

Between-Country Comparison of Whole-Body SAR from Personal Exposure Data in Urban Areas

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Running title: between-country comparison of SAR

Abstract- In five countries (Belgium, Switzerland, Slovenia, Hungary, and the Netherlands), measurements were performed in different microenvironments such as homes, public transports, or outdoor using the same personal exposure meters. From the mean personal field exposure levels (excluding mobile phone exposure), whole-body absorption values in a 1-year old child and adult man model are calculated using a statistical multipath exposure method and compared for the five countries. All mean absorptions (maximal 2.2 $\mu\text{W/kg}$ for DAB) are well below the basic restriction of 0.08 W/kg for the general public. Generally, incident field exposure levels are well correlated with whole-body absorptions (SAR_{wb}) although the type of microenvironment, the frequency of the signals, and the dimensions of the considered phantom are modifying the relationship between these exposure measures. Most important exposure to digital radio, Terrestrial Digital Audio Broadcasting (T-DAB), (up to 65%) causes relatively higher SAR_{wb} values for the 1-year old child and FM (up to 80%) in the adult man than signals at higher frequencies due to the body-size dependent absorption rates.

Key Words- radio frequency electromagnetic fields (RF-EMF); exposimeter; personal exposure; whole-body absorption; specific absorption rate (SAR), RF measurement; exposure of general public

INTRODUCTION

Personal RF-EMF (radio frequency electromagnetic field) exposure of the general public is nowadays assessed using personal exposure meters (exposimeters). Several countries have performed separate measurement studies [Trcek et al., 2007; Bolte et al., 2008; Joseph et al., 2008; Rösli et al., 2008; Thomas et al., 2008a, b; Thuróczy et al., 2008; Frei et al., 2009; Viel et al., 2009] and various results have been presented, each country with its own procedures. Rösli et al. [2010] and Mann [2010] discuss measurement protocols for exposure meters (exposimeters) and the state-of-the-art of personal exposure measurements. In Joseph et al. [2010], mean field strength levels obtained from personal radio frequency electromagnetic field measurements in different microenvironments were compared between urban areas in five European countries by applying the same data analysis methods. From a biological perspective absorbed radiation may be more relevant than the electric field occurring at the body surface (incident field). Thus, Joseph et al. [2009] proposed a method to calculate whole-body specific absorption rates (SAR) from personal exposimeter data for different human spheroid phantoms. Single plane-wave exposure for different phantoms and frequencies has been discussed in [Dimbylow 2002, 2008; Joseph and Martens, 2003; Wang et al., 2006; Conil et al., 2008; Vermeeren et al. 2008b; Kühn et al., 2010; Uusitupa et al., 2010]. These studies show that the SAR depends very much on the type of phantom, anatomy, and posture. In [Vermeeren et al., 2008, 2008b; Joseph et al., 2009] absorption in real environments is determined using a statistical multipath exposure method.

The objective of this paper is to compare and calculate the whole-body specific absorption rate (SAR_{wb}) for a child and adult model in five countries (Belgium, Switzerland, Slovenia, Hungary, the Netherlands) for different wireless signals, based on the mean exposure levels measured with

personal exposimeters in specific scenarios in real environments (named microenvironments in this paper) and published in Joseph et al. [2010]. For this purpose, the pooled data from the countries are combined and the method of Joseph et al. [2009] is applied to determine the actual whole-body SAR in the human phantom.

This paper is the first one where a comparison of SAR_{wb} (for child and adult model) based upon personal exposure between different countries is made and it enables to distinguish between the field exposure situation and on the other hand on the actual absorption in real circumstances. Epidemiological studies can use the results of this paper to relate possible health effects to both exposure values and absorptions.

MATERIALS AND METHODS

Microenvironments

Five typical microenvironments for the general public were defined in order to enable a comparison between the different countries. To inform about place (outdoor vs. indoor) and time (daytime vs nighttime) of measurements, the five microenvironments are denoted with a short name of the form: “location – environment - time”: (i) *outdoor - urban* – day, (ii) indoor – *office* – day, (iii) indoor - *train* – day, (iv) indoor - *car/bus* – day, (v) indoor – *urban home* – day/night. Details are provided in Joseph et al. [2010]. To minimize heterogeneity among the studies, urban areas are defined as areas with more than 400 persons per square km and offices as working places of employees working at desks. Daytime and nighttime are here defined with respect to working hours: “daytime” is defined as the period from 6 am to 6 pm (working hours) and “nighttime” is the period where most people do not work or are sleeping, thus the period after 6 pm and before 6 am. Table 1 lists the considered microenvironments.

Measurements in participating countries

In each of the countries, electric field measurements were performed using the selective isotropic personal exposure meter of type DSP90-120-121 EME SPY of SATIMO (Avenue de Norvège 17, 91953 Courtaboeuf, France). The exposimeter measures 12 frequency bands (see footnote of Table 2, noted in this paper as FM, TV / digital radio (DAB), TETRA, TV, GSM900: downlink (i.e., communication from base station to mobile phone) and uplink (i.e., communication from mobile phone to base station) at 900 MHz, GSM1800 down- and uplink at 1800 MHz, DECT, UMTS down- and uplink, WiFi). The measurement procedures and number of samples and subjects are summarized in Joseph et al. [2010]. The measurements were performed in the period 2007-2009. In the studies of Belgium and the Netherlands, measurements were made by hired staff whereas the studies of Switzerland, Slovenia, and Hungary were based on volunteers from a population sample.

Procedure and data analysis

Figure 1 shows a flow graph of the procedure to compare the data from the different countries and to convert the data to SAR_{wb} . The procedure consists mainly of three steps. Firstly, exposimeter data is collected from the different national studies. The robust ROS (regression on order statistics) method was used to compute mean exposure levels [Röösli et al. 2008] (Figure 1). Secondly, a human body model is selected and thirdly, SAR_{wb} in the phantom is calculated for the mean power density using the statistical tool of Vermeeren et al. [2008, 2008b] and the method proposed in Joseph et al. [2009], and is compared for the different countries.

Field data analysis (step 1 in Figure 1)

In all countries, all measurements taken in each microenvironment were combined and analyzed. Since a large proportion of the measurements was censored, i.e., below the lower detection limit of the exposimeter (0.0067 mW/m^2), we applied the robust regression on order statistics (ROS) method proposed by Rösli et al. [2008] to determine the mean values of the power density S (mW/m^2) for each microenvironment. Exposimeter data of all participating countries were processed in exactly the same way using the ROS algorithm with the statistical software R (www.r-project.org), which is discussed in detail in Helsel [2005].

The total exposure S_{tot} (mW/m^2) was calculated by summing up the mean power density values of all frequency bands:

$$S_{tot} = \sum_i S_i \text{ (W/m}^2\text{)} \quad (1)$$

With S_{tot} the total power density of all signals and S_i the power density for each source at its specific frequency i (different sources are considered), respectively.

Selection of human phantoms (step 2 in Figure 1)

An appropriate human phantom has to be selected. We have selected a spheroid human body model because this simple model gives a realistic estimation of the SAR_{wb} [Durney et al. 1986]. The homogeneous tissue of the spheroid human body phantoms has been assigned the dielectric properties of the tissue suggested by IEC 62209 [IEC, 2005] for compliance testing for the different frequencies. Here we investigate the adult man phantom and the 1-year old child phantom (highest whole-body absorptions are obtained for this phantom as explained in Joseph et al. [2009]). The sizes of these phantoms have been taken from Durney et al. [1986].

Calculation of whole-body SAR and comparison (step 3 in Figure 1)

Calculation of whole-body SAR using the statistical tool of Vermeeren et al. [2008, 2008b] is extensively described in Joseph et al. [2008] and [2009]. 5,000 realistic exposure samples have been generated to obtain statistically relevant results with the statistical tool for the appropriate “simulation environment” of the considered microenvironment. We obtain then functions of the form:

$$\langle SAR_{wb} \rangle_i = a \cdot (\langle E \rangle_i)^2 = a \cdot 377 \cdot \langle S \rangle_i \quad (\text{W/kg}) \quad (2)$$

$\langle SAR_{wb} \rangle_i$ represents the mean value of the whole-body SAR at frequency i and parameter a ($\text{m}^2/(\Omega\text{kg})$) depends on the type of phantom, the different frequencies, and the type of environment [Joseph et al., 2009]. E represents the electric field E (V/m) and S the power density in (W/m^2). $\langle \cdot \rangle_i$ denotes mean values for a source at its specific frequency i . Here we calculate the *mean* whole-body SAR from the *mean* power densities $\langle S \rangle$ provided by each country for the different microenvironments.

SAR_{wb} will be determined for 9 different radio-frequency sources (of the 12 bands of the exposimeter) at 100 MHz (FM), 200 MHz (DAB), 400 MHz (TETRA), 600 MHz (TV), 950 MHz (GSM900 DL), 1850 MHz (GSM1800 DL), 1900 MHz (DECT), 2150 MHz (UMTS), 2450 MHz (WiFi). For uplink (GSM900 UL, GSM1800 UL, and UMTS UL), SAR_{wb} is not determined because personal exposure measurements do not allow to differentiate uplink from the own phone producing localized exposure and uplink from other people’s phone producing a generally a more homogenous whole-body exposure. Without such a differentiation, SAR_{wb} calculations would not be reliable.

Appropriate environments have to be selected when calculating SAR_{wb} [Vermeeren et al., 2008; Joseph et al., 2009]. For *urban-outdoor* the “urban macro/micro-cell environment” is selected for the statistical tool for all sources (i.e., outdoor sources) except for WiFi and DECT where the “outdoor-indoor environment” is chosen, because WiFi and DECT are mostly located inside houses and buildings. For *office, train, car/bus, urban-home* (indoor) the “outdoor-indoor environment” is selected for all sources except for WiFi and DECT, which are now indoor sources and where the “indoor pico-cell environment” is selected.

The *total* SAR_{wb} values due to the considered sources (88 – 2450 MHz) will be determined and compared to the ICNIRP limit of 0.08 W/kg for the general public. They are calculated as follows (from (6) in [ICNIRP, 1998]):

$$SAR_{wb}|_{total} = \sum_{i=100\text{ MHz}}^{2450\text{ MHz}} SAR_{wb}|_i \text{ (W/kg)} \quad (3)$$

With $SAR_{wb}|_{total}$ and $SAR_{wb}|_i$ the total whole-body SAR and the whole-body SAR for each source at its specific frequency i (9 sources are considered), respectively.

Values for a-parameter per phantom, frequency, and environment

Figure 2 shows the parameter a from Equation (2) for ***mean*** SAR_{wb} values in the 1-year old child and adult man for the different environments (urban-macro-cell, indoor-outdoor, indoor pico-cell). The value of parameter a equals the value of SAR_{wb} for an incident electric field of 1 V/m, see (2) (power density of 1/377 W/m²). Thus, Figure 2 provides whole-body SAR values for normalized incident fields. The parameter a is clearly higher for the child than for the adult phantom due to its smaller dimensions. For both phantoms, the whole-body absorption decreases

with increasing frequencies. Because of the dimensions of the 1-year old child, 200 MHz is about the resonance frequency of the 1-year old child model for a horizontal plane wave [Durney et al. 1986] and half the wavelength at 200 MHz is 0.75 m, while the length of the 1-year old child is 0.74 m. For the adult phantom, the resonance frequency is about 73 MHz and thus below the considered frequency range of dosimeter, explaining only the decreasing trend of a for the adult phantom and highest value at FM (100 MHz).

Method for ranking of environments for mean SAR_{wb} and power densities S

To compare which microenvironment causes the highest absorptions and which one the highest (incident) power densities we normalize SAR_{wb} and S as follows:

$$\overline{SAR_{wb}}(c, e, b) = \frac{SAR_{wb}(c, e, b)}{\max_{\substack{e \in \text{all env} \\ b \in \text{all bodies}}} (SAR_{wb}(c, e, b))} \quad (4)$$

With $\overline{SAR_{wb}}(c, e, b)$ (c = country, e = environment, and b = body model) the normalized total whole body SAR_{wb} due to an RF source for each country (in interval $[0, 1]$), *all env* denotes all environments, *all bodies* denotes the considered 1-year old child phantom and adult man phantom.

$$\overline{S}(c, e) = \frac{S(c, e)}{\max_{e \in \text{all env}} (S(c, e))} \quad (5)$$

With $\overline{S}(c, e)$ (c = country, e = environment), the normalized incident power density due to an RF source for each country (in interval $[0, 1]$), *all env* denotes all environments. These quantities will enable to compare absorptions and power densities in the different environments (see Results).

RESULTS FOR DIFFERENT COUNTRIES

SAR for different environments and countries

Figures 3 (a) and (b) summarize the total mean SAR_{wb} values for all the microenvironments and countries for the 1-year old child and adult man model, respectively. The same scale is used for both figures to enable easy comparison. All mean absorptions in Figure 3 satisfy the ICNIRP basic restriction of 0.08 W/kg for all considered environments and countries [ICNIRP, 1998]. Absorptions in all countries are of the same order of magnitude. Total mean absorptions in the adult phantom (Figure 3.b) are lower for the one year-old child (Figure 3.a) because of the larger dimensions of the adult. The highest total mean SAR_{wb} values (for mean exposure) are obtained in Belgian office and are 3.4 $\mu\text{W/kg}$ for the child and 1.8 $\mu\text{W/kg}$ for the adult man.

Other microenvironments with relatively higher whole-body absorptions ($> 1 \mu\text{W/kg}$) are outdoor-urban (child, and adult in Belgium and the Netherlands) and car/bus in Slovenia and Hungary (Figure 3). Low downlink whole-body absorptions occur in urban homes in all countries.

Ranking of environments for mean SAR_{wb} and power densities

Figure 4 compares the ranking of each environment for the normalized quantities ($\overline{SAR_{wb}}(c, e, b)$ and $\overline{S}(c, e)$) per country (both phantoms, see method section). This figure enables to rank now the environments *per country* with respect to SAR for both phantoms (black and gray bars) and compare this ranking with the one of the incident power density measured with the exposimeter (white bars, excluding uplink). In general, the ranking of SAR_{wb} for the five microenvironment in each country is equal to the ranking of the power densities S_{tot} . However, exceptions occur, for

instance in Belgium highest absorptions are found in offices in contrary to highest power densities in outdoor-urban environments.

Table 2 lists the whole-body absorptions in the 1-year old child for all sources, environments, and countries. The highest SAR_{wb} values in Table 2 are obtained in Belgium for DAB (200 MHz) in offices and GSM DL in outdoor-urban environments namely about $2.2 \mu\text{W/kg}$. Higher SAR_{wb} values correspond again with higher power densities $\langle S \rangle$ in Joseph et al. [2010] (e.g., for outdoor-urban 0.33 mW/m^2 for downlink in Table 4 of Joseph et al. [2010] corresponds with $2.2 \mu\text{W/kg}$ for GSM900 DL in Table 2) but depend also on the frequency of the signal and the dimensions of the phantom.

For FM and DAB relatively lower power densities were obtained in Joseph et al. [2010] but due to the frequency of the signal and the dimensions of the phantom higher SAR_{wb} values are observed for the 1-year old phantom (Table 2). This effect is also present for the adult man phantom for FM (100 MHz) but less pronounced because of its larger dimensions (see Figure 2; resonance at 73 MHz [Durney et al., 1986], which is lower than the 100 MHz FM frequency). The total mean absorption in the 1-year old child is higher than the absorption in the adult (black bars versus gray bars in Figure 4).

Contribution of RF sources

Figure 5 shows the contribution of the different sources to SAR_{wb} in the five microenvironments for all countries for the 1-year old child and adult man. In all microenvironments, absorption to downlink mobile telecommunication is important and clearly dominating for outdoor-urban environments. FM radio absorptions are present in all countries (typically 10% or higher for the 1-year old child) and are important for *adults* in urban-homes, office, car-bus, and trains. DAB

(200 MHz) in the 1-year old child causes important absorption contributions in offices and urban-homes in Belgium. The contribution of FM (100 MHz) is clearly higher for the adult than for the 1-year old child for all environments and countries because of its frequency close to the adult's resonance frequency. For both SAR and incident power density, contributions from mobile telecommunication signals are important in all environments (comparing Figure 5 and Joseph et al. [2010]). The contributions of FM and DAB are higher for absorptions than for incident power densities due to the dimensions of the phantoms.

In outdoor-urban environments downlink absorptions (GSM900, GSM1800, UMTS) due to mobile phone base stations are important for all countries and dominating for all countries (>65%).

In offices, DAB and FM dominate in Belgium (DAB for 1-year old child, FM for adult) and FM for adults in Hungary, while DECT causes highest absorptions in Switzerland, Slovenia, and the Netherlands. Downlink (GSM) is also important in Slovenia and Hungary. Also WiFi causes absorptions in offices.

In the mobile microenvironments (train and car/bus) GSM DL and FM (up to 80% for the adult model in the Netherlands) cause the main absorptions for both phantoms. Absorption contributions in car/bus are similar to the contributions in trains.

In urban homes, absorption contributions are diverse for the different countries. The most important absorption contributions are DECT in Switzerland (>50% for child), Slovenia, and Hungary, FM radio absorptions in all countries and for both phantoms (15- 68% for adult phantom in all countries), DAB in Belgium (child: 43.4%), Hungary (child: 9.2%), and the Netherlands (child: 11.5%), and mobile phone base stations (GSM, UMTS) in all countries. Also absorptions to WiFi are present in urban homes and offices, in contrary to other environments.

Total absorptions in homes are similar among the different countries and somewhat higher in Belgium (Figure 3).

TETRA, UMTS, and TV are sources of minor importance in most of the microenvironments. The contributions of TV are only more than 10% for outdoor-urban environments in Switzerland (Figure 5).

DISCUSSION AND CONCLUSIONS

Our study compares mean whole-body absorptions in two phantoms and contributions of RF sources in five relevant microenvironments in different European countries (Belgium, Switzerland, Slovenia, Hungary, and the Netherlands).

Strengths and limitations

This paper is the first one where a comparison of absorptions in phantoms from personal RF-EMF exposure data in real environments in urban areas in different countries is made. The proposed methodology combined with the application of a statistical multipath exposure method enabled us to compare whole-body absorptions from exposimeter data in different countries.

The differences in study design, the selection of study participants in the population surveys, and a limited number of some microenvironments (for example offices in the Netherlands and Belgium) are limitations of the study and discussed in detail in Joseph et al. [2010]. Also, due to the effect of the shielding of the human body when exposimeters are carried on the body some measurement values might be underestimated up to 6.5 dB [Knafl et al. 2008; Neubauer et al. 2008; Iskra et al. 2010; Joseph et al. 2010, Bolte et al., 2011; Iskra et al. 2011].

In the current study we considered whole-body absorptions from various sources emitting RF-EMF in the frequency range between 80 MHz and 2.5 GHz. However, we did not consider uplink

exposure from mobile phones because the SAR calculations require far-field conditions. Uplink exposure from the own mobile phone causes highly localized exposure, which does not fulfil this assumption and would require a different calculation procedure. However, uplink from other people's phone would generally fulfil the far-field assumption and Frei et al. [2010] demonstrated that this contribution is relevant for the average personal exposure. Thus, our SAR_{wb} values underestimate somewhat the total far-field exposure.

Also only a 1-year old child and adult spheroidal phantom are considered here (Joseph et al. [2009]). For whole-body absorptions, spheroid human body models give a realistic estimation of the SAR_{wb} [Durney et al., 1986]. For localized absorptions, heterogeneous models will be needed.

Interpretation

In a realistic environment electromagnetic waves are traveling along multiple paths. It is obvious that the homogeneous exposure of a single plane wave is not representative for the multipath exposure in a realistic environment. Therefore, to assess the statistics of the absorption correctly and correlate it with the incident field levels, the method of Vermeeren et al. [2008] is used.

We observed quite consistently in all countries that the highest whole-body absorption contributions were from GSM DL, FM, DAB, and DECT and mainly for outdoor-urban and office environments (also car/bus in Slovenia). A similar pattern was observed for the power density. This demonstrates that choice of exposure surrogate in epidemiology might not be very crucial, if interested in the ranking of exposure only. Nevertheless, the relative importance of the DAB contribution is considerably increased in the child phantom compared to the power density and for adult SAR the relative importance of FM is increased. The reason for high values of SAR_{wb} for DAB in the child phantom at 200 MHz (or lower frequencies as FM) are the

dimensions of the 1-year old child (length of 0.74 m and width of 0.16 m in Durney et al. [1986]): 200 MHz is about the resonance frequency of the 1-year old child model for a vertically polarized plane wave arriving at a zero elevation angle [Durney et al. 1986] and half the wavelength at 200 MHz is 0.75 m, while the length of the 1-year old child is 0.74 m. Figure 2 explains this too, with higher values for a for FM and DAB for the child than for the telecommunication frequencies of 950 MHz or higher. The contribution of FM at 100 MHz is clearly higher in the adult than for the 1-year old child, because FM is closer to the resonance frequency of the adult man (73 MHz for the adult according to Durney et al. [1986]) than the frequencies of the other signals and sources.

Absorptions were in general lower in homes, which is a relevant environment in terms of cumulative absorption, as one spends most of the time at home. Indoor levels are lower due to penetration losses of outdoor sources into homes. These result in lower absorptions compared to outdoors. Also in homes less sources such as WiFi and DECT are present than in offices. Total power densities in homes in Joseph et al. [2010] were quite similar in the different countries and this is also the case for whole-body absorptions despite the different source contributions for the different countries. The only pattern showing is that whole-body absorption due to (downlink) mobile telecommunication and FM is important in all countries. However, the exposure contributions in urban homes have to be interpreted with caution. Different recruitment strategies and the limited numbers of participants or microenvironments make a direct comparison difficult. In trains, lowest whole-body absorptions occur because uplink exposure has not been considered. Several studies demonstrated that uplink is the main source in trains [Frei et al., 2009; Joseph et al., 2010]. For downlink signals, the (metallized) windows in trains cause high penetration losses, resulting in low power density values and thus low absorptions.

In Slovenia and Hungary, higher absorptions occur in car/bus because of the lower penetration losses compared to trains (no metalized windows), and the fact that the busses drove mostly in urban regions while trains have also trajectories which are in less dense populated areas and with thus less base stations. However, the highest absorptions in Slovenia have to be treated with care because of the limited number of samples available.

Similarly as for power density values, whole-body absorptions in all countries are of the same order of magnitude (Table 2) as the same RF-EMF sources and technologies (base stations, FM radio, TV/DAB) are present in similar amounts and densities.

It is thus important to conclude that higher power densities mostly but not always correspond to the highest whole-body absorptions. This depends much on the environment in the different countries, the frequency of the signals, and the dimensions and type of human or phantom that is considered. DAB causes relatively higher SAR_{wb} values for the 1-year old child and FM for the adult than signals at higher frequencies (GSM, UMTS, DECT, WiFi, etc.). These absorptions are the basic quantities for RF human exposure [ICNIRP, 1998].

Because we suspect the absorbed radiation to be biologically more relevant than the incident field or power density, future research should aim to estimate the SAR by applying the proposed method or similar approaches. Future developments should also include localized absorptions. Estimations of localized SAR based on exposimeter data is, however, a very challenging task as one will have to distinguish between a participant's own mobile phone and local exposures of surrounding mobile phones of other people. Nevertheless, the more appropriate internal exposure can be estimated, the more reliable exposure comparisons can be made and the more accurate future studies will be, relying on such exposure measures.

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TABLE 1: Considered microenvironements for comparison.

TABLE 2: Mean SAR values ($\mu\text{W/kg}$) corresponding with mean exposures S (mW/m^2) for all microenvironments and all countries.

Figure 1: Flow graph of the procedure to determine and compare SAR_{wb} between countries (ROS= robust regression on order statistics).

Figure 2: Parameter a for 1-year old child and adult man model (mean SAR_{wb} values) for different environments (UM: urban-macro-cell, OI: outdoor-indoor, IP: indoor pico-cell) (the value of a corresponds with the value of SAR_{wb} for an incident field strength of 1 V/m)

Figure 3: Mean total whole-body absorptions ($\mu\text{W/kg}$) (a) in the 1-year old child model and (b) adult man model for all considered microenvironments in all countries.

Figure 4: Whole-body absorptions (1-year old child and adult man) normalized to the maximum SAR of each country and incident power density normalized to the maximum S of each country for all considered microenvironments.

Figure 5: Comparison of the contribution of the different sources of exposure to SAR_{wb} in child and adult for all countries.

logical name	microenvironment	description
out-urban	outdoor - urban - day	outdoor walking, standing, sitting in urban environment during daytime, > 400 persons/km ²
office	indoor – office - daytime	office environment (employees)
train	indoor - train - daytime	exposure in train
car/bus	indoor - car/bus - daytime	exposure in car or bus: driving
urban-home	indoor – urban home – day/night	in home in urban area > 400 persons/km ²

TABLE 1

mean SAR ($\mu\text{W/kg}$) for mean power densities: RF sources														
micro- environment	country	FM	TV/ DAB	TET- RA	TV	GSM 900 UL	GSM 900 DL	GSM 1800 UL	GSM 1800 DL	DECT	UM TS UL	UMTS DL	WiFi	total
outdoor-urban	Belgium	0.102	0.085	0.022	0.094	-	2.195	-	0.074	0.017	-	0.019	0.001	2.608
	Switzerland	0.050	0.009	0.002	0.135	-	0.194	-	0.295	0.030	-	0.014	0.008	0.739
	Slovenia	0.032	0.007	0.011	0.014	-	0.829	-	0.048	0.061	-	0.002	0.005	1.009
	Hungary	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Netherlands	0.169	0.028	0.015	0.017	-	0.443	-	1.589	0.051	-	0.065	0.000	2.377
office	Belgium	0.743	2.235	0.002	0.045	-	0.163	-	0.001	0.138	-	0.001	0.093	3.423
	Switzerland	0.026	0.007	0.006	0.012	-	0.024	-	0.092	0.325	-	0.023	0.074	0.589
	Slovenia	0.065	0.031	0.002	0.002	-	0.591	-	0.005	0.336	-	0.003	0.010	1.047
	Hungary	0.073	0.028	0.010	0.036	-	0.131	-	0.036	0.007	-	0.007	0.022	0.350
	Netherlands	0.006	0.008	0.003	0.003	-	0.002	-	0.021	0.316	-	0.003	0.005	0.366
train	Belgium	0.057	0.013	0.004	0.006	-	0.100	-	0.026	0.004	-	0.004	0.006	0.221
	Switzerland	0.004	0.007	0.002	0.018	-	0.249	-	0.188	0.011	-	0.014	0.012	0.505
	Slovenia	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Hungary	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Netherlands	0.149	0.056	0.003	0.012	-	0.035	-	0.052	0.003	-	0.007	0.000	0.316
	Belgium	0.312	0.044	0.003	0.026	-	0.255	-	0.066	0.029	-	0.017	0.001	0.753
	Switzerland	0.012	0.023	0.003	0.026	-	0.178	-	0.140	0.020	-	0.012	0.007	0.422

car/bus	Slovenia	0.038	0.007	0.002	0.005	-	0.449	-	0.029	1.406	-	0.001	0.014	1.952
	Hungary	0.101	0.016	0.013	0.020	-	0.662	-	0.074	0.078	-	0.026	0.009	0.998
	Netherlands	0.105	0.112	0.010	0.019	-	0.050	-	0.144	0.006	-	0.013	0.008	0.468
urban-home	Belgium	0.242	0.359	0.010	0.009	-	0.133	-	0.001	0.001	-	0.001	0.070	0.827
	Switzerland	0.023	0.008	0.006	0.020	-	0.034	-	0.068	0.259	-	0.007	0.009	0.435
	Slovenia	0.040	0.007	0.009	0.009	-	0.157	-	0.005	0.086	-	0.001	0.010	0.325
	Hungary	0.078	0.031	0.015	0.024	-	0.065	-	0.011	0.070	-	0.015	0.032	0.341
	Netherlands	0.012	0.008	0.003	0.003	-	0.005	-	0.014	0.002	-	0.002	0.022	0.070

NA = not available

FM = frequency modulation, DAB = Digital Audio Broadcasting, DECT = Digital Enhanced Cordless Telecommunications, DL = downlink, GSM = Global System for Mobile Communications, GSM900 = GSM at 900 MHz, GSM 1800 = GSM at 1800 MHz, TETRA = Terrestrial Trunked Radio, TV = television, UMTS = Universal Mobile Telecommunications System, UL = uplink, WiFi = wireless ethernet for Wireless Local Area Networks

TABLE 2

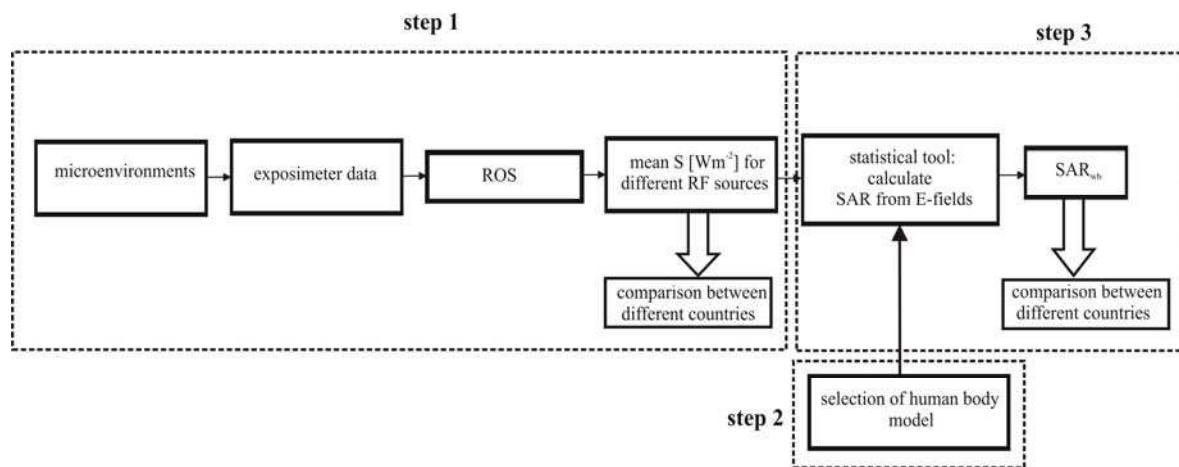


Figure 1

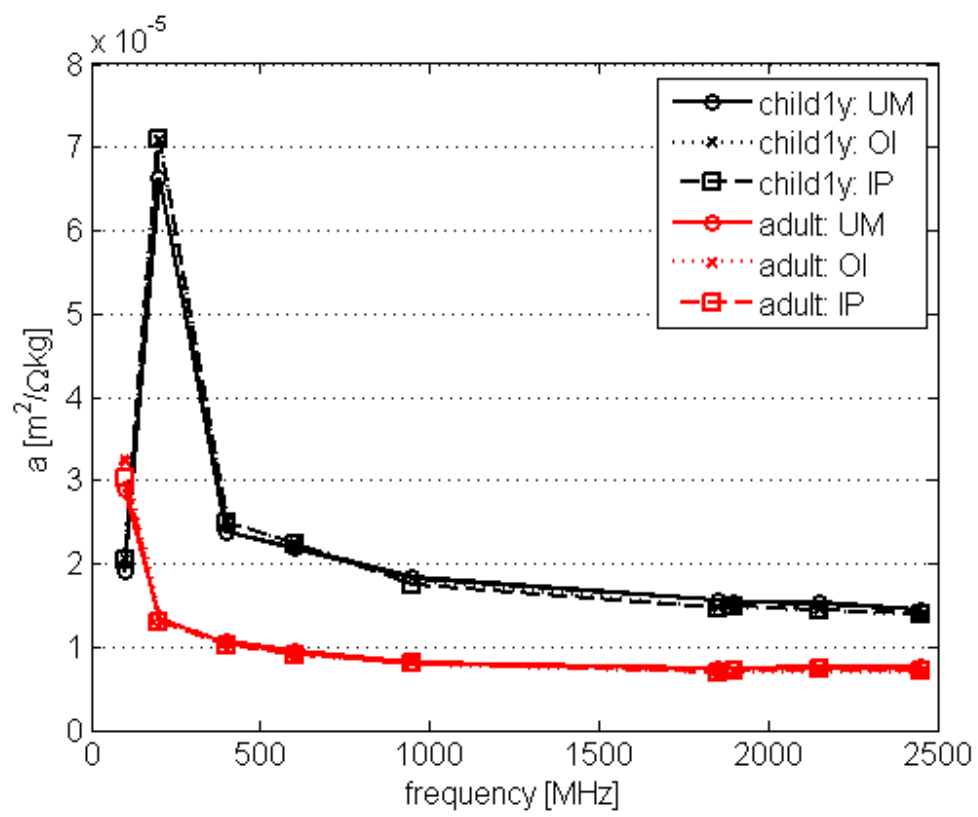
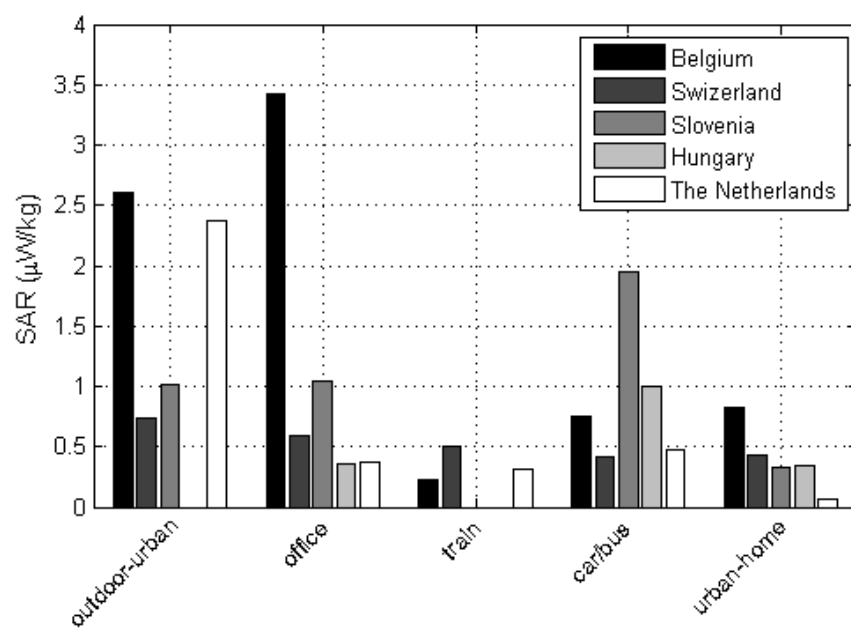
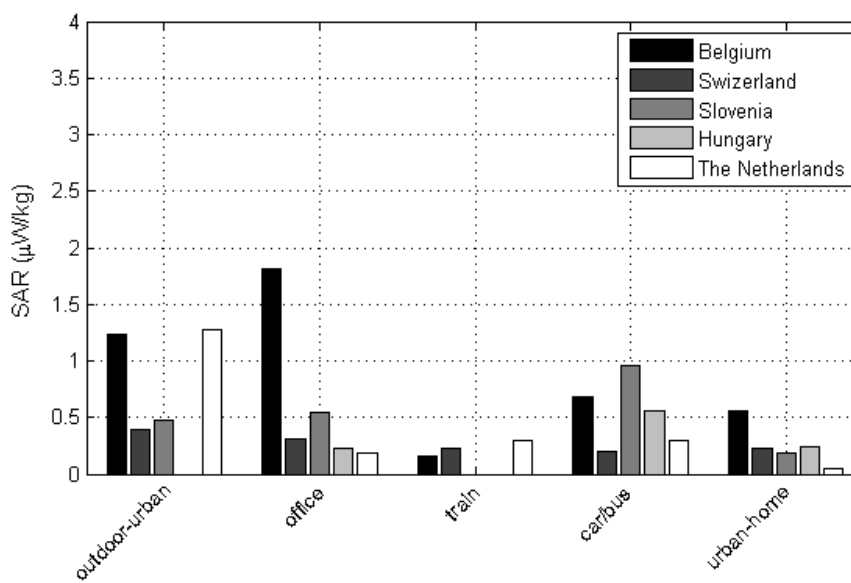


Figure 2



(a)



(b)

Figure 3

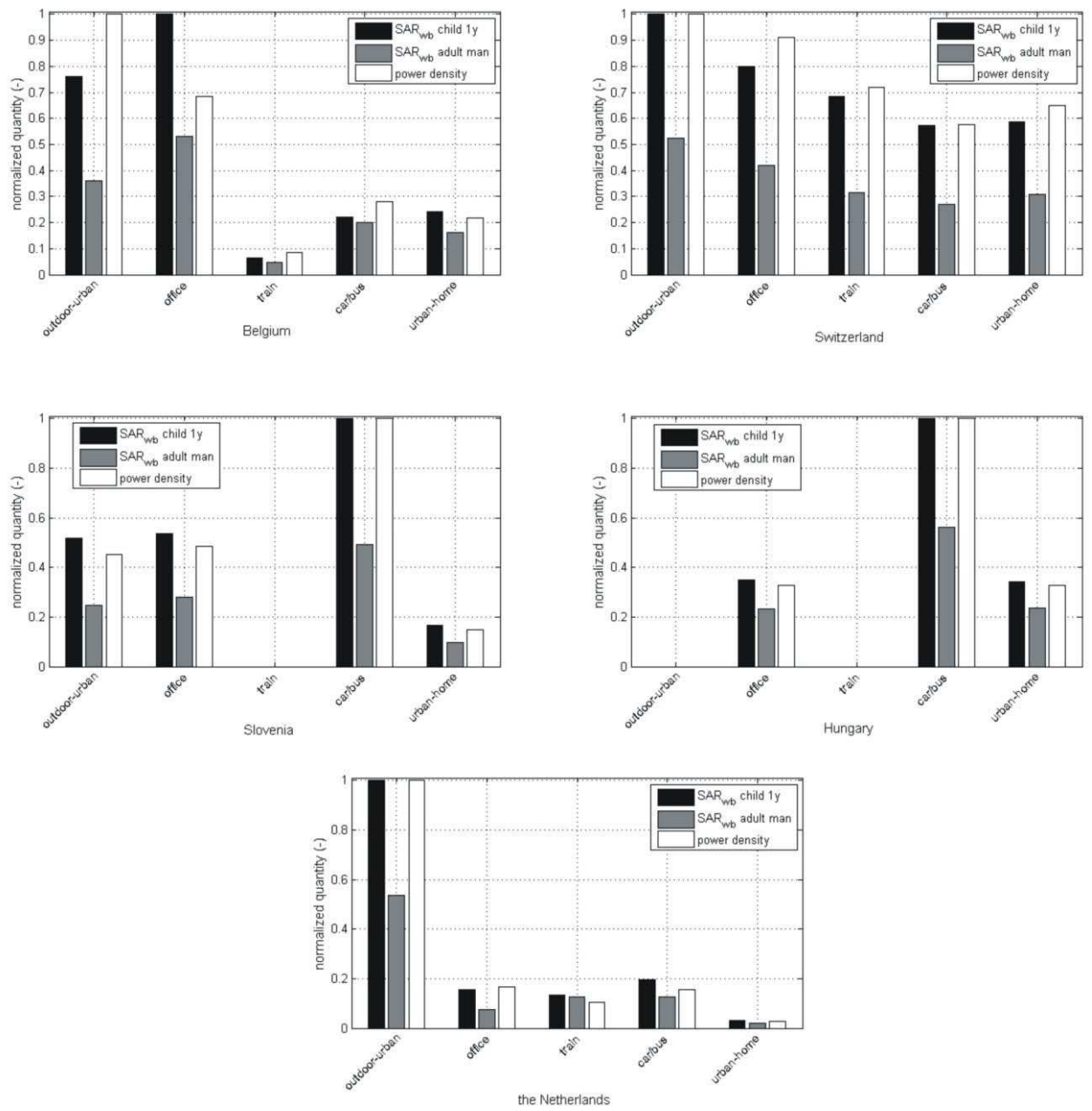


Figure 4

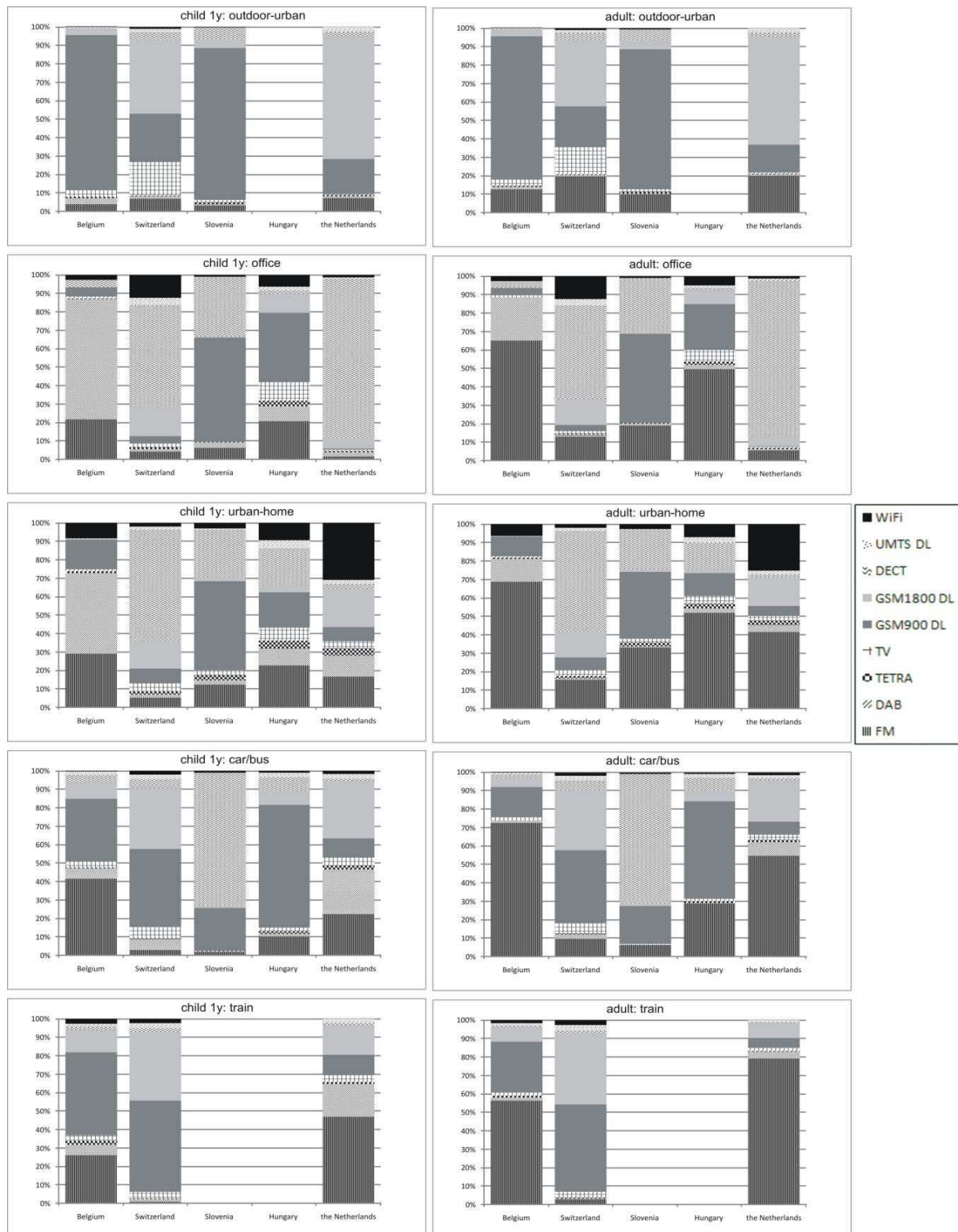


Figure 5