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Measurements and Analysis of Personal Exposure to Radiofrequency Electromagnetic Fields at Outdoor and Indoor School Buildings: A Case Study at a Spanish School

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ABSTRACT Personal exposure to Radiofrequency Electromagnetic Fields (RF-EMF) has increased due to the development of a society of information and the implementation of new technologies. Most studies about RF-EMF are focused on adult exposure in different microenvironments, but these studies do not usually consider places where children are exposed. We present results of measurements and analysis of personal exposure to RF-EMF at outdoor and indoor school buildings, at a Spanish school, a place where children and employees spend a significant time period and are exposed to RF-EMF. The highest exposure levels were recorded inside school buildings during the week, and around the school area during the weekend. Our measurements show that levels of RF-EMF intensity from Wi-Fi band registered around school area are affected by Wi-Fi from neighbors of residential areas. Exposure levels from Wi-Fi band and mobile phone antennas are below reference levels established by international guidelines.

INDEX TERMS Radiofrequency electromagnetic fields (RF-EMF), Wi-Fi, personal exposure, spot measurements, outside and inside school.

I. INTRODUCTION

In the last two decades, personal exposure to Radiofrequency Electromagnetic Fields (RF-EMF) has increased. Among the main emission sources, mobile phone and Wi-Fi antennas are the most numerous and they have been subject to multiple studies [1]–[7]. Consequently, society's concern about possible effects on our health has increased as well. This in turn has led to a rise in discussions about the possible negative effects that RF-EMF could have on our health [5], [8]–[15].

In order to study such potential health effects, RF-EMF exposure assessment is a crucial step. Previous studies have focused on different objectives and therefore have used different methodologies for exposure assessment. Some studies have carried out intermittent measurements outdoors and indoors, during daily activities [5], [6], [16]–[20]. Other studies have compared levels of RF-EMF exposure in different areas and moments of the day [21], [22] and have compared those levels with maximum levels allowed by international guidelines [23]. Several studies have also measured exposure levels and determined contributions from different sources [5], [9], [24]–[26], through monitoring of exposure levels in microenvironments with the participation of volunteers [13], [27]–[31], or specific measurements carried out by a researcher [10], [14], [32]–[37].

Personal exposimeters are a convenient measurement device to execute such measurements. They have been used to measure personal exposure to RF-EMF in different microenvironments [11], [13], [17], [29], [30], [38]–[40]. One advantage of personal exposimeters is that they provide frequency-selective exposure values. Therefore, previous studies have used these devices to examine personal exposure according to the frequency band that generated it [14], [23], [31], [35], [41]–[43]. In these studies, exposure

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levels obtained were compared with levels determined by international guidelines and they were found to be below levels established by the said guidelines [44], [45].

International Commission on Non-Ionizing Radiation Protection (ICNIRP) [45] together with World Health Organization (WHO) and Institute of Electrical and Electronics Engineers (IEEE) [46]–[48] have issued a series of guidelines of exposure, establishing limits of the different types of non-ionizing radiation and these guidelines are in turn used to develop legislation. In addition, IEEE Standard C95.1-2005 Standard [49] provides levels of occupational and general public exposure, occupational limits generally being five times higher than those of the general public.

ICNIRP establishes that reference levels for the intensity of wave frequency between 2 and 300 GHz are 50 W/m^2 for occupational exposure and 10 W/m^2 for general population exposure [44], [45]. These standards are periodically reviewed and updated, considering new technological implications for exposure to RF-EMF, and including possible effects and health risks. A revised version of these limits appeared in 2019 for IEEE C95.1-2019 Standard [47], and a new version of ICNIRP guidelines was published in March 2020 [44]. Reference levels for whole body exposure should be averaged over a 30-minute interval, while for local exposure reference levels should be averaged over a 6-minute interval. About localized exposures, ICNIRP Guidelines separate exposure longer than 6 minutes from exposure lasting less than 6 minutes, to protect against exposures due to non-continuous signals such as the ones produced by a 5G beamforming.

Among these studies, we find Foster and Moulder's [50], which reviews the state of the investigation about possible effects of Wi-Fi-generated exposure on our health, concluding that results are below international restrictions. A study by Khalid *et al.* [51], in which six primary and secondary schools are monitored, all results show exposure levels below the allowed limits. On the other hand, there are many related studies about RF-EMF considering children [8], [9], [52]–[58].

A study by Pall [59] presents a review of seven effects of Wi-Fi networks on animal and human cells. In this work it is stated that repeated studies show that Wi-Fi causes oxidative stress, damages sperm, alters encephalograms, causes damage to DNA, produces changes in the endocrine system and overloads calcium ion concentrations in our organism, blocking its ionic channels [60]. In another published work, Russell [61] says that a new industrial revolution is taking place in telecommunications, and therefore the population will suffer an increasing exposure to higher frequencies of the electromagnetic spectrum.

In Table 1, we highlight some studies with results obtained from the Wi-Fi band, which are compared with our results and commented on in the discussion section.

Wi-Fi 5G technology needs to use higher frequencies to feed Internet of Things (IoT), which needs a continuous and massive interconnectivity. As regards the current controversy about possible harmful effects of present-day 2G, 3G and

TABLE 1. Results from studies that considered measurements from Wi-Fi band.

Publication	Countries and microenvironments measured	Mean ($\mu W/m^2$)
Röösli et al., 2010 [26]	France (all environments)	1.92
Vermeeren et al., 2013 [58]	Belgium (Schools area)	3.32
	Greece (Schools area)	10.7
Verloock et al., 2014 [35]	Belgium (School area)	306.6
Valic et al., 2015 [62]	Slovenia (all environments)	4.77
Hardell et al., 2017 [63]	Sweden (School)	3.32
Bhatt et al., 2017 [52]	Australia (kindergarten area)	84.9
Aminzadeh et al., 2016 [41]	Belgium (office indoor, urban)	38.3
Gonzalez-Rubio et al., 2016 [10]	Spain (outdoor)	0.53
Roser et al., 2017 [64]	Switzerland (all environments)	1.19
Hedendahl et al., 2017 [65]	Swedish (outdoor, old town)	0.13
Gallastegi et al., 2018 [9]	Basque Country (School area)	81.1
Birks et al., 2018 [8]	Denmark (all environments)	1.19
	Netherlands (all environments)	1.19
	Slovenia (all environments)	0.53
	Switzerland (all environments)	0.53
	Spain (all environments)	6.50
Massardier-Pilonchery et al., 2019 [12]	France (all environments)	0.15
Ramirez-Vazquez et al., 2020 [14]	Jordanian (university area)	28.8

4G wireless technology, we must now add 5G technology, whose effects on the environment and on humans have not been widely studied. We must try to clarify if these high frequency 5G electromagnetic waves, together with a complex combination of lower frequencies, have any negative effect on public health, both from a mental and a physical perspective. We are now before the first generation of people who will live their whole lives (from birth to death) immersed in a sea of radiofrequency waves generated by humans. Years or decades will pass before the real consequences for our health are known [61].

As a consequence of what was previously commented, the use of Wi-Fi networks for educational purposes has increased in recent years. This type of communication is produced by radiofrequency, which leads to exposure of people

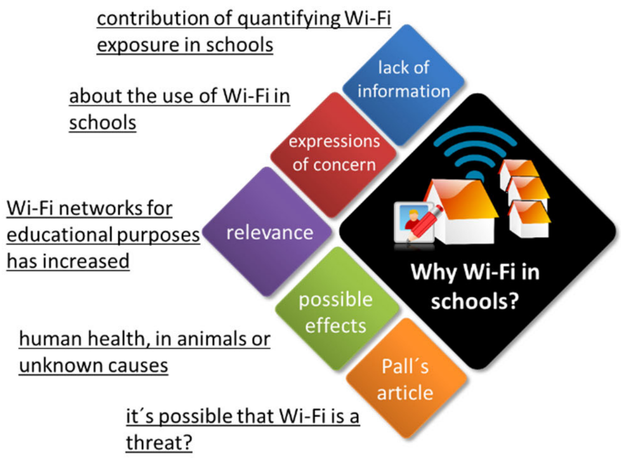

FIGURE 1. Reasons for Wi-Fi measurements at school.

near these fields. A lack of information and concerns about this issue has led us to carry out this study (Figure 1).

The objective of this study is to measure RF-EMF exposure of children in school areas, where children are exposed for a significant time period to RF-EMF. We select an area at Antonio Machado School, located in Albacete, outside and inside school buildings; with the purpose of finding out levels of personal exposure to radiofrequency electromagnetic fields from Wi-Fi antennas that reach this sensitive area, and comparing them to levels established by international guidelines for sensitive areas and for the general population. Additionally, we have identified differences between personal exposure to RF-EMF that is received inside and outside school buildings, and sources generating exposure.

II. METHOD

A. STAGES OF THE STUDY

This study was developed in six stages, directly related to the objectives stated above (Figure 2). Firstly, a protocol for measuring personal exposure to RF-EMF at Antonio Machado School in Albacete was developed. Secondly, the measurement area was analyzed, and a measurement plan was developed. Thirdly, measurements took place on site, in the different selected points, around school area and inside school buildings. Later, statistical analyses of data resulting from measurements were carried out, together with georeferentiation and interpolation of the results obtained in each of the measured points, allowing us to elaborate maps of intensity of personal exposure.

Stage 1: Designing the measuring protocol.

Drawing up the protocol that measures personal exposure to RF-EMF, a protocol that was adhered throughout the study.

Stage 2: Selecting the area and the main measuring points.

For selection of the area of study for on-site measuring, Google Earth and Maps were used (Figure 3).

Once selected, ten points in which carrying out measurements were identified, from A to J point (Figure 3), around

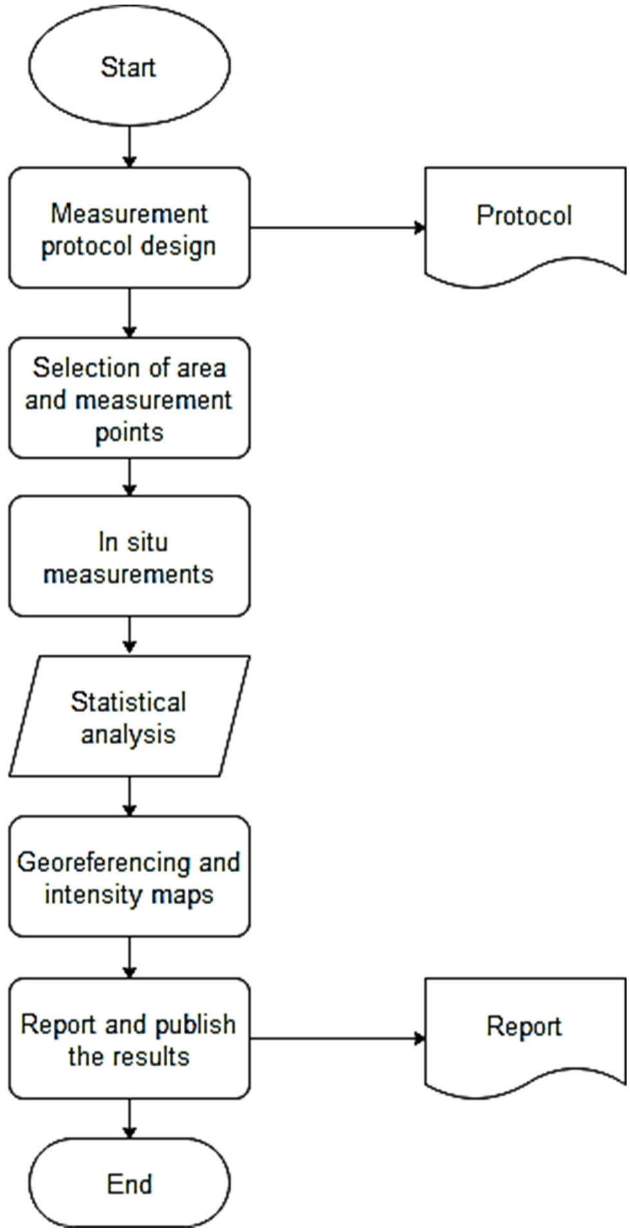

FIGURE 2. Stages of the study.

school area, and the coordinates were then obtained through Google Earth, coordinates that were used in stage 5 to georeferenced data.

This measurement methodology around the school area was designed and applied in order to estimate exposure within the school area. Apart from the selected points around the school area, we selected 7 points (1 to 7 point), located inside the building, where children and employees spend most of the time (Figure 3).

In addition, we applied for the necessary permission from school authorities, and we were authorized to carry out measurements on the week and on the weekend, from 10.00 to 11.00 am.

Stage 3: Measuring personal exposure to RF-EMF.

Measurements were performed for a period of six minutes at each point (ICNIRP reference). The exposimeter was set

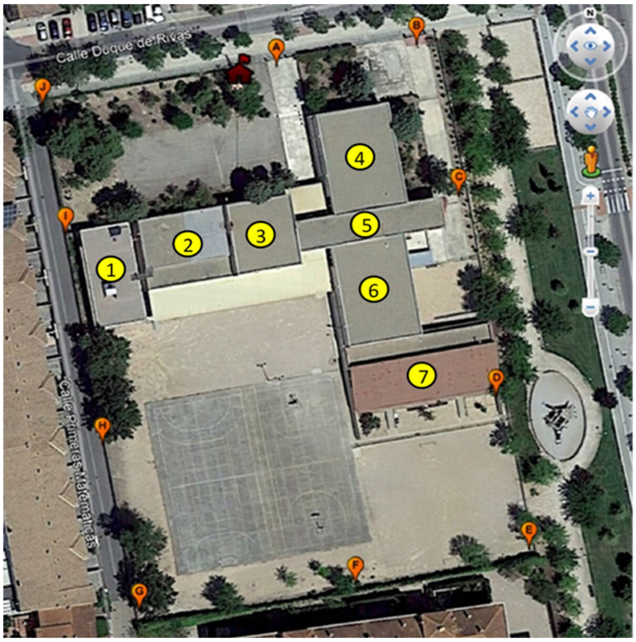

FIGURE 3. **Points measured at Antonio Machado Public School (around the school area: A-J and inside school buildings: 1-7).**

FIGURE 4. **Personal exposimeters EME SPY 140 (Satimo) attached to a cardboard tube ready to carry out the measurements.**

to take measurements every 5 seconds, obtaining a total of 72 measurements per point.

Measurements registered during the movement from one point to another were discarded. A 1.5-meter long cardboard tube was prepared, and the two exposimeters were attached onto it, so that the measurements could take place above the researcher's head (Figure 4) [14], [66].

This approach is used to avoid underestimation of measured exposure due to body shadowing [67], and to show personal exposure received around or inside and outside school area (Figure 5).

After selecting the area and the points, as well as the equipment, we proceeded to set the exposimeter and to check that it was switched on and in working order. We then reached the measuring point, taking care to keep the equipment above the researcher's head. When measuring time (6 min) was over at each point, a mark was made by pressing the exposimeter on button. These measurements were carried out on the week, when the school was full of children, and on the weekend,

FIGURE 5. **Research group member with the two exposimeters used during the measurement process.**

when the school was empty, in order to compare results obtained at those scenarios.

Stage 4: Data processing and Statistical analysis.

Registered measurements were downloaded using EME Spy Analysis 3.20 software, they were then exported to Excel, later the data cleaning was done, and we proceeded to statistical analysis. Only measurements registered within the 6-minute range were selected, obtaining a total of 72 measurements at each point, for each day measured (week and weekend).

Measurements were carried out with two devices, if we find differences in the measurements recorded by each exposimeter, we will calculate the average for both exposimeters and they will be presented separately.

The electromagnetic wave intensity was represented in W/m^2, taking into account the Wi-Fi band and mobile phone bands.

Stage 5: Georeferencing and elaborating a map of intensity.

Geographical location of the points measured through Google Earth was identified, UTM (Universal Transverse Mercator) coordinates were obtained and then used for georeferencing the points on the school map, around the area. Then, using ArcGIS, maps of RF-EMF intensity were defined, making use of the interpolation tool named Kriging method, separating morning and afternoon measurements [68]. This method was used with the aim of verifying the approximate RF-EMF exposure level in the school area selected. Personal exposure levels to RF-EMF presented in this work, were gathered from measurements performed in the selected points outside and inside school buildings.

Stage 6: Report and publish the results

When the statistical analysis, the drawing up of graphs and the maps of intensity were concluded, a report was made revealing the comparative analysis with reference levels established by international guidelines, for urban outer and inner areas of sensitive places (schools, medical centers, old-people home and hospitals), and the report was delivered and communicated to the school management.

B. EXPOSIMETER

The personal exposimeter used to carry out measurements was EME Spy 140 of Satimo (Figure 4 and 5). This device can

TABLE 2. Measured frequency bands of the EME SPY 140 exposimeter.

Band	Description of Frequency bands	Frequency (MHz)
FM	FM radio signal	88 – 108
TV3	Television signal	174 – 223
TETRA	Mobile communication for closed groups	380 – 390
TV4&5	Television signal	470 – 830
GSM UL	Transmission from a mobile phone to a base station	880 – 915
GSM DL	Transmission from the base station to a mobile phone	925 – 960
DCS UL	Transmission from a mobile phone to a base station	1710 – 1785
DCS DL	Transmission from the base station to a mobile phone	1805 – 1880
DECT	Digitally enhanced wireless telecommunications	1880 – 1900
UMTS UL	Transmission from a mobile phone to a base station	1920 – 1980
UMTS DL	Transmission from the base station to a mobile phone	2110 – 2170
Wi-Fi 2G	Wireless local area network	2400 – 2500
WiMAX	Worldwide interoperability for microwave access	3400 – 3800
Wi-Fi 5G	Wireless local area network	5150 – 5850

measure up to 14 frequency bands (from 88MHz to 5GHz), and shows, separately, the contribution of each emission band (Table 2). It registers up to 12,540 measurements in periods of time from 4 to 255 seconds, and they can be selected according to the circumstances in which one wishes to measure.

The minimum value detected by the exposimeter in each frequency band is, in FM: 6.631 $\mu W/m^2$; TETRA, TV4 and 5: 0.265 $\mu W/m^2$; GSM, DCS, DECT, UMTS, Wi-Fi 2G: 0.066 $\mu W/m^2$; and in TV3, WiMAX, Wi-Fi 5G: 1.06 $\mu W/m^2$.

After the release of the first digital dividend, the 800 MHz band was no longer used for TDT transmission and has been assigned to mobile phone operators to provide fourth generation (4G) broadband services [69].

Out of the 14 frequency bands measured by the exposimeter, in this study results are presented from Wi-Fi band and mobile phone bands: GSM DL, DCS DL, UMTS DL. The exposimeters were attached to a 1.5-meter cardboard tube. The selected area was covered on foot and the researcher remained six minutes in each of the selected measuring points (Figure 5). An additional exposimeter was used for validation purposes [70]. The advantage of using two exposimeters was to minimize the effect on the body of the exposimeters when held above the person's head (Figure 4 and 5), this way we can get to know exposure levels directly from a person.

To know the values of non-measured areas, we used a method of interpolation for geographical information systems, named Kriging, through which the non-measured area values were obtained, and throughout the intensity map, we observe the whole study area. In addition to punctual measurements performed around the school or buildings area, (around or outer points: A-J); it was possible to know the approximate values for the selected points inside the building, these ones being also measured (inside points: 1-7), at their location. The following software was used: ArcGIS version 10.7, software EME Spy Analysisv3.20, Excel, and IBM SPSS Statistics 22.

TABLE 3. Personal exposure to RF-EMF from the Wi-Fi band outside the school building (the highest points for each period are in bold).

Points	Average personal exposure for the Wi-Fi band (μW/m²)	
	Weekend	Week
A	0.93	1.07
B	1.03	0.61
C	1.51	0.89
D	1.57	5.77
E	1.63	0.93
F	28.5	38.0
G	38.3	5.37
H	**121**	35.4
I	1.81	**38.6**
J	7.90	3.82

TABLE 4. Personal exposure to RF-EMF from Wi-Fi band inside the school building (the highest points for each period are in bold).

Points	Average personal exposure of the Wi-Fi band (μW/m²)	
	Weekend	Week
1	**28.1**	**33.1**
2	25.5	29.3
3	16.3	23.5
4	13.9	19.6
5	13.3	19.3
6	20.1	25.4
7	19.6	26.8

III. RESULTS

This work shows results of personal exposure to RF-EMF from the Wi-Fi band, for each of the points measured, for each period (Table 3 and Table 4). We have also included results from the mobile phone antenna, and a total of 14 bands measured by the exposimeter, for each period (Table 3). Results are expressed in $\mu W/m^2$.

Table 3 shows results for RF-EMF intensity from the Wi-Fi band, registered at each point and for each period measured (Figure 6a and 6b), around the school area.

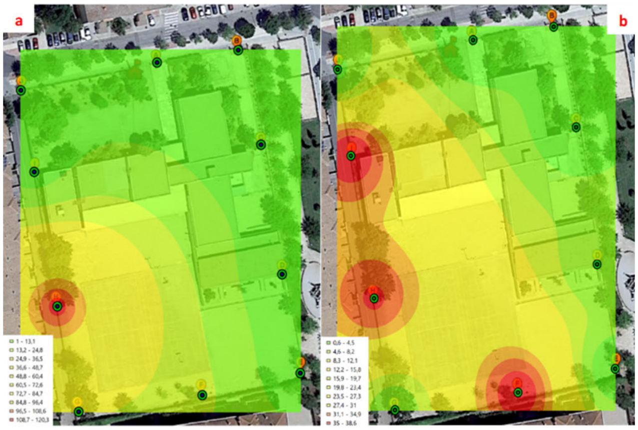

FIGURE 6. **Personal exposure to RF-EMF from Wi-Fi. a) on the weekend and b) on the week (around the school area).**

Weekend measurements registered the maximum value of 121 $\mu W/m^2$, at H point and for the week measurements the maximum value registered was 38.6 $\mu W/m^2$ at I point, showing that a higher exposure occurred on the weekend. The coordinates for each point measured were georeferenced using Google Earth, which led us to the graphic representation through maps of intensity (outer area) using ArcGIS (Figure 6a and 6b).

In Figure 6a and 6b, we can see the maps of intensity in which the values for each point and period are shown, recorded in the Wi-Fi band, around the school area. The points in red are the points that registered a higher intensity. If we compare intensity levels registered on the weekend and during the week, we observe that levels are higher on the weekend, due to the fact that Wi-Fi from neighbors contributed the most to the points located around the school area (buildings).

As well as this, we identified that the intensity was higher near our area of study, and there is a residential area with antennas for wireless connection, which also have an effect on measurements (Figure 7).

As indicated in the method section, in addition to intensity levels measured around the school area, we have measured personal exposure levels to RF-EMF inside the building, figures that we can see on Table 4. It is at these points that students and employees spend most of the time and they are connected to the closest Wi-Fi router.

When comparing results for exposure inside the school buildings, on the weekend and on the week, we can observe that intensity levels are higher during the week, and the opposite situation happens when comparing intensity levels around the school area, because higher values are registered during the weekend. This is due to the fact that students and employees spend most of the time inside the school buildings, and the devices connected and used in the schools are active during the week (Table 4 and Figure 8).

However, when comparing exposure levels registered around the school area (Table 3 and Figure 8), where higher values are gathered on the weekend, we have identified that

FIGURE 7. **Study area and points markers with residential areas near at the school.**

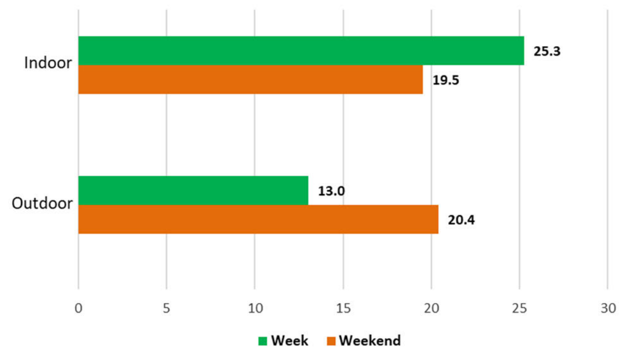

FIGURE 8. **Average exposure to RF-EMF from Wi-Fi around the school area and inside school buildings ($\mu W/m^2$).**

Wi-Fi sources contributing the most come from the residential area, since neighbors are connected and using their electronic devices and Wi-Fi band on the weekend, whilst they are at work and out of home during the week.

In addition to the measurements registered for Wi-Fi band, in Table 5, we can see results for RF-EMF intensity from mobile phone bands.

We compared results of personal exposure to RF-EMF, with reference levels both for occupational health exposure (50 W/m^2) and general public exposure (10 W/m^2), established by ICNIRP [44], [45]. Apart from comparing our results with international guidelines, we have done it with

TABLE 5. Personal exposure of contribution from mobile phone bands by measurement periods (mean in μW/m²).

Mobile phone bands	Frequency (MHz)	Personal exposure in μW/m²	
		Weekend	Week
GSM DL (Global System for Mobile Communications)	925 – 960	89.9	300
DCS DL (Digital Communications System)	1805 – 1880	63.4	96.2
UMTS DL (Universal Mobile Telecommunications System)	2110 – 2170	99.2	214

a regional law published in 2001, specifically, in Castilla-La Mancha, Spain, the exposure limit is 0.1 W/m^2 in urban areas, independently of the frequency, and for sensitive indoor areas the allowed maximum level for mobile phone frequency (GSM, DCS and UMTS) is 0.001 W/m^2 [71], identifying that values obtained are below established limits, and therefore they are within the guidelines.

A detailed analysis of the results was carried out and we investigated why the values for each period increased or decreased, both for Wi-Fi and mobile phone bands.

In the case of the Wi-Fi band, the highest values measured were at H and I point, on a weekday and on the weekend, the weekend being the one with a higher value. However, for the mobile phone bands, a higher average was taken on a weekday. We found out that one reason was that during school hours there is a high number of mobile phones in use, making use of the Wi-Fi band. Teachers also access Wi-Fi band with their smartphones and laptops.

To sum up, we would like to point out that the highest average from Wi-Fi band was registered on the weekend, due to the use of Wi-Fi band made by the residents of the area around the school. The highest average originating from the mobile phone bands was registered on a weekday, owing to the use of the bands by the school community: pupils, teachers, and administrative staff (employees).

IV. DISCUSSION

There are three wireless networks in the school, for use of students, teachers, and school management (employees). These three networks pervade not only the school building but also its surrounding areas, as we will now see. Wi-Fi antennas inside schools are usually placed in corridors, offices, or laboratories to permit that a good signal is received throughout the area. It is known that walls weaken the signal, so the higher number of walls the weaker the signal. In addition, Wi-Fi antennas operate on low power, between 0.1 and 1 W with a frequency between 2.4 and 5 GHz. For this reason, the signal outside the school area is expected to be weak. However, the highest values from the Wi-Fi band have been obtained at H and I point, even G point (especially at H point on the week). We may wonder the explanation for these data. We will now try to answer this question.

As we can see in Figure 6a and 6b, G, H and I point are near single-family houses, most of which have internet access with an optic-fiber cable and through a modem create wireless networks inside each house. This is usual in the single-family houses, where part of Albacete's middle-class families live. Electromagnetic waves from these wireless networks pervade the whole house and reach the area outside, though weakened by the walls. This may explain why at these three points (especially at H point) exposure to Wi-Fi band is higher.

Looking into this in detail, during the weekend H point has an intensity of 121 μW/m^2, which is the highest value measured for this band, followed by its neighboring G, with a value of 38.3 μW/m^2. An explanation for this is that in the house opposite H point there is a higher activity in the Wi-Fi band than in the houses closer to other points. In fact, in that house on the particular weekend, where the measurement was taken, there was considerable traffic in the wireless connections.

During the week when the measurements were taken the situation changes. There are three points with very similar intensities and much higher than the rest. They are F, H and I point, with respective intensities of 38.0 μW/m^2, 35.4 μW/m^2 and 38.6 μW/m^2. The values are practically the same and must correspond to houses in which some activity in the Wi-Fi networks was taking place at the moment of the measuring, together with the activity from the school modem.

We would like to point out the following fact: I and H point are in the school, but nearby there are a number of houses, on Primeras Matemáticas Street, particularly 8 and 20 number. In this space there are more than 20 wireless networks detected by our smartphones. These networks come also from other houses on Historia Street, parallel to the one mentioned before. They are the Wi-Fi networks of the people who live in these houses and who use the networks on demand, that is to say, they only send out or receive when there is some kind of information request, when they access the internet, for example, to download files or use an application that generates wireless traffic.

During the weekdays at the times the measurements were carried out, there was a little traffic in those Wi-Fi networks because most people from the houses in the area were away in their normal daily activities (work, school...). However, on the weekend, when people stay at home for longer time periods, the Wi-Fi activity is higher and there was a higher demand of wireless services. This explains why the highest value measured from the Wi-Fi band was at H point, this value being 121 μW/m^2 registered on the weekend. Intensity levels registered inside the school building are not affected by Wi-Fi connections from the residential area, as commented on in results section. The higher values were registered during the week, both values coinciding at 1 point with 28.1 μW/m^2 on the weekend and 33.1 μW/m^2 on the week, due to the fact it is inside school buildings that both students and employees

TABLE 6. Measurements taken at Machado School at 6 am on a weekday.

Points	Average Wi-Fi band (μW/m²)
G	3.35
H	24.4
I	13.3
J	2.10

spend most of the time being connected and making use of their electronic devices.

With the purpose of knowing the influence of intensity levels from the points with the higher values found near the residential area, we carried out measurements at G, H, I and J point on a weekday, at 6 am, when it is supposed that people will not be using the Wi-Fi network (except for a possible download of a big file). We chose 6 am because we wanted to be sure that most people at home would be still asleep and wireless services would not be requested. When we compared these measurements, we identified that intensity levels were lower, leading to the explanation that neither the Wi-Fi networks from the houses nor the school Wi-Fi networks were in use at the same time (Table 6).

For future works in this field, we would recommend that a monitoring of the devices used by students and employees should be carried out, in order to find out if these devices are being used or are switched off during school hours. It would also be useful to know the number of devices and Wi-Fi repeaters that are in use in the school when there are people inside and when the school is empty.

In reality, this is difficult to achieve because we would be close to crossing the limit where privacy is concerned, and privacy is something that every scientific experiment should respect. Nevertheless, it is likely that someone could be using a Wi-Fi network for an activity and they do not wish to become known. Additionally, it could be measured inside and outside in other schools in the same city in order to compare results.

Finally, if we compare our results obtained in the Wi-Fi band, average exposure to Wi-Fi band around the school area and inside school buildings (20.4 $\mu W/m^2$ on the weekend and 13.0 $\mu W/m^2$ on the week, and 19.5 $\mu W/m^2$ on the weekend and 25.3 $\mu W/m^2$ on the week, respectively) with results of other studies about Wi-Fi in schools and some microenvironments [8]–[10], [12], [14], [26], [35], [41], [52], [58], [62]–[65], we can find that our results are similar to some of them (Table 1), and below that the international guidelines [43], [44].

Measurements were carried out with two devices, but we did not find differences between measurements recorded by each exposimeter.

This study was carried out on a school located in a medium-sized Spanish town, and the information provided is a picture of the situation in the said school. We found interesting to carry out these measurements outside the school area and inside school buildings because, as observed, both kids and employees were exposed to different intensity levels, given that Wi-Fi bands from neighbors contributed as well. In the future, we intend to reproduce the same study in more schools to perform a comparative study and identify if there are significant differences between schools, in addition to verifying if international guidelines are complied.

V. CONCLUSION

This study investigated levels of personal exposure to RF-EMF at Antonio Machado School, in Albacete, Spain. On the one hand, average exposure to Wi-Fi on the weekend was 20.4 $\mu W/m^2$ and on the week 13.0 $\mu W/m^2$, around the school area. There is a difference between the two periods, due to the fact that the Wi-Fi used the most on the weekend is that of the neighbors who are resting in the residential areas. Average exposure to Wi-Fi inside school buildings was 19.5 $\mu W/m^2$ on the weekend and 25.3 $\mu W/m^2$ on the week, intensity levels being higher during the week, due to the fact that students and employees spend most of the time connected to Wi-Fi with their electronic devices.

On the other hand, if we compare measurements recorded by telephone antennas, we identify that the highest value on the weekend was 99.2 $\mu W/m^2$ from UMTS DL band (Universal Mobile Telecommunications System), and during the week it was 300 $\mu W/m^2$ from GSM DL band (Global System for Mobile Communications). In the light of these results, we can clearly observe that it is during the week that the use of smartphones and the connection is more frequent.

When we compare results obtained with reference levels allowed by regional, national and international guidelines, we have identified that intensity levels for RF-EMF originated from Wi-Fi and mobile phone antennas are below legal limits, and thus they conform to regional, national and international guidelines both for urban and sensitive areas.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

All authors contributed equally to this work.

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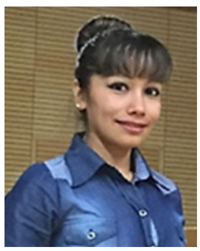

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