupational questionnaire on EMF sources

Introduction

The occupational section of the INTERPHONE questionnaire commences with a **screening question** that asks subjects about their involvement in certain occupations with potential for high EMF exposures. The interviews were carried out using a Computer-Assisted Personal Interviewing (CAPI) system.

The main occupational sources of interest are those associated with high levels of exposure from: 1) ELF EMFs, such as electric equipment or power lines; 2) RF EMFs, such as industrial heaters, radar, or broadcasting antennas. Specific questions on ionizing radiation, exposure to EMF from fuel-powered vehicles (e.g. aviation) and non-occupational EMF sources (e.g. ham radio) were included in the original questionnaire but are not described in this document.

It will not be uncommon for people to answer positively to more than one occupational screening question. In some cases, it will be the same occupation causing two or more exposures, such as workers who use electric-powered industrial equipment and are exposed to both ELF-EMFs and RF-EMFs.

Twelve source-based occupational sections were developed. Most sections involve asking details about (a) the devices or equipment used and (b) the conditions of use (including the job in which they were used).

The emphasis placed upon each of these aspects of work may vary. In most sections the emphasis is on the EMF sources (devices or equipment) used or exposed to, because it is such use which is associated with significant exposures, rather than necessarily the occupation. However, in some sections the focus is on the job titles and activities, such as working as an electrician, which drives the actual level of exposure. Moreover, CAPI does not ask questions about equipment which was not powered by electricity (e.g. using gas, coal etc) or which was not manually operated (e.g. automatic machines).

General comments

A number of questions are common for various sections. They are as follows:

Was the process automated or done manually?

The question determines whether the process is done automatically (e.g. from by remote control from a distance), or manually by the subject. If the process is automatic, no further questions are asked for this subsection.

Did you have to hold the material in place while the equipment was working?

The question determines whether, for processes that are completed manually, the subject is required to hold the material in place and is therefore close to the heat source. If not, no further questions are asked for this subsection.

What products or goods did you make (for example rubber dinghies, laminated furniture)?

This question is open-ended and asks the main products or goods produced as a result of the heating process.

Compared with the previous period, were there any changes [e.g. in your job description or the type of electric vehicles you worked on]?

This question is designed to determine two primary aspects of the subject's work for the next period of employment:

- was there a change in the type of work they did?
- was there a change in the hours they worked?

The first aspect 'Was there a change in the type of work they did?' refers to whether, in their next period of employment, there was a change in their duties, the machines or equipment they worked with, the activities or processes associated with the work, etc.

If there was a change in nature of the subject's work, then it will be necessary to ask most of the section again for the next period of employment. For example, consider a subject had two periods of employment, both using industrial heating equipment. In the first period of employment, 1990-1995, they operated a furnace that was used to heat metal. In their second period of employment, 1996-1999, they operated a kiln that was used to heat ceramics. These jobs, although both involving industrial heating equipment, are different, and therefore it will be necessary to go through the section two times.

Screening questions

- In any of the jobs or industries in which you worked, have you used industrial heating equipment either to cook, dry, sterilise or pasteurise food or to sterilise needles or other medical or dental equipment?
- In any of the jobs or industries in which you worked, have you used industrial heating equipment to bond or seal or weld materials of any kind?
- In any of the jobs or industries in which you worked, have you used industrial heating equipment to melt or dry or cure materials of any kind (except food)?
- Have you worked with radar?
- Have you worked with broadcasting and telecommunication antennas and masts?
- Have you worked for an electric company or utility?
- Have you worked directly on or around any kind of electric transport?
- Have you constructed repaired or maintained electric machinery or equipment?
- Have you used industrial machinery powered by electric motors, other than in any jobs already mentioned?
- Have you worked as electrician, other than in any jobs already mentioned?
- Have you manufactured semiconductor "chips" or micro-electronic devices?

- Have you used or maintained electromagnetic devices to treat or diagnose disease?
- Have you worked with ionising radiation?
- Have you worked as an airline pilot or crew member?

Source-based questionnaire

In order to identify both the subjects exposed to the various devices used as well as the actual existing sources of EMF exposure in the workplace, different questions were asked through each of the twelve occupational sections developed:

Before the start of the source-base questionnaire for the occupational sections involving industrial heating the subject was asked “For the equipment you operated, how was it powered?” [THE SUBJECT MAY TICK MORE THAN 1 RESPONSE]

This question determines what energy source was used to power the equipment. Electricity must be selected for the subject to proceed; for all other options the section is concluded.

1. Heating Food & Medical-Dental equipment

(1) Introduction

This occupational section covers a range of activities where electric heating devices and machinery are used during heating, cooking and curing of foodstuffs or for sterilization of medical and dental equipment.

(2) Main type of exposure

ELF, IF & RF

(3) Specific questions (examples)

The screening question, **“In any of the jobs or industries in which you worked, have you used industrial heating equipment either to cook, dry, sterilise or pasteurise food or to sterilise needles or other medical or dental equipment?”**, led to a detailed source-based questionnaire as follows:

The following question permitted to disregard possible non-electric heating devices, **“How was the equipment powered?”**, such as those powered by gas, steam or any other non-electric energy source.

After clarifying **“In which of the jobs you mentioned was electricity used to power the heating equipment?”**, a question regarding the type of equipment used **“Did you work with any of these machines or processes?”** offered a list of possible devices associated with electric heating such as electric heating / drying, induction plates, radiofrequency (dielectric) heating, microwave heating. An **“other”** option allowed the introduction as free text of other types of equipment not previously considered in the list provided.

Another free text section allowed the introduction of the type of foodstuff/medical equipment heated. A final list with different possible processes allowed the identification of the specific process used (e.g. cooked, dried, pasteurised, cured).

2. Industrial Heating

(1) Introduction

Industrial heating equipment refers to a range of machines used to heat materials such as metals, glass, ceramics, rubber etc. This section is probably the most complicated in terms of its structure. However, because of the way the questions were branched, most subjects will only end up answering a few questions.

It is useful to classify the processes and jobs where heating equipment is used as follows:

- Heating processes involving **metals**

Jobs include (a) operating and monitoring furnaces or other heating devices for smelting, melting, hardening, stirring, or refining metal; (b) operating and monitoring machines which melt the metal before rolling or shaping it into different forms (e.g. making metal sheets, tubes or wires); (c) welding, in which an electric arc, a gas flame or some other source of heat is used to weld together metal parts

- Heating processes involving **plastic and rubber**

Jobs include operating and monitoring machines which blend rubber or plastics to produce various components or products, such as household items, footwear, tyres etc. These include radiofrequency or 'dielectric' heaters, which use radiofrequency energy to seal or bond these materials.

- Heating processes involving **wood, laminates and fibreglass**

Jobs include operating and monitoring machines which heat wood, such as using hot-plate presses in the creation of plywood.

- Heating processes involving **ceramics**

Jobs include operating and monitoring kilns and furnaces used in the manufacture of ceramics, such as pottery, porcelain, bricks, tiles and so on.

- Heating processes involving **nylons and other materials**

Jobs include the processing of fabrics and textiles.

There may be some overlap in these tasks. For example, in the manufacture of particular product made of metal and plastic, the worker may be involved in heating both materials.

(2) Main type of exposure

Mainly RF, IF and ELF

(3) *Specific questions*

The screening question, “**In any of the jobs or industries in which you worked, have you used industrial heating equipment to melt or dry or cure materials of any kind (except food)?**” led to a detailed source-based questionnaire as follows:

The first aspect of industrial heating work, “**How is the heating equipment powered?**”, determines the energy source used to power the equipment. In this questionnaire, the main division of importance is “electricity” or “other” – e.g. gas, steam etc. The section proceeds only if the subject worked with equipment **powered by electricity**, because this equipment is associated with the exposures of interest.

For the equipment powered by electricity, the next factor to determine is “**What materials are being heated?**”. These classifications are defined in the introduction, and include metal, plastic, wood etc. Each of these groups of materials is associated with different machines and processes, and thus the questions branch off appropriately. For example, asking about the use of arc welders is appropriate to metal; arc welders are not usually used to heat ceramics.

Next, for **each** appropriate material, the subject is asked “**What equipment was being used?**” and “**What are the processes or activities involved?**” The subject is provided with lists of equipment and processes suitable for each type of industrial heating. These multi choice questions not only provided a detailed list of possible devices but an “**other**” option was also available, through which the subject could enter the specific device/process used if not in the list. Therefore, the subject was asked to name the process/equipment used rather than select from a list. This was entered as **free text**.

The final important aspect to determine is whether the machines used were **automated** or **manually operated**. For machines which are manually operated, the subject is asked whether they **held the material in place**. The difference between automated and manually operated machines is important in terms of the exposure the subject receives. Subjects who sit in a control room, far from the heating machinery, usually have much less exposure than a person who is standing adjacent to the machine, holding the material in place while it is being heated.

3. *Radar*

(1) *Introduction*

Radar is a system for detecting objects (e.g. in the air, land or at sea) using radio signals, usually by emitting a series of short pulses of radiofrequency energy. If these signals strike a conducting object, then some of the energy is reflected. Forms of radar broadly include search radar (with wide beams used to give the approximate location of objects) and tracking radar (used to follow a target).

People who are most exposed to EMF from radar include workers testing or maintaining radar systems and military personnel using radar to gain tactical information.

(2) Main type of exposure

Mainly RF

(3) Specific questions

The screening question, “**Have you worked with radar?**”, led to a detailed source-based questionnaire as follows:

First, the question, “**Which of the following most closely matches your job title?**”, asked about the job most closely related to the one involving radar use. A list of possible jobs was provided (e.g. radar tester, speed radar operator) and an “**other**” option allowed the possibility of entering the name of the job carried out if it was not included in the list provided.

Next, the subject was asked about the location of the radar antenna, “**For the radar you worked on, what was the location of the antenna?**”. A list of possible locations was provided (e.g. hand-held, fixed on a vehicle). An “elsewhere” option allowed the introduction of free text if the location was not in the list provided.

The subject was also asked about the distance to the radar, “**How far away were you from the radar antenna while it was operating?**” Free text entering was allowed in order to include a point estimate as well as lower and upper range estimates in meters or kilometres.

Finally, a question to find out about the involvement on radar electronics asked “**Did you work on the radar electronics?**”. This question was added since exposure from radars can also come from leaks in the waveguides from the RF generator to the antenna, although such leaks are rare and unpredictable.

4. Telecommunication Antennas and Masts

(1) Introduction

Antennas and masts refer to structures which use radiating electromagnetic waves for communication, including FM radio and television towers. Antennas may be used for transmitting, receiving, or both.

Antennas may be described according to their use (e.g. TV, radio), shape, and the frequency of their signal (e.g. HF, VHF, UHF).

Workers who construct or repair antennas and masts (particularly if the devices are actively transmitting) may be exposed to high EMF levels.

(2) Main type of exposure

Mainly RF

(3) *Specific questions (examples)*

The screening question, “**Have you worked with broadcasting and telecommunication antennas and masts?**”, led to a detailed source-based questionnaire as follows:

First, the subject was asked, “**I would like to know what types of antennas you worked on**”, These question refers to the antennas the subject usually worked upon (e.g. radio and TV broadcasting, mobile telephone base stations). For subjects able to supply this information, it was necessary to determine the scale of the unit in hertz, “**For the antennas you usually worked on, what range of frequencies did they operate on?**” A free text option allowed entering digits and the following question allowed the selection of megahertz or gigahertz.

Next, the interviewer asked “**Did you climb on antenna masts or work on antennas while they were broadcasting?**” followed by “**How much of the time?**”, providing a list of options (e.g. under a third ($<1/3$), a third to two thirds ($1/3-2/3$)).

Finally, the subjects were asked if they were surrounded by other antennas while working, whether on other masts or not: “**Were there usually any other antennas on the same mast or within 100 metres (or 300 feet) of where you worked?**”, and again the same list of options provided above was given in order to select the type of antennas in the surroundings. This question refers to other antennas close to the subject, not necessarily those on which they worked directly. For example, there may be an array of antennas close to one another, thus bringing a subject in close proximity to a selection of different antennas separate from the specific one the worker is working upon. On the other hand, a worker may be exposed to antennas in the surroundings while carrying out unrelated maintenance tasks on a roof.

5. Electric Company / Electric Utility

(1) *Introduction*

Electric company or utility work encompasses a wide range of occupations. The main work categories may be considered in terms of the five main stages of electricity production and distribution:

- **Power stations**: i.e. the building in which electric power is generated, including hydroelectric, fossil fuel or nuclear power stations. Examples of workers at these locations include boiler room staff and maintenance technicians.
- **Transmission lines** are high-voltage lines carrying electricity from the power station to substations. Examples of occupations which involve electric lines include linemen or line-workers.
- **Substations**
 - **Transmission substations** are sites where electricity to or from transmission lines are either increased (e.g. immediately after leaving the power station) or decreased in voltage (e.g. close to the destination of the electricity)

- **Distribution substations** are sites where electricity from transmission lines is passed to distribution lines with an associated decrease in voltage
- **Distribution lines** are lower-voltage lines carrying electricity to the customers in a local area.
- The **destination** (e.g. businesses/residences of the electricity ‘customers’).
- Examples of workers at these locations include electricians, who are covered in the section ‘Other electric work, including being an electrician’.

(2) *Main type of exposure*

Mainly ELF

(3) *Specific questions*

The screening question, “**Have you worked for an electric company or utility?**”, led to a detailed source-based questionnaire as follows:

The following question, “**Where did you mainly work?**”, offered a list of sites within an electric utility (such as power station, substations/switchyards, distribution lines, high voltage transmission lines, workshops etc.) to be selected. An “**other**” option allowed the possibility of entering other sites/equipment not mentioned in the list provided.

The question “**Which of the following most closely matches your job title?**” allowed for the selection of different jobs from a list provided (e.g. turbine hall, boiler house, or reactor building worker, control room operator, engineer/fitter/electrician, mechanic, switchyard/substation worker, line worker/lineman etc.). Another “**other**” option allowed the introduction of different types of jobs not considered in the list provided.

For some of the jobs listed, a second list with additional occupation titles (such as supervisor, trained worker/journeyman, apprentice or other) allowed the identification of these specific duties within the job reported.

6. *Electric Transport*

(1) *Introduction*

Electric transport work involves the driving, maintenance or staffing of vehicles powered by electricity, such as electric buses, trains, trams, and underground transport.

(2) *Main type of exposure*

Mainly ELF

(3) *Specific questions*

The screening question, “**Have you worked directly on or around any kind of electric transport?**”, led to a detailed source-based questionnaire as follows:

The question, “**What types of vehicles did you mainly work with?**”, allowed the selection of one or more possible electric transportations means from a list (such as train, tram, metro, mono-rail etc.).

For each of these transportation means the question, “**Which of these best describes your main job when you were working on electric transport?**”, allowed the identification of the duties carried out (i.e. driver/conductor or maintenance of track, electric supply, yard workers). An “**other**” option allowed the introduction of duties not previously considered as free text.

7. Construction, Repair, Testing and Maintenance of Electric Machinery or Equipment

(1) Introduction

The construction, repair, testing and maintenance of electric machinery or equipment covers a range of activities. The types of equipment or machinery on which subjects may work include:

- Industrial equipment or machinery, such as machinery used in buildings, factories or workshops
- Home entertainment equipment, such as radio and television equipment; video recorders and other audio-visual equipment
- Home appliances, such as vacuum cleaners and electric ovens

These are not mutually exclusive: subjects may work on more than one of these categories of equipment

(2) Main type of exposure

Mainly ELF

(3) Specific questions

The screening question, “**Have you constructed, repaired or maintained electric machinery or equipment?**”, led to a detailed source-based questionnaire as follows:

The following question, “**Which type of electric machinery or equipment did you mainly work on?**” offered a list of possible types of machinery/equipment used (such as industrial equipment or machinery, home entertainment equipment, home appliances etc.). An “**other**” option allowed the introduction of different types of equipment not considered in the list provided.

After several questions regarding the amount of time worked with these equipment/machinery, an open ended question, “**What were your main activities on this job?**” allowed the introduction of the duties carried out as free text.

8. Electric Motors

(1) Introduction

Work with industrial electric motors refers to the operation or monitoring of industrial machines which contain electric motors. There are a large array of commonly-used machines, including sewing machines and tools to perform repetitive work, such as lathes, presses, and drills.

These industrial machines can be operated in the following ways: at a distance (e.g. automatically, or using remote control), close to the object (e.g. manually) or both. Proximity to the machine is one of the important factors in how much EMF exposure a person receives.

Devices used in offices or residences with small electric motors are not included in the classification of 'Industrial electric motors'. Therefore, this section does NOT apply to people who have solely used, for example, office equipment such as photocopiers, computers, home appliances and so on.

(2) Main type of exposure

Mainly ELF

(3) Specific questions

The screening question, **“Have you used industrial machinery powered by electric motors, other than in any jobs already mentioned?”**, led to a detailed source-based questionnaire as follows:

*For your <first, next etc> period of employment], **what types of machinery or equipment were you using?** [check all that apply].* A list of possible devices was offered (such as sewing machine, electric hand tools, lathe, milling machine etc.). Some subjects may work with many of these devices in the same period of employment.

An **“other”** option allowed the introduction of different devices not previously considered in the list provided as free text.

After a series of questions regarding the amount of time spent working in proximity (less than half a meter) to the particular motor, an “free text” section allowed for the inclusion of information on the activities carried out during the use/exposure to the motor/s selected (**“What were your main activities on this job?”**).

9. Work as an Electrician

(1) Introduction

Working as an electrician covers a wide range of activities including setting up, maintenance and repair of electric installations in residences, commerce and construction sites. Specialized electricians or fitters can work on specific industries, including electric utilities.

(2) Main type of exposure

Mainly ELF

(3) Specific questions

The screening question, “**Have you worked as electrician, other than in any jobs already mentioned?**”, led to a detailed source-based questionnaire as follows:

The question, “**What type of work were you mainly doing?**” allowed for the identification of different types of work, such as working on the construction of industrial or residential sites, repair and maintenance of residences or industrial sites. An “other” option allowed the introduction of other types of work such as electricians for vehicles or other structures (e.g. neon lights etc.).

The following question, “**What were your main activities on this job?**” allowed the introduction of detailed activities carried out as free text.

10. Semiconductor / Microelectronic Manufacturing

(4) Introduction

The field of semiconductor/microelectronic manufacturing includes the development of components for computers (e.g. microchips), telecommunications equipment, and numerous other electronic devices.

The relevant aspects of the semiconductor process can be briefly described as follows, using silicon semiconductor manufacturing as an example:

- ◆ The locations in which this manufacture occurs are called “clean rooms,” so-called because all the fine particles in the air are removed and workers must wear confining clothes to prevent shedding of skin and hair.
- ◆ The basic unit which is manufactured is the integrated circuit, in which often millions of transistors are connected by a pattern of conductors to create a circuit (e.g. for computer memory).
- ◆ The manufacture of the integrated circuit starts with a silicon wafer, about 10–30 cm in diameter. The main processes the wafer undergoes in the manufacture of an integrated circuit are: oxidation, lithography, etching, doping, chemical vapour deposition (CVD), and metallisation.

(5) Main type of exposure

Mainly RF and ELF

(6) Specific questions

The screening question, “**Have you manufactured semiconductor “chips” or micro-electronic devices?**”, led to a detailed source-base questionnaire as follows:

The first aspect of interest in semiconductors manufacturing, “**Did you ever work in a clean room where these “chips” were being manufactured?**” The question determines whether the subject has ever worked in a “clean room”, which is the environment in which semiconductors are manufactured. If they respond ‘no’ or ‘don’t know,’ there were no further questions.

Following to this question, the subject was asked “**In which of the jobs you mentioned?**” and “**What was your job title?**”, in order to identify the actual involvement in the manufacturing process. For this purpose, a list of possible occupations was provided (e.g. operator, technician).

Next, the subject was asked, “**In that job, did you work with processes or equipment that used plasmas?**” If the response was affirmative the following question asked “**What type of plasma processes or equipment did you work with?**”, providing a list of possible processes commonly used (e.g. plasma etcher, CVD).

Finally, the subject was asked “**Did you work with any other pieces of clean room equipment?**” and an affirmative response led to the final source-based question, “**What other types of clean room equipment did you work with?**”, which also provided a multiple choice list of devices/equipment (e.g. sputtering, epitaxy reactors, lithography). An “other” option offered the possibility to introduce the name of the equipment or device used as free text if it was not included in the lists provided.

11. Diagnosis & Treatment of Disease

(1) Introduction

These devices include those used in a health context for treatment - such as the diathermies used in operating theatres or the various heat treatments used by physiotherapists - or diagnosis, such as magnetic resonance imaging machines (MRIs). Activities which may be significantly associated with EMF exposure include the use, maintenance and repair of such devices.

Occupational groups who use such equipment include (a) physiotherapists (physical therapists) who may use heat therapies to treat disorders of e.g. bones, muscles, the nervous system etc; (b) operating theatre staff, who use diathermies to cut through tissues and cauterise blood vessels; (c) staff using hyperthermia equipment, which is used in some centres to treat tumours, often together with radiotherapy or chemotherapy; (c) magnetic resonance imaging operators, who may be exposed to magnetic fields during the imaging process.

NOTE: Subjects who may have received exposures from some of these devices – such as patients undergoing MRIs or receiving heat therapy from a physiotherapist - are questioned about their exposure in the ‘Medical EMF exposure’ section of the questionnaire (Heating Food & Medical-Dental).

(2) Main type of exposure

Mainly RF, ELF and SMF

(3) Specific questions

The screening question, “**Have you used or maintained electromagnetic devices to treat or diagnose disease?**”, led to a detailed source-based questionnaire as follows:

First, the question, “**Which of the following most closely matches your job title?**”, asked about the job most closely related to the one involving treatment or diagnosis. A list of possible jobs was provided (e.g. physiotherapist, MRI technician) and an “other” option allowed the possibility of entering the name of the job carried out if it was not included in the list provided.

Next, depending on the job title selected, the subject was asked about the type of equipment used, “**What kind of equipment did you use?**” and different lists of possible devices were provided whether for physical treatment (e.g. microwave, short wave diathermy) or operating theatre (e.g. surgical diathermy). If hyperthermia was selected the subject was asked “**What type of hyperthermia did you use the devices for?**” and the choice list provided options such as superficial or interstitial. The subject was also asked “**How were the tissues heated?**” and the options included two possibilities (i.e. microwave/radiofrequency energy and ultrasound) as well as an “other” option if the process was not any of these two.

If the response to the job title question was “equipment repair and maintenance”, the subject was then asked “**What kind of equipment did you use?**” A list of options included the devices listed above (i.e. physical therapy, surgical diathermies, MRIs and hyperthermia) as well as an “other” option for free text in case the device was not listed.

Finally, a free text section preceded by the question “**What process or activity were you using the devices for?**” allowed the introduction of descriptions for the specific activities carried out.

12. Transmitters

(1) Introduction

Transmitters or radio transmitters are electronic devices used in telecommunications to generate a radio frequency alternating current which with the aid of an antenna excited by the current emit electromagnetic or radio waves. Transmitters are used in broadcasting, but also as components in mobile phones, wireless networks, Bluetooth, two-way radios etc. In telemetry, a transmitter is a device which converts measurements from a sensor into a signal which is sent to be received by some display or control device.

(2) Main type of exposure

Mainly RF

(3) *Specific questions (examples)*

The screening question, **“Have you ever used the following communication devices regularly? CB radios, walkie talkie, DECT phones or other types of radios or transmitters?”**, led to a detailed source-based questionnaire as follows:

The following question, **“What types of transmitters or 2-way radios did you use?”** allowed the identification of specific types of equipment from a list provided (e.g. CB radio, walkie talkies, satellite telephones, UHF/VHF radios used on boats and other marine vessels, other personal radios for professional use such as aviation, private security, car radios other than listed above, DECT phones. An **“other”** option allowed the introduction of other types of equipment not included in the list provided as free text.

Two more questions, **“Did you use them at work or outside work? By outside work, I mean for recreational use, compulsory military service (if applicable) and volunteer work”** (e.g. at work outside work or both) and **“Were the CB radios you operated...portable, fixed in a position or both types?”** allowed a more detailed assessment of the exposure to the particular transmitter.