SECTION 5

ESTIMATES OF EXPOSURE PARAMETERS OF THE GENERAL POPULATION

5.1 Sample Unit Weight

In order to generate representative sample estimators of the general population, each participant was assigned a weight that takes into account the chance of selection of the person in the sample, and the refusal rate for each group of people in the sample. This weight can be interpreted as the number of persons in the population that the sample person is "representing". Sample estimators which are computed using these weights are "unbiased" (see footnote) estimators of the corresponding population totals of interest.

The sampling weight for each sample person with usable data is a product of four components: SW = (telephone sample weight factor) × (household weight factor) × (non-response adjustment factor) × (calibration adjustment factor*). The telephone sample weight is the inverse of the probability of selection of the household's telephone number from the random digit dialing telephone sample frame. The telephone sample weight factor is equal to 23,350 for all sample units (i.e., each household represents 23,350 other telephone households whose telephone numbers were not drawn). The household weight factor is the number of persons in the household (i.e., this factor equals 1, 2, 3, ...). The randomly sampled person in each household "represents" with this weighting adjustment the other household members not selected into the household sample.

The non-response adjustment factor consists of two components: a non-response adjustment for households in the sample which were not recruited into the survey, and a non-response adjustment for persons who were sent monitors, but did not return them or returned unusable data. Each of the two non-response adjustments are equal to the reciprocal of the response rate for the response subgroup in which the sample person belongs.

The list of sample unit weights is shown in Appendix B, Table B-4. An estimator of the general population, for instance the arithmetic mean value, B_{Mean}, of the 24-hour averages of all the people of the U.S., is calculated using the weights, w_i (i=1, 1012), as follows:

$$B_{Mean} = \frac{\sum_{i=1}^{1012} w_i b_{i,24-hour}}{\sum_{i=1}^{1012} w_i} \qquad (5.1)$$

where $b_{i,24\text{-}hour}$ is the 24-hour average field measured for the person i.

* Footnote: The calibration adjustment factor is set so that the final weight SW across the sample units aggregates to Current Population Survey national population totals by age, sex, household size, and geographic location. These adjustments reduce the sampling variance for estimators which are correlated in the population to these socio-demographic variables.

5.2 Estimate of the Distribution of the 24-Hour Average Magnetic Field

The distribution of the 24-Hour Average Magnetic Field for the U.S. population from which the surveyed sample was extracted is described by the data in Tables 5.1 and 5.2, and by the curve of Figure 5.1. Figure 5.2 is the same as Figure 5.1, but with an expanded scale of the percentage of persons, in order to show in details the high field portion of the distribution curve. Of the 1012 participants, 986 had valid data for an entire 24 hour (1440 minute) period. The other 26 participants had data valid for periods less than the full 24 hours, 21 of them had more than half a day of data and 9 had more than three quarters of a day of data. In these cases, the average for the recording period was calculated and taken as the best estimate of the 24 hour average.

Table 5.1 Estimated Percentage of People with 24-Hour Average Magnetic Field above Given Values

24-Hour Average	Percentage of Population with Field Equal to or Exceeding Given Value
0.0 mG	100 %
0.5 mG	76.3 %
1.0 mG	43.6 %
2.0 mG	14.3 %
3.0 mG	6.3 %
4.0 mG	3.35 %
5.0 mG	2.42 %
10.0 mG	0.43 %
15.0 mG	0.1 %

Table 5.2 Personal Exposure Survey - Descriptive Statistics of the Distribution of 24-Hour Average Magnetic Fields

Parameter of the Distribution of 24-Hour Average Fields	Result	Parameter	Result
Mean	1.25 mG	**Minimum**	0.07 mG
Standard Deviation	1.51 mG	1^{st} Percentile	0.18 mG
Geometric Mean	0.89 mG	5^{th} Percentile	0.27 mG
Geometric Standard Deviation	2.18	10^{th} Percentile	0.35 mG
Median	0.87 mG	25^{th} Percentile	0.51 mG
		50^{th} Percentile (**Median**)	0.87 mG
		75^{th} Percentile	1.41 mG
		90^{th} Percentile	2.38 mG
		95^{th} Percentile	3.39 mG
		99^{th} Percentile	6.09 mG
		Maximum	25.7 mG

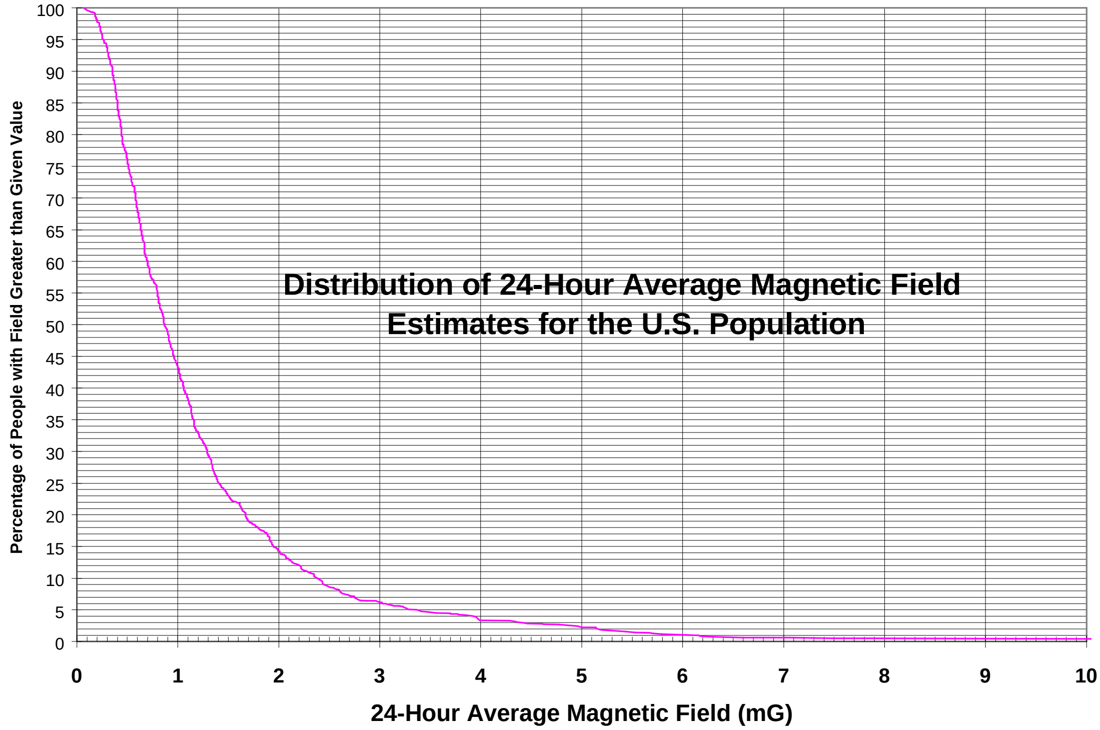

Figure 5-1 Estimated Distribution of 24-Hour Average Magnetic Field for the U.S. Population. Percentage of People with Average Magnetic Field Exceeding a Given Value.

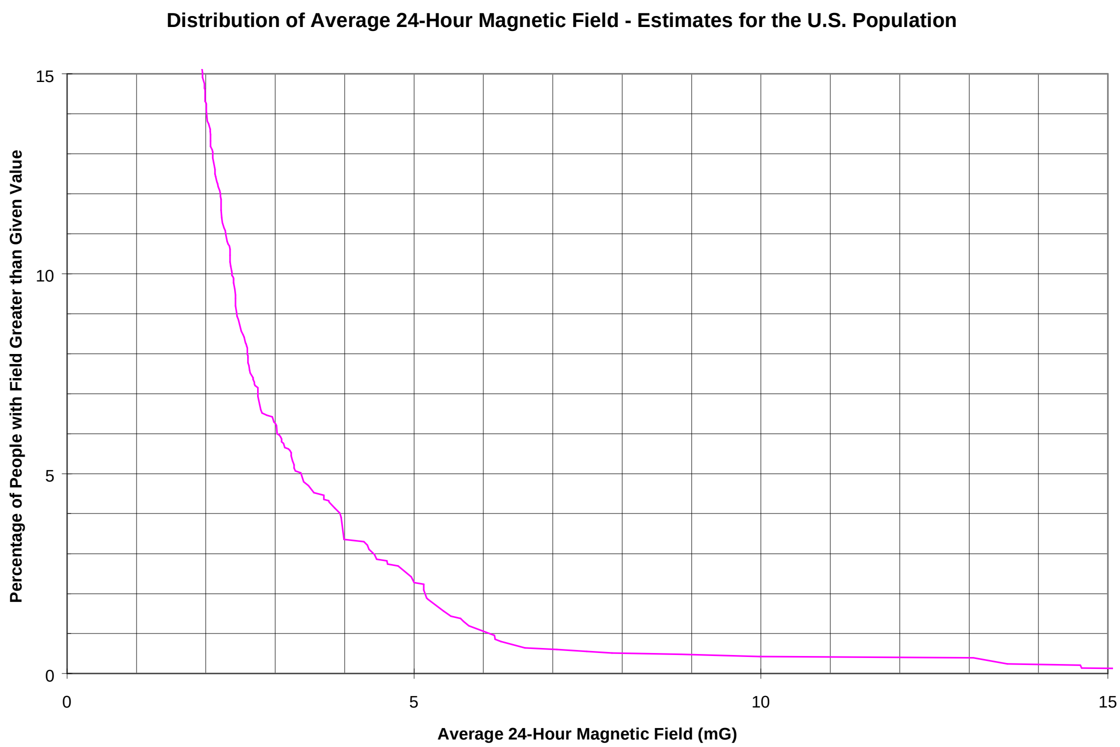

Figure 5-2 Same as Figure 5-1, but with Expanded Vertical Scale. Percentage of Persons with Average Magnetic Field Exceeding a Given Value.

Tables 5-1 and 5-2 and Figures 5-1 and 5-2 show the most important results of this project. The statistical accuracy of these data, caused by the fact that measurements were made with a limited number of samples, is discussed in the next sub-section (5.3). There are additional reasons why the results must be interpreted very cautiously. First, the survey did not cover non-telephone households (about 6 percent in the U.S.). Second, the survey did not address military personnel, nursing homes, hospitalized people, people in prisons, and any other institutionalized people. Finally, the participation rate was very low (only 28.4%), which means that the potential for non-response bias is significant.

The distribution of the logarithms of the average field values is plotted in a normal scale in Figure 5-3. The log-normal distribution that best describes the 24-hour average fields has a geometric mean of 0.89 mG and a geometric standard deviation of 2.18. However, the largest average fields (greater than 3 mG) are better approximated by a log-normal distribution with a geometric mean of 0.5 mG and a geometric standard deviation of 3.1.

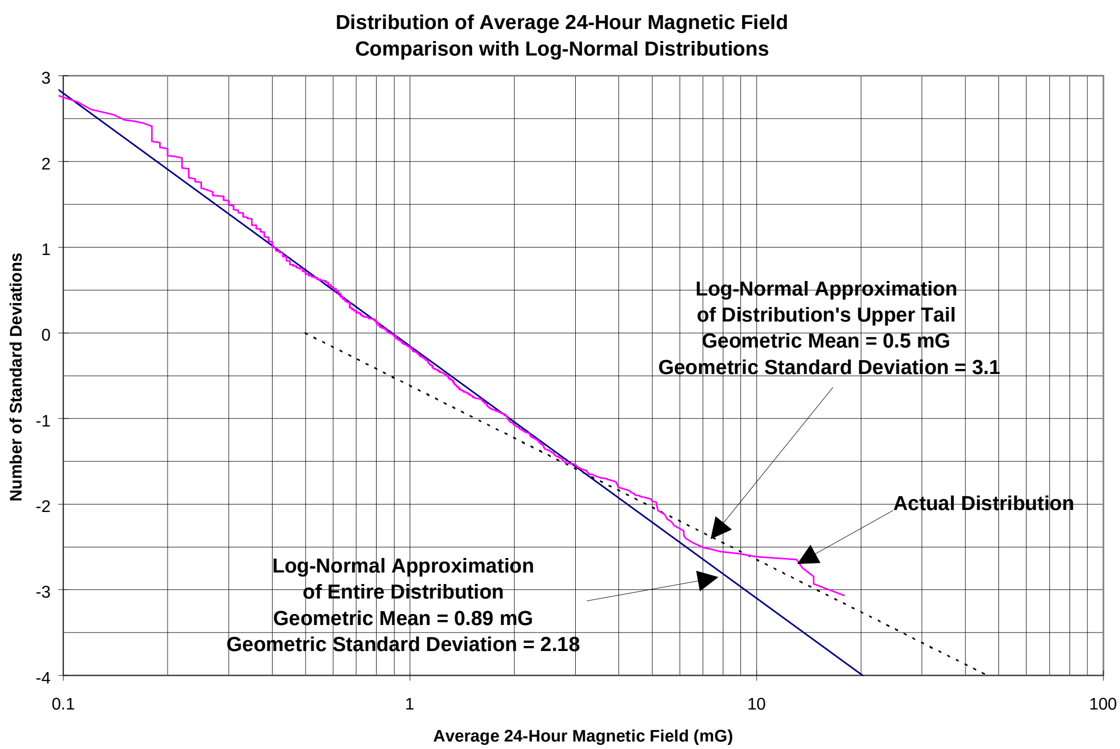

Figure 5-3 Distribution of 24-Hour Averages Plotted with Log-Normal Scales

5.3 Calculation of Statistical Accuracy

A standard error was computed for several nationally representative estimators. This standard error measures how much the estimator would vary over other samples from the same sample design. The standard error that was estimated also includes a component of variability added from the loss to the sample from non-respondents, and a component of variability from the presence of nonsystematic measurement errors. The methodology for estimating this standard error is called the jackknife.

The jackknife variance estimation methodology is compatible with the sample design of the EMF survey, and is known to give reliable and accurate standard errors for this sample design and the types of estimators which are used in this report. It should be noted, however, that the standard errors defined above and estimated using the jackknife do not include any measures of non-sampling error due to non-response biases not adjusted for in the weighting procedure, systematic measurement errors, or deficiencies in the frame (the primary problem in the latter case is that non-telephone households are not represented on the sampling frame).

The jackknife variance estimator, $v(\hat{A})$, was calculated by computing R=50 replicate versions of the population estimator, $\hat{A}$, as follows (with $w_{i(r)}$, r = 1 to R, indicating the replicate weights for each sample unit i):

$$v(\hat{A}) = \sum_{r=1}^{R} (A(r) - \hat{A})^2 \qquad (5.2)$$

The approximate 95 percent confidence interval is:

$$C.I. \qquad \hat{A} \pm 1.96\sqrt{v(\hat{A})} \qquad (5.3)$$

The replicate weights were generated with special procedures that took into account the sample design of the survey. They are listed in Table B-4 of Appendix B.

5.4 Variance of the Estimates of 24-Hour Average Distribution Parameters

The calculated values of the standard errors of the parameters of the 24-hour average field distribution are shown in Table 5-3. The best estimates of the distribution of 24-hour averages and of the 95 % Confidence Limits are shown in Figure 5-4.

Table 5.3 Best Estimate, Standard Error, and 95% Confidence Interval of the Parameters of the Descriptive Statistics of 24-Hour Average Magnetic Field

Parameter	Estimate	Standard Error	95% CI 2.5%	95% CI 97.5%
Mean of 24-Hour Average Fields	1.25 mG	0.044 mG	1.16	1.33
Standard Deviation	1.51 mG	0.19 mG	1.13	1.88
Geometric Mean of Average Fields	0.89 mG	0.022 mG	0.85	0.93
Geometric Standard Deviation	2.18	0.043	2.10	2.27
Median of 24-Hour Average Fields	0.87 mG	0.033 mG	0.81	0.93

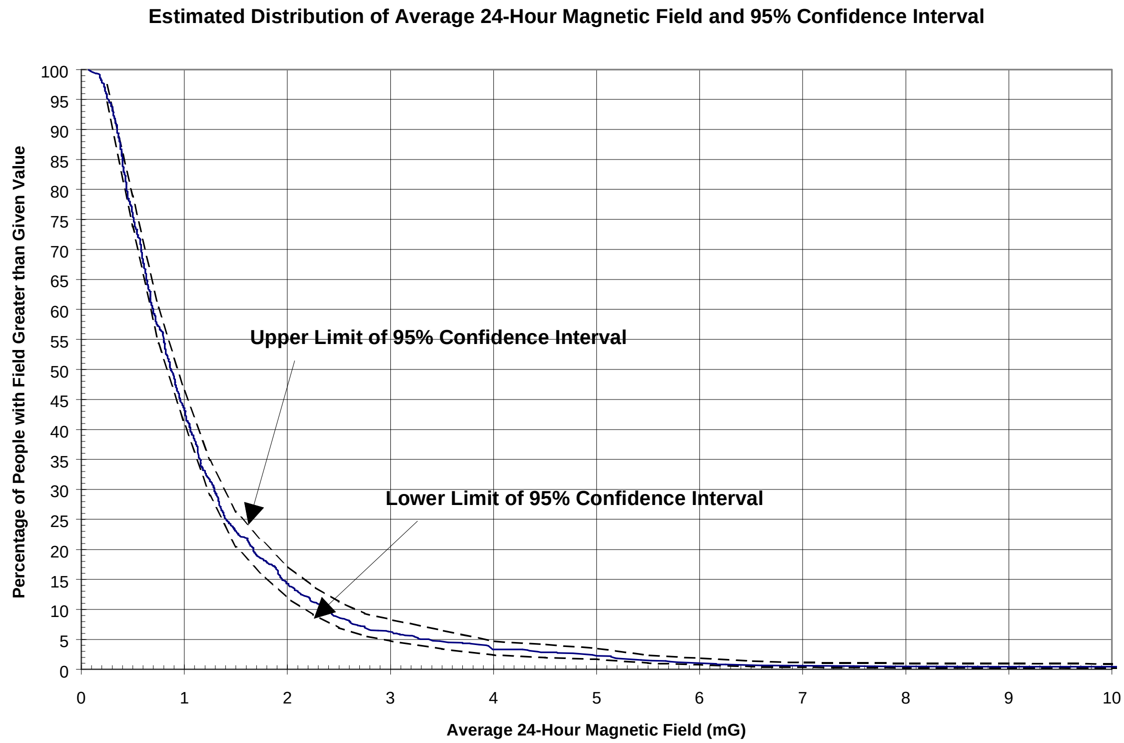

Figure 5.4 Estimated Distribution of 24-Hour Average Magnetic Fields and 95 % Confidence Interval

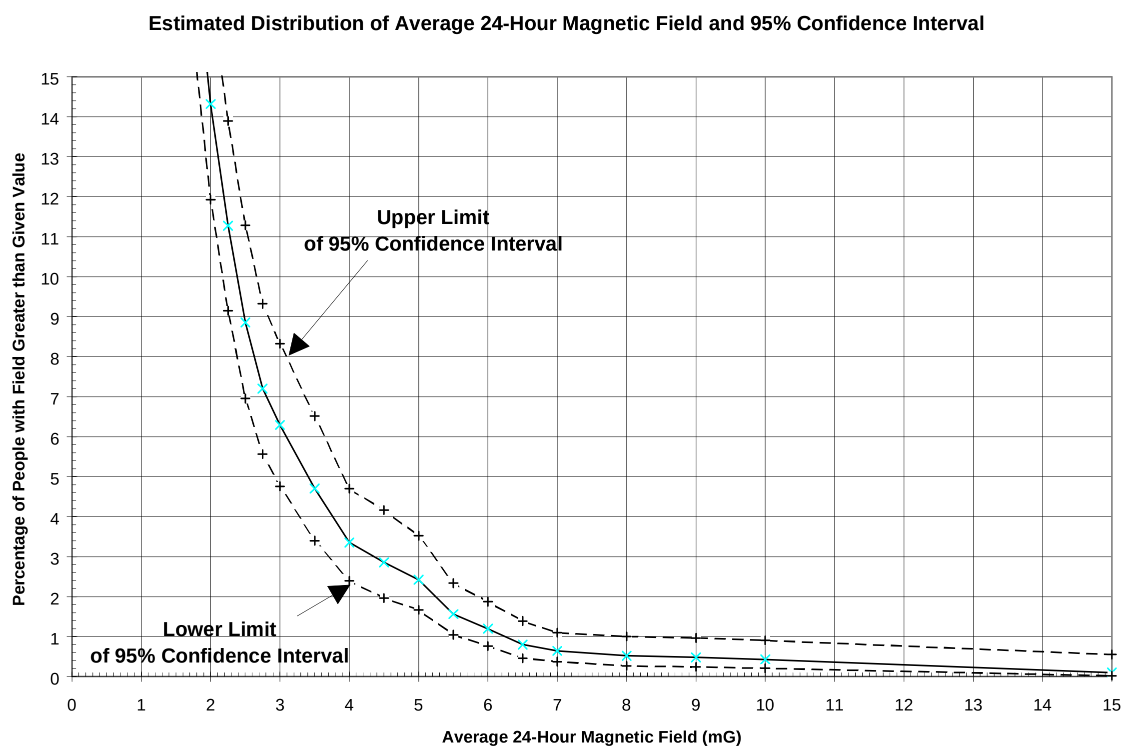

Figure 5.5 Same as Figure 5.4 but with Expanded Vertical Scale. Estimated Distribution of 24-Hour Average Magnetic Fields and 95 % Confidence Interval

The estimated percentage of the population with average field above given values and their 95% CI are shown in Table 5.4.

Table 5.4 Percentage of the Population with Average Field Exceeding Given Values

Average 24-Hour Field	Estimated Percentage	95% Confidence Interval	Number of people (Based on 1996 Census)
> 0.5 mG	76.3 %	73.8 % - 78.9 %	197 - 210 million
> 1 mG	43.6 %	40.9 % - 46.5 %	109 - 124 million
> 2 mG	14.3 %	11.8 % -17.3 %	31.5 - 46.2 million
> 3 mG	6.3 %	4.7 % -8.5 %	12.5 - 22.7 million
> 4 mG	3.6 %	2.5 % - 5.2 %	6.7 - 13.9 million
> 5 mG	2.42 %	1.65 % - 3.55 %	4.4 - 9.5 million
> 7.5 mG	0.58 %	0.29 % - 1.16 %	0.77 - 3.1 million
> 10 mG	0.46 %	0.20 % -1.05 %	0.53 - 2.8 million
> 15 mG	0.17 %	0.035 % -0.83 %	93 thousand - 2.2 million

5.5 Estimates of Other Quantities Recorded During 24-Hour

5.5.1 Time Above Given Field Values

The length of time during which the field exceeded a number of specified field levels was recorded by the personal exposure meter. For each specified field level the distribution of times was calculated from the measurements on the 1,012 people sample, applying the weights described in Section 5.1. The results are shown in Figure 5.6. The figure shows, for example, that about 25% of the people spend more than one hour at fields greater than 4 mG, and that about 8.5% of the people spend more than one hour at fields greater than 8 mG. Figure 5.7, with expanded scales, allows reading the values of time above the highest specified field levels. For example, the figure shows that about 11% of the people spend more than one minute at fields greater than 32 mG.

The maximum magnetic fields measured with the 1,012 people sample during the 24-hour recording period was used to generate estimates for the U.S. population. The distribution of the maximum magnetic fields is shown in Figure 5.8. The upper curve has an expanded vertical scale. The figure shows that about 1.6% of the people experience at least 1 gauss (1000 mG) during a 24-hour period. The personal exposure meter could not measure more than 1.024 gauss for each of the three orthogonal axes. Therefore, the maximum possible reading is $\sqrt{3} \cdot 1.024$ gauss (1774 mG). Readings above 1024 mG are suspect. Most readings up to about 1150 mG are probably correct, because significant field components may have existed along more than one axis. For instance, if the fields along the three axes of the meter were 850 mG, 700 mG, and 200 mG, the field would have been measured correctly by the meter and the resultant value recorded would be 1120 mG. However, if the fields were 1275 mG, 1050 mG, and 300 mG, the meter would have recorded a value of $\sqrt{1024^2 + 1024^2 + 300^2}$ = 1479 mG instead of the correct value of $\sqrt{1275^2 + 1050^2 + 300^2}$ = 1678 mG. Therefore, the data above about 1150 mG were extrapolated (see dashed curve in Figure 5.8).

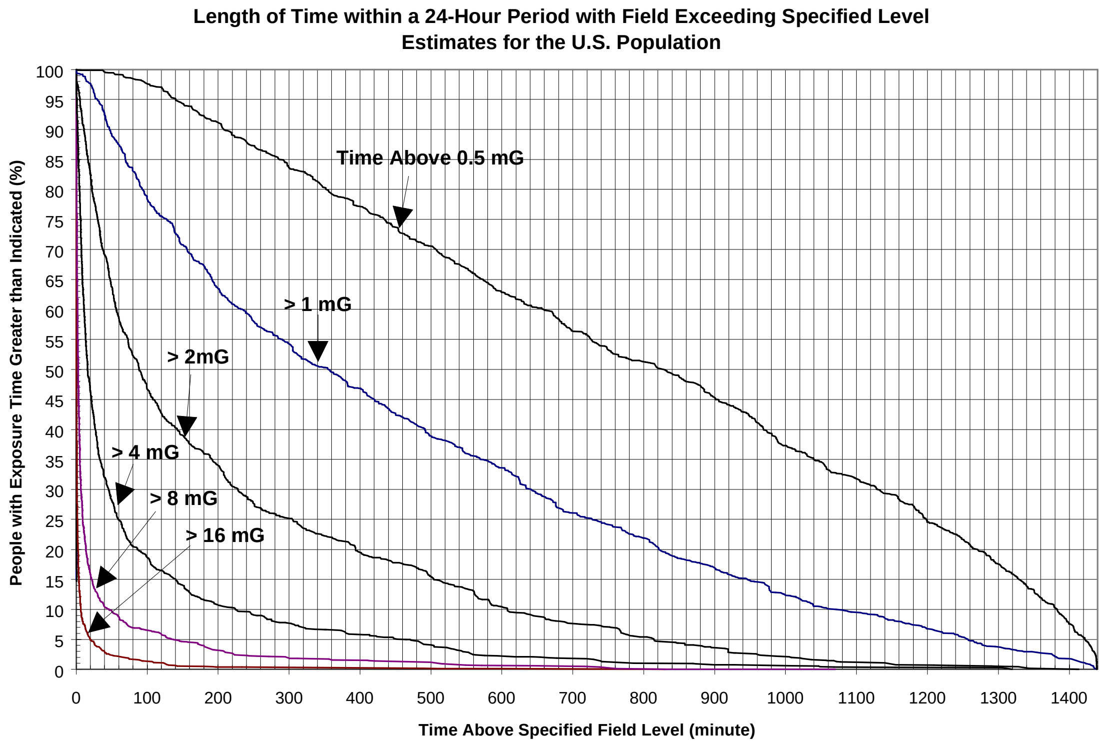

Figure 5.6 Estimated U.S. Population Distributions of Times Above Specified Field Levels: 0.5, 1, 2, 4, 8, 16, 32, and 64 mG.

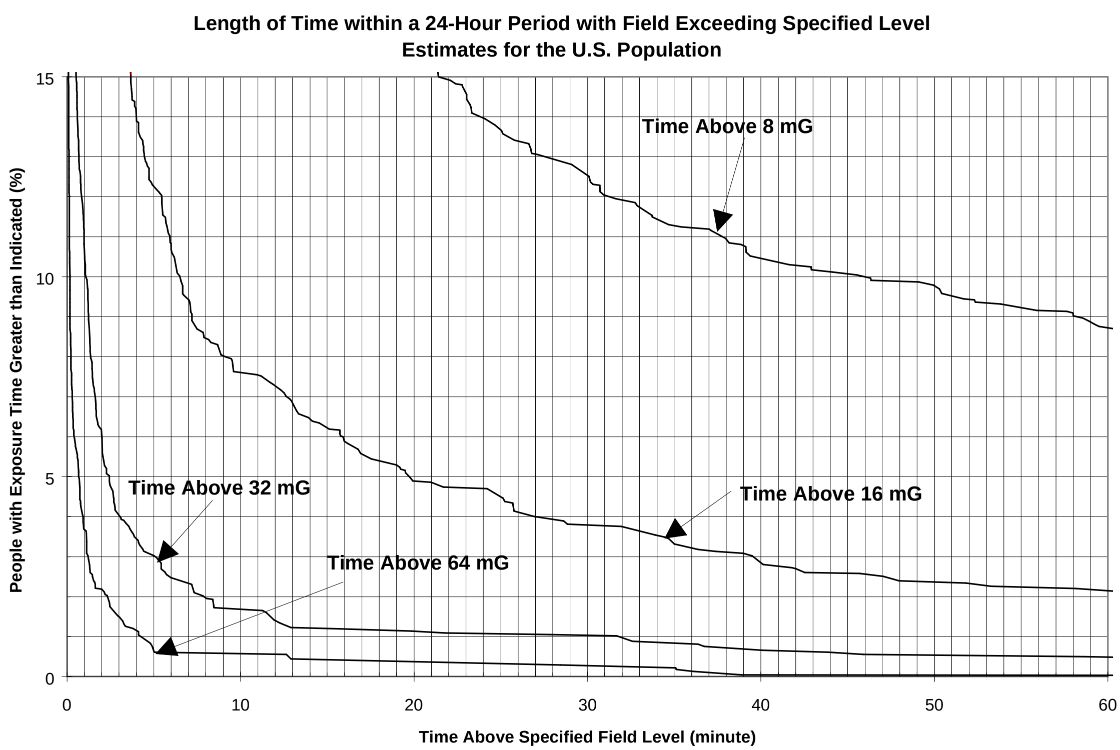

Figure 5.7 Same as Figure 5.6, but with Expanded Scales. Estimated U.S. Population Distributions of Times Above Specified Field Levels: 0.5, 1, 2, 4, 8, 16, 32, and 64 mG.

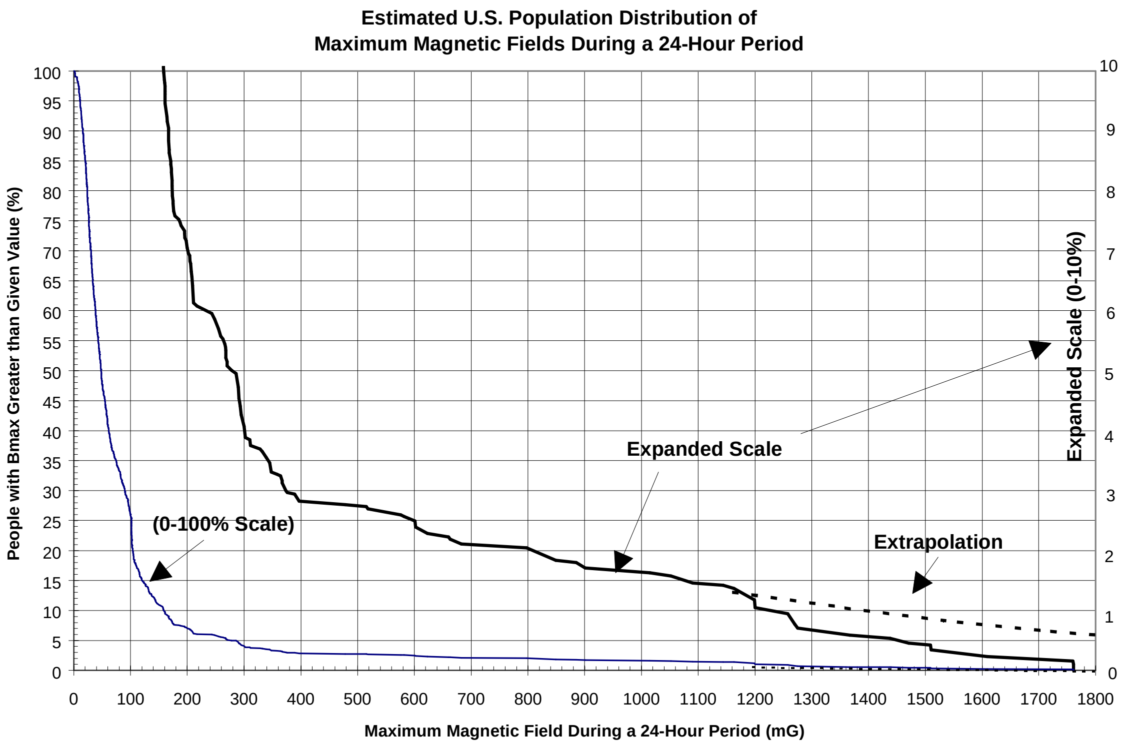

Figure 5.8 Estimated Distribution of Maximum Magnetic Field during a 24-Hour Period.

5.5.2 Number of Sudden Field Changes

As described in Section 2.2, the personal exposure meter keeps count of the number of sudden field changes. A field change is equal to the absolute value of the difference between a field record and the next one (0.5 seconds later). A field change is called “sudden” if it is equal to or greater than one half of the average value of the two consecutive records. For instance, a field change of 4 mG going from a 6 mG field to a 10 mG field qualifies as “sudden”, but a field change of 5 mG going from 10 mG to 15 mG is not considered sudden because it does not meet the criterion stated above.

The number of sudden field changes between 2.5 and 5 mG, between 5 and 10 mG, or greater than 10 mG, were counted. The estimates of the number of sudden field changes in one day are plotted in Figure 5.9 and, with an expanded vertical scale, in Figure 5.10. More than 50% of the people experience in one day more than 10 sudden field changes greater than 10 mG, more than 30 greater than 5 mG, and more than 90 greater than 2.5 mG.

Because of the high sampling rate, a sudden field change is likely to be caused by the application or removal of an electrical load. Because switching electrical loads may cause transient magnetic fields [3], the number of field changes is, in essence, a proxy for the number of transients. However, the correlation between number and amplitude of sudden field changes and number and amplitude of transients is not known.

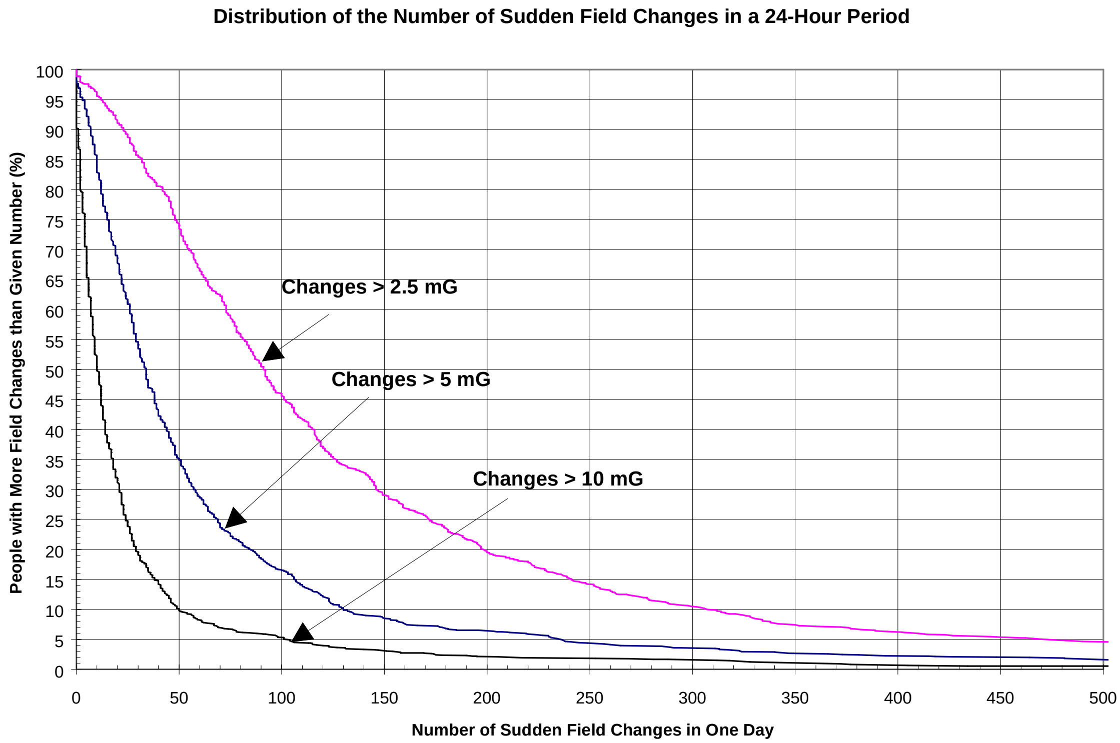

Figure 5.9 Distribution of the Number of Sudden Field Changes Greater than Given Amount

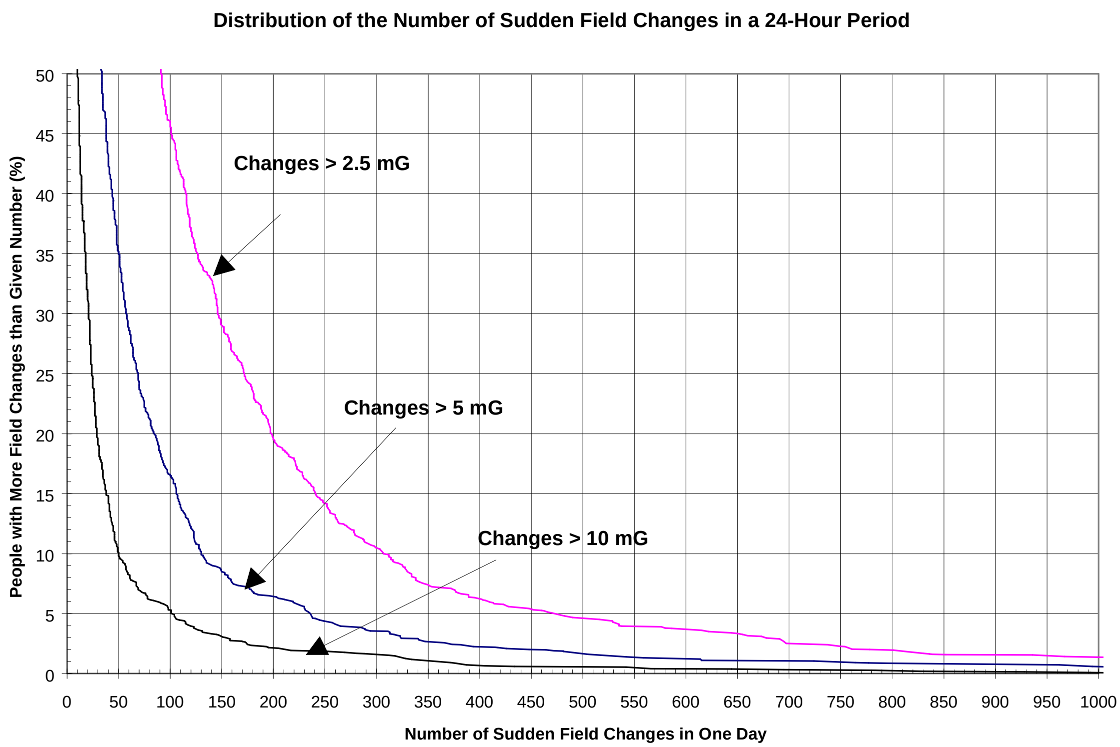

Figure 5.10 Same as Figure 5.9, but with Expanded Vertical Scale. Distribution of the Number of Sudden Field Changes Greater than Given Amount

5.5.3 Length of Time with Constant Field

The length of time with constant field is defined as the sum of the length of all periods of time during which the magnetic field remains constant on all the three axes. Each constant field period must last for 10 seconds or longer. In each constant field period, each field component cannot vary more than 10% of the resultant. Finally, the field must be greater than 2 mG. The interest in the length of time with constant field derives from the biological literature, with some researcher [2] saying that a coherent field is a prerequisite for biological effects.

The U.S. population estimate of the length of time during one day with constant field above 2 mG was calculated and plotted in Figure 5.11. The figure shows that a field greater than 2 mG is constant for at least one hour in one day for about 37.5% of the people, and for at least 10 hours in one day for about 6% of the people.

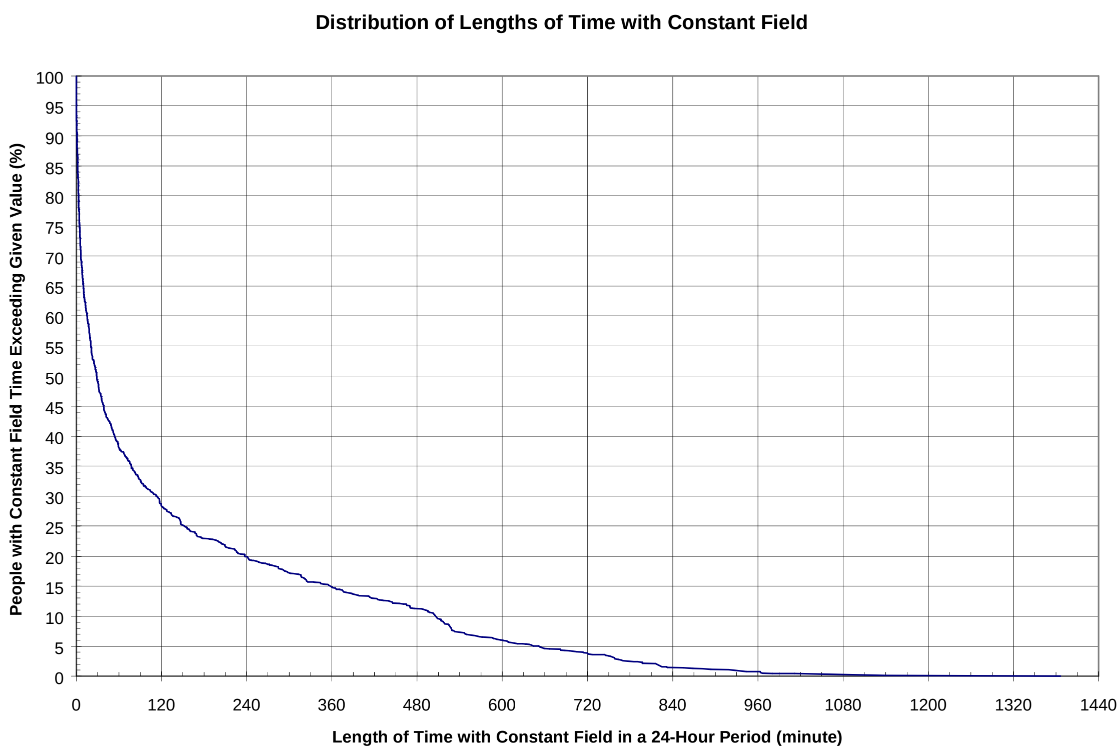

Figure 5.11 Distribution of the Lengths of Time with Constant Field within a 24-Hour Period

5.5.4 Intermittence

The intermittence is defined by the average change (absolute value) between two consecutive magnetic field records. This parameter may be expressed as a percentage of the average field or as a percentage of the standard deviation, and then it may be called “intermittence index”. A constant field has an intermittence index equal to zero, while a field that keeps changing from a minimum to a maximum value has an intermittence index equal to twice the standard deviation (i.e. 200%). A field that keeps jumping up and down has a high intermittence index. A field that varies slowly in time has a low intermittence index, even though it may have a high value of the standard deviation. Three examples of sequences of records with widely different intermittence indices are shown in Figure 5.12. All the three functions (A, B, and C) have the same standard deviation. The intermittence index of function A is close to zero, the intermittence index of function B is about 200%, and the intermittence index of function C is about 100%. The intermittence index, when expressed as a percentage of the standard deviation, depends also on the duration of the period analyzed. For instance, if two consecutive periods have equal intermittence indices and equal standard deviations but different averages, the standard deviation for the combined period will be greater and the average field change will be the same and, therefore, the intermittence index as a percentage of the standard deviation will decrease.

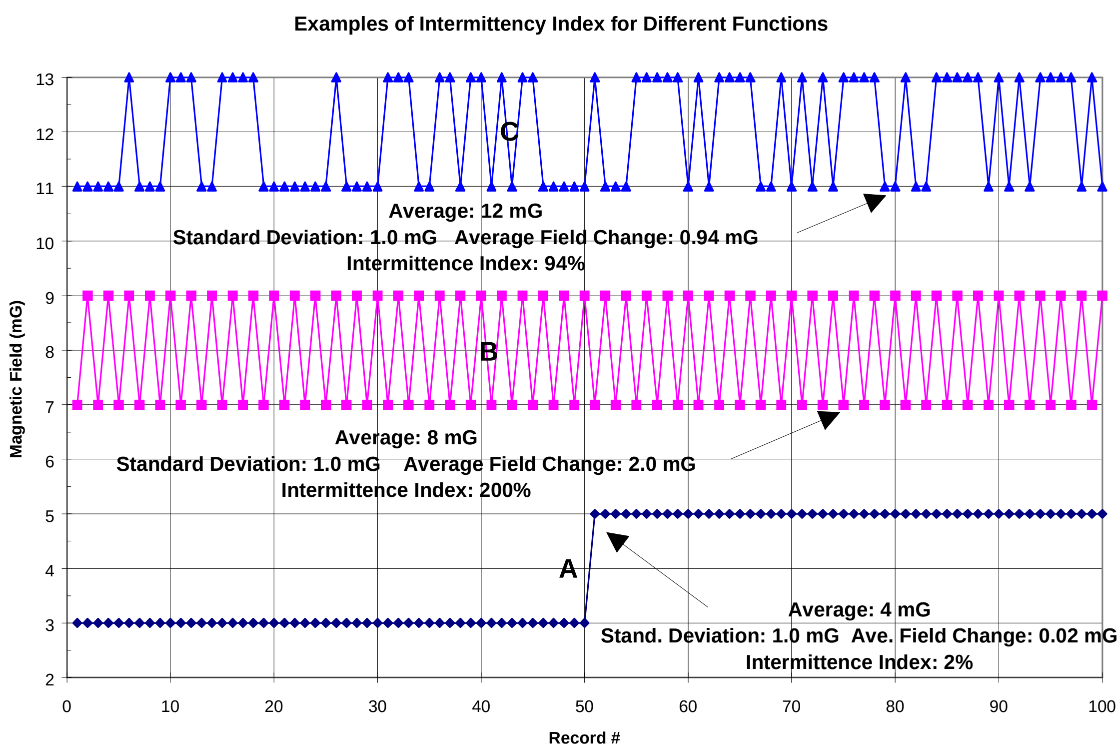

Figure 5-12 Examples of Functions with the Same Standard Deviation, but Different Intermittence Indices.

The U.S. population estimates of the distribution of various intermittence indices were calculated and plotted in Figure 5.13. The average change between consecutive records was expressed in three different ways: as a percentage of the standard deviation, as a percentage of the average, and as a percentage of 1 mG.

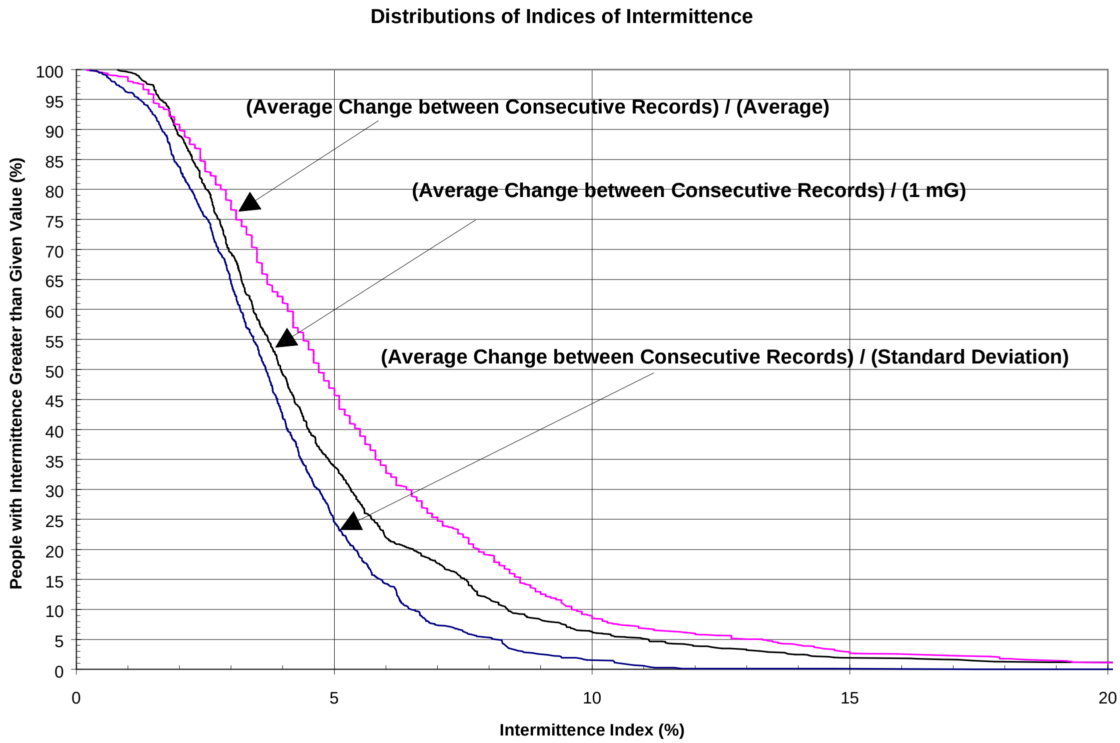

Figure 5.13 Distribution of Intermittence Indices for 24-Hour Data Sets

5.5.5 Correlation between Different Exposure Metrics

Correlation coefficients were calculated between pairs of different measures of 24-hour exposures obtained for the 1012 people in the survey sample: 24-hour average magnetic field, standard deviation of the magnetic field during the 24 hours, 24-hour geometric mean, geometric standard deviation, time spent above 4 mG, time spent above 16 mG, maximum field measured during the 24 hours, number of sudden field changes exceeding 10 mG, time with constant field above 2 mG, and intermittence expressed as average change between two consecutive field measurements.

The correlation coefficients are shown in Table 5-5. The table shows that the average field is well correlated with and, therefore, a suitable surrogate for geometric mean, time above 4 mG, time above 16 mG, and intermittence. On the other hand, the average field is not well correlated with the maximum field and with the number of sudden field changes above 10 mG.

Table 5-6 shows the sensitivity (number of people classified as exposed as a percentage of all people exposed) and the specificity (number of people classified as non exposed as a percentage of all non exposed) of using time weighted average (TWA) instead of other metrics to define exposure. For this purpose the people with exposure greater than the 90th percentile for each metric was defined as exposed and the remaining 90% of the people was classified as non exposed.

Table 5-5 Correlation Coefficients. Linear Regression between Different Exposure Metrics (Measures of 24-Hour Exposure of 1012 People Representative of the U.S. Population)

	Ave	Stand. Dev.	Geo Mean	Geo. Stand. Dev.	Time above 4 mG	Time above 16 mG	Max	Sudden Changes > 10 mG	Const. Field Time	Interm.
Ave	1.00	0.65	0.76	0.53	0.71	0.73	0.22	0.35	0.59	0.83
Stand. Dev.		1.00	0.17	0.34	0.22	0.30	0.53	0.46	0.17	0.64
Geo. Mean			1.00	0.14	0.75	0.51	0.04	0.09	0.77	0.83
Geo. St. Dev.				1.00	0.51	0.50	0.10	0.27	0.28	0.71
Time > 4 mG					1.00	0.43	0.05	0.14	0.67	0.90
Time >16 mG						1.00	0.06	0.26	0.23	0.91
Max							1.00	0.24	0.06	0.44
Changes >10 mG								1.00	0.08	0.75
Const. Field									1.00	0.68
Interm.										1.00

Table 5-6 Sensitivity and Specificity of Using TWA instead of Other Metrics

Metric	Sensitivity related to TWA	Specificity related to TWA	90^{th} Percentile Value
TWA	100 %	100 %	2.39 mG
Time above 4 mG	79 %	97.7 %	206 min
Time above 16 mG	46 %	94.0 %	7.2 min
Maximum	20 %	91.1 %	167 mG
Number of Sudden Changes > 10 mG	26 %	91.8 %	57
Length of Time with Constant Field above 2 mG	58 %	95.3 %	495 min
Inermittence (average change between consecutive records)	48 %	94.2 %	0.087 mG

5.6 Average Field During Different Types of Activities

The average field was calculated separately for the following periods: in bed, at home not in bed, work, school, and travel.

5.6.1 Period "In Bed"

The distribution of average fields during the period "in bed" is shown in Figure 5-14 and in Figure 5-15 using expanded scales. The data in these figures are not for all the 1,012 people, but only for the 996 people that had an "in bed" period with valid data of at least one hour. Of the other 16 people, 15 did not have any valid data for the period "in bed" and one had only a 10 minute period in bed. The 15 people who did not have valid data placed the exposure meter on or very near the alarm-clock radio, contrary to the instructions on how to use the meter. As a result, the field was perfectly constant and at an elevated value during the entire period "in bed".

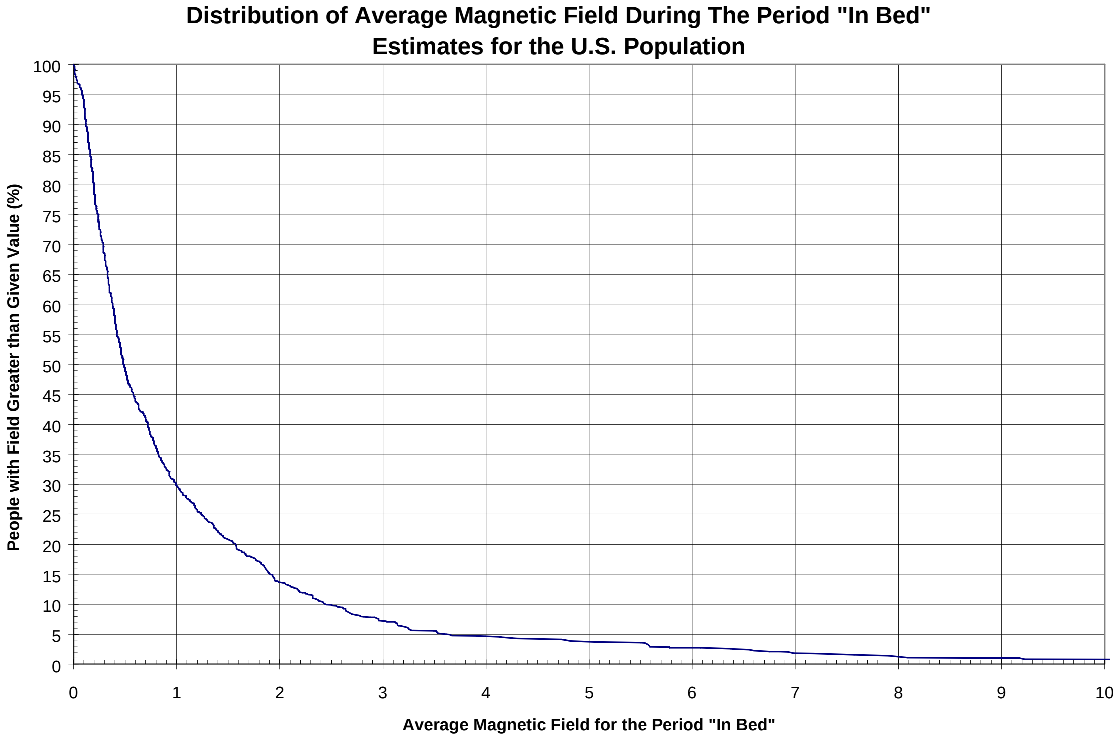

Figure 5-14 Distribution of Average Magnetic Fields Measured During the Period "In Bed"

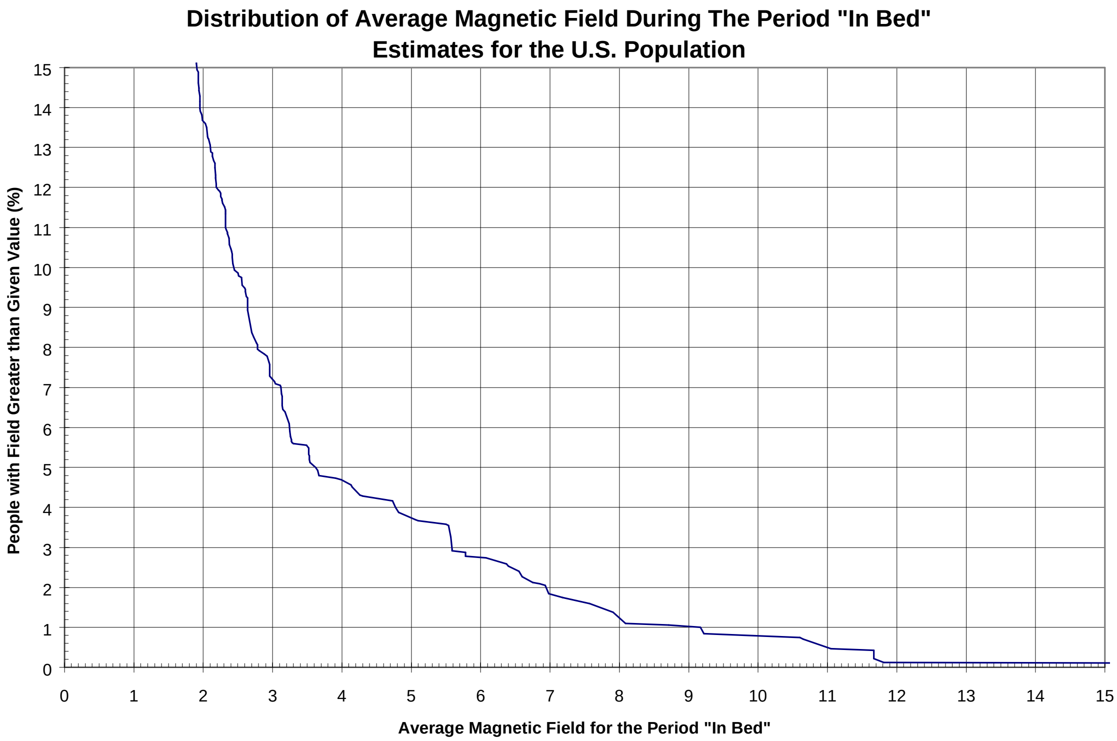

Figure 5-15 Same as Figure 5-14, but with an Expanded Vertical Scale. Distribution of Average Magnetic Fields Measured During the Period "In Bed"

5.6.2 Period "At Home Not In Bed"

The distribution of average fields during the period "at home not in bed" is shown in Figure 5-16 and in Figure 5-17 using expanded scales. The data in these figures are for all the 1,012 people except one, who had no valid data for the "at home not in bed" period (this particular person reported spending less than 10 minutes at home not in bed).

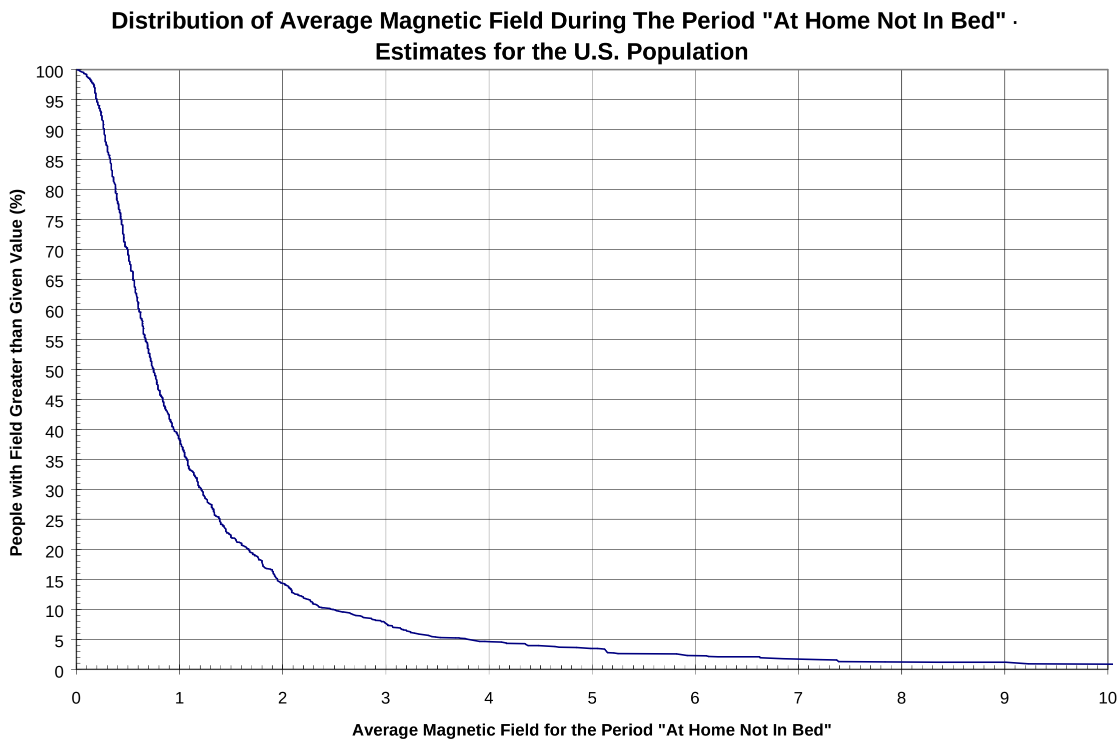

Figure 5-16 Distribution of Average Magnetic Fields Measured During the Period "At Home Not In Bed"

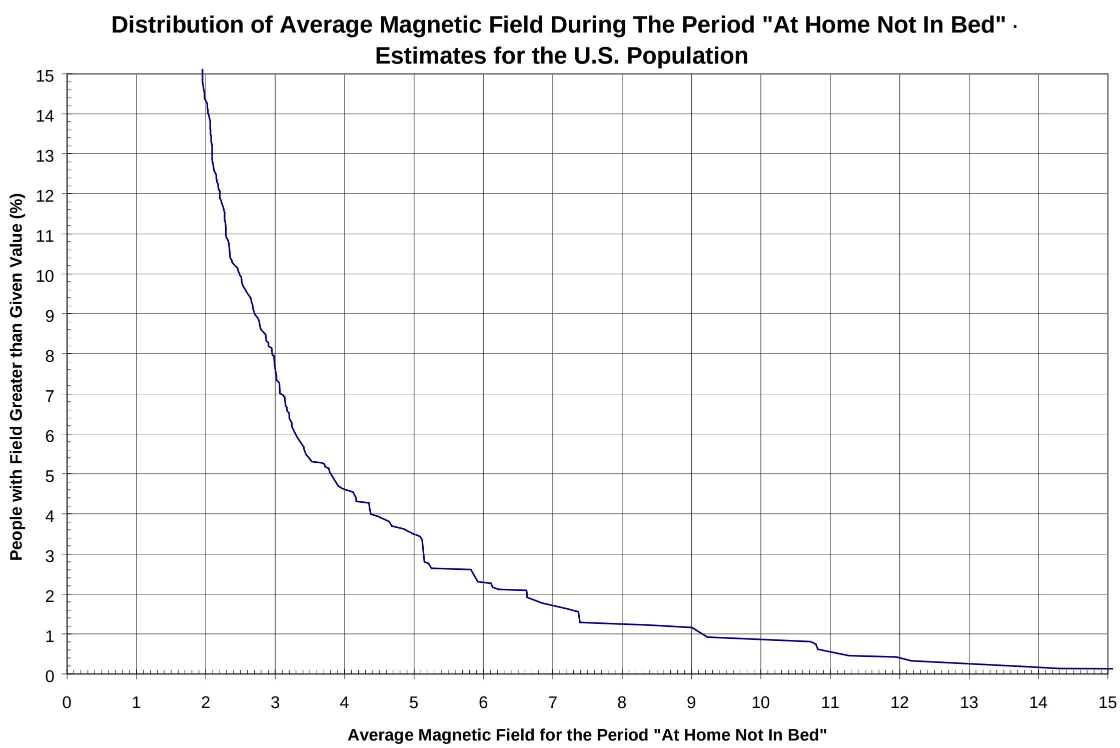

Figure 5-17 Same as Figure 5-16, but with an Expanded Vertical Scale. Distribution of Average Magnetic Fields Measured During the Period "At Home Not In Bed"

5.6.3 Period “At Work”

The distribution of average fields during the period “at work” is shown in Figure 5-18 and in Figure 5-19 using expanded scales. The data in these figures are for the 525 people who reported spending some time at work.

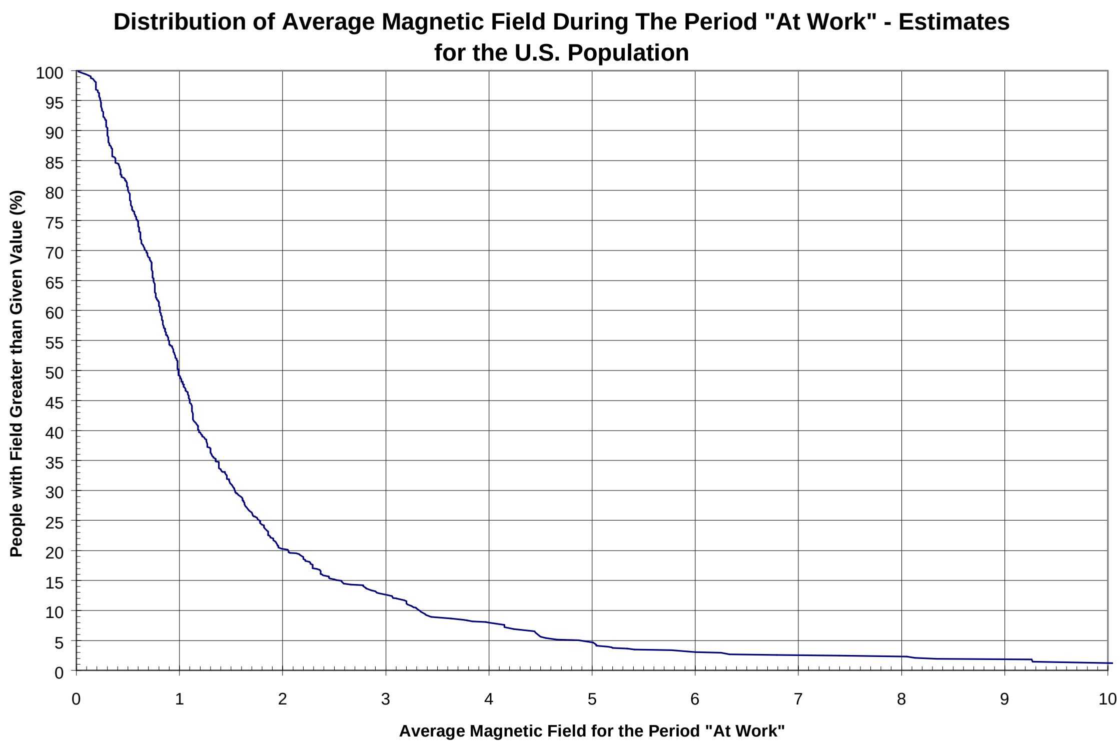

Figure 5-18 Distribution of Average Magnetic Fields Measured During the Period “At Work”

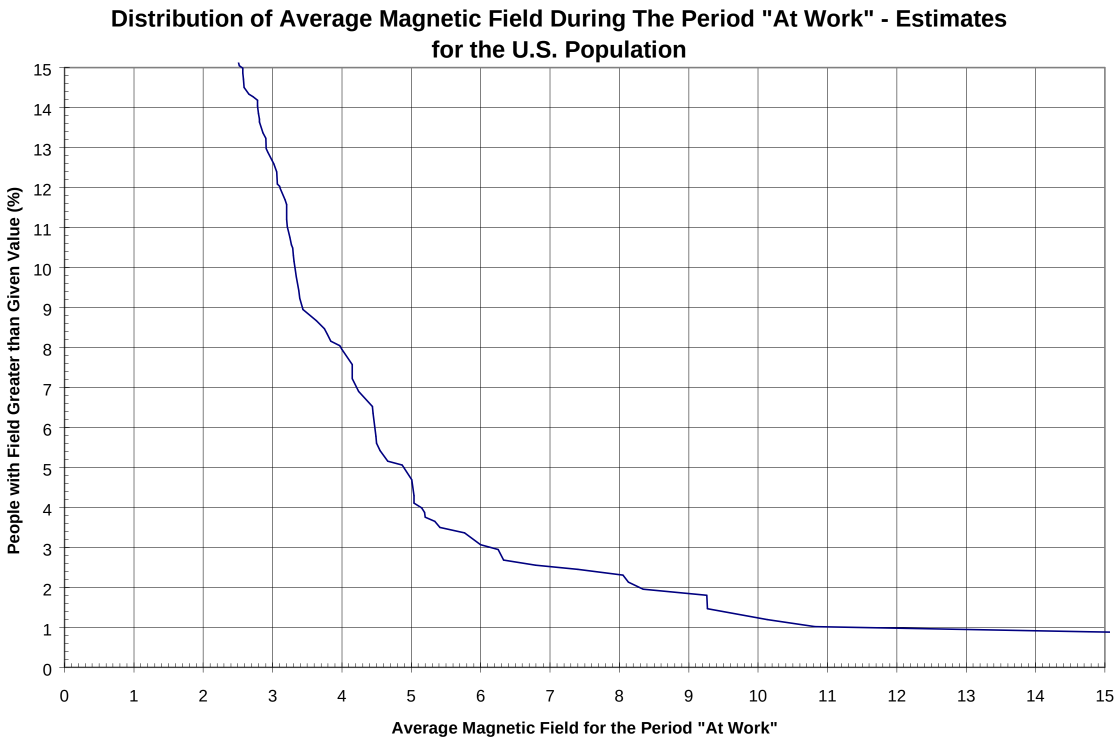

Figure 5-19 Same as Figure 5-18, but with an Vertical Expanded Scale. Distribution of Average Magnetic Fields Measured During the Period "At Work"

5.6.4 Period "In School"

The distribution of average fields during the period "in school" is shown in Figure 5-20 and in Figure 5-21 using expanded scales. The data in these figures are for the 139 people who reported going to school for some time during the 24 hour measurement period.

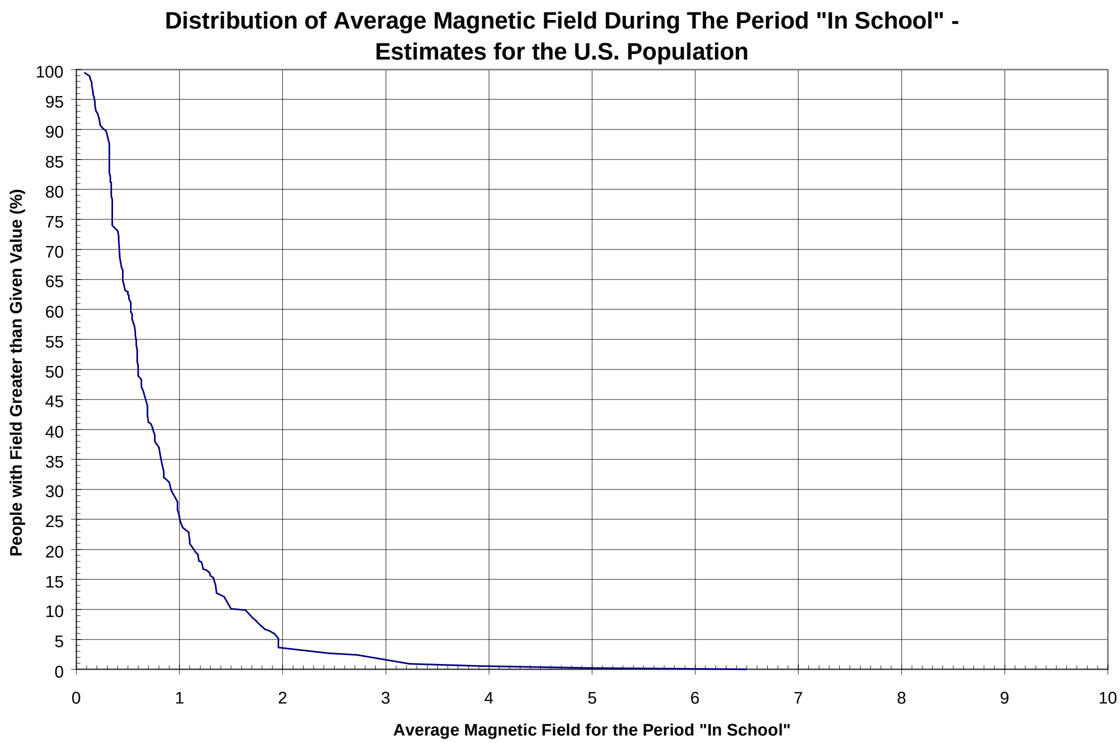

Figure 5-20 Distribution of Average Magnetic Fields Measured During the Period "In School"

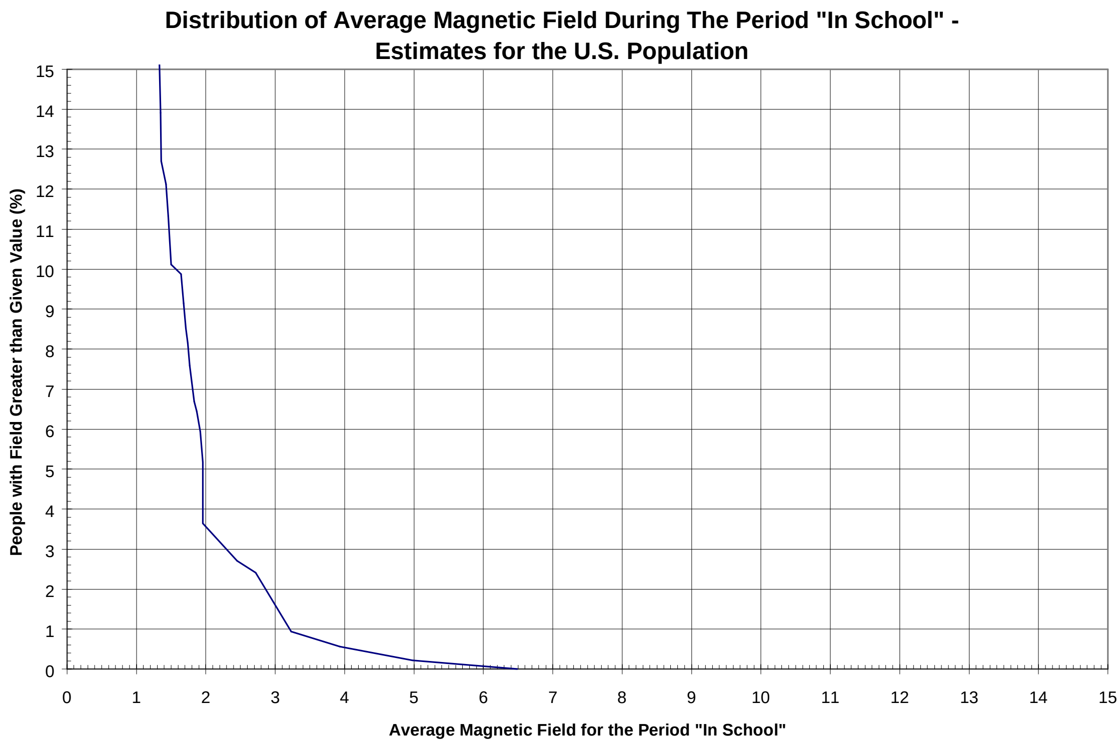

Figure 5-21 Same as Figure 5-20, but with an Expanded Vertical Scale. Distribution of Average Magnetic Fields Measured During the Period "In School"

5.6.5 Period "During Travel"

The distribution of average fields "during travel" is shown in Figure 5-22 and in Figure 5-23 using expanded scales. The data in these figures are for the 765 people who had some valid data during travel. The other 247 people, either did not travel or did not have valid data. For several people the periods of travel were not sufficiently longer than 10 minutes and there was no 10-minute recording period that could be fully allocated to travel.

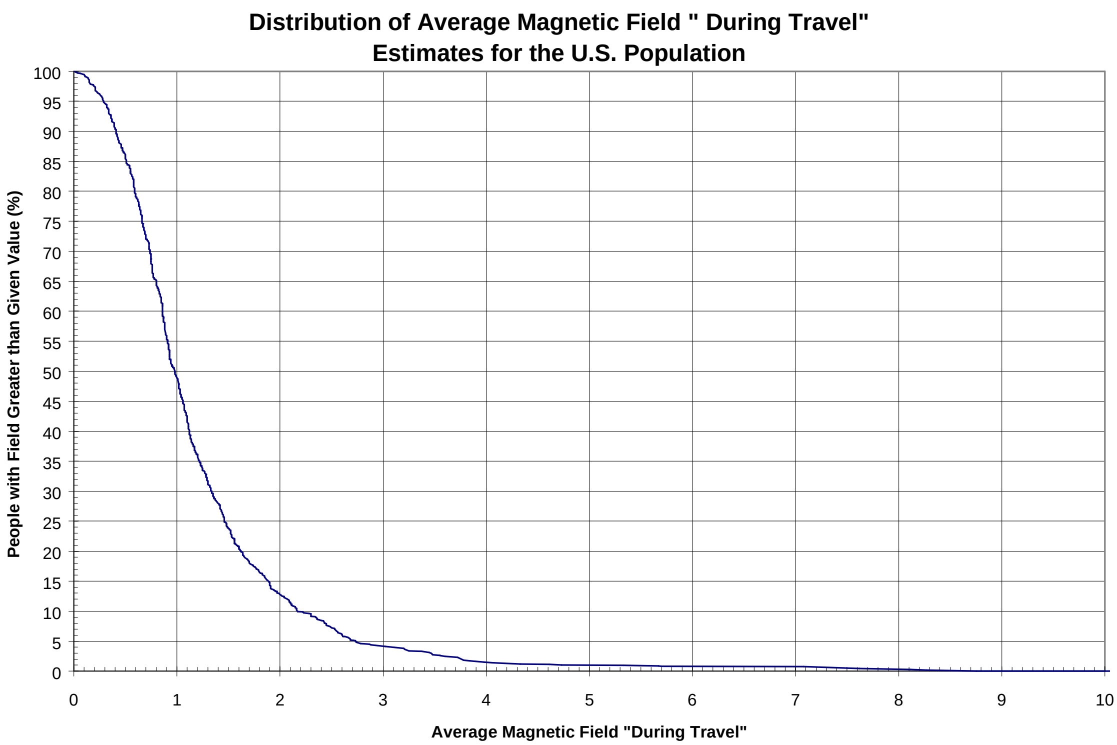

Figure 5-22 Distribution of Average Magnetic Fields Measured "During Travel"

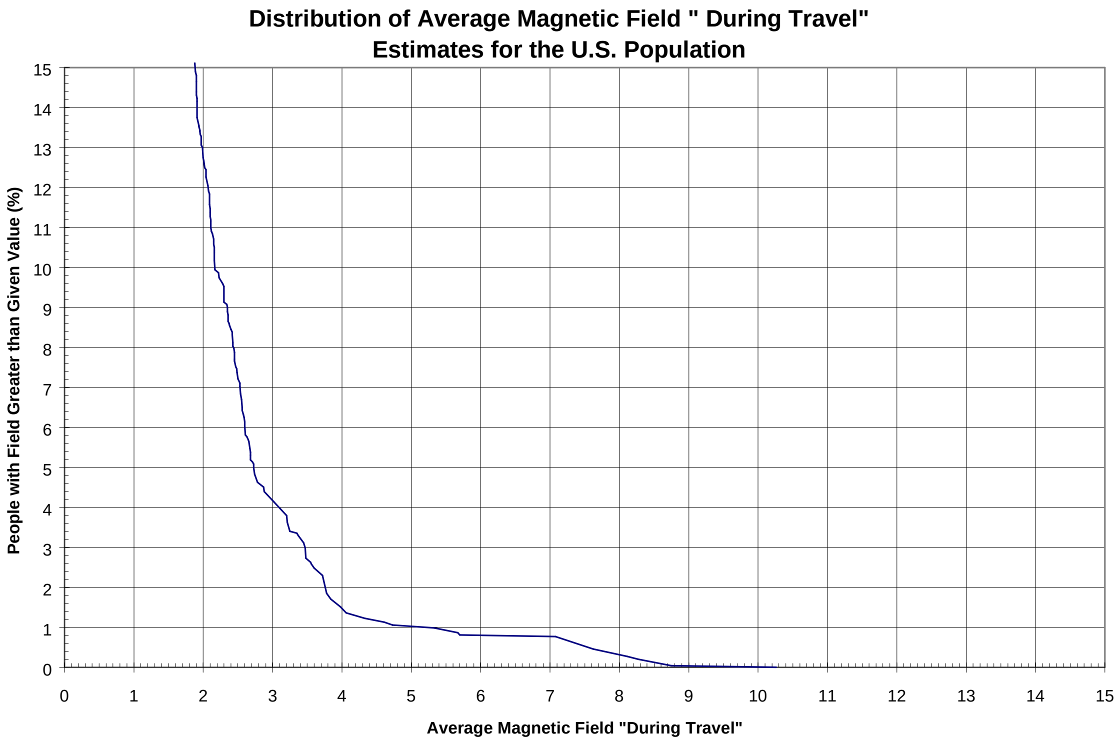

Figure 5-23 Same as Figure 5-22, but with an Expanded Vertical Scale. Distribution of Average Magnetic Fields Measured “During Travel”

5.6.6 Comparison of Average Magnetic Field During Different Activities

The distribution curves shown separately in Figures 5-14 to 5-23 are shown together in Figures 5-24 and 5-25. A detailed comparison between the results for different activities is shown in Table 5-7. Examination of the data leads to the following observations:

The upper portions of the distribution curves show that the lowest average fields were recorded “in bed”, followed by “in school” and “at home not in bed”.

The lower portions of the distribution curves show that the largest average fields were recorded “at work”, followed by “at home not in bed”, and “in bed”.

The largest median, mean, and geometric mean of the average magnetic field distribution were obtained for the work period.

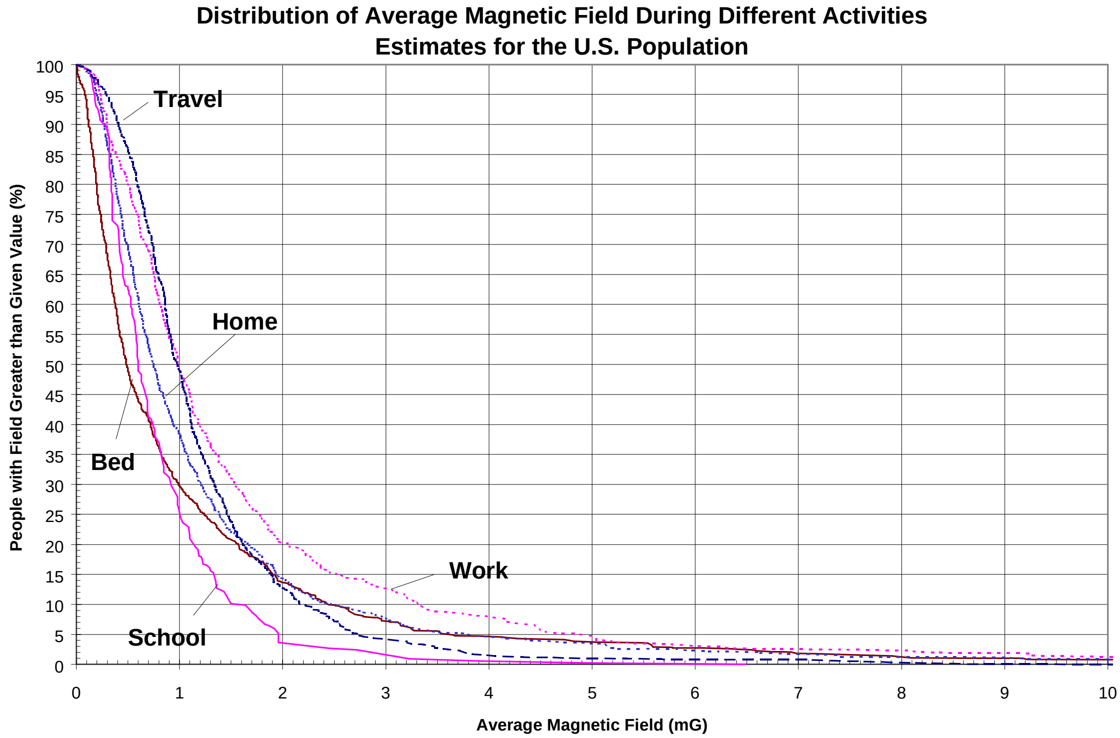

Figure 5-24 Distribution of Average Magnetic Fields Measured During Periods of Different Activities

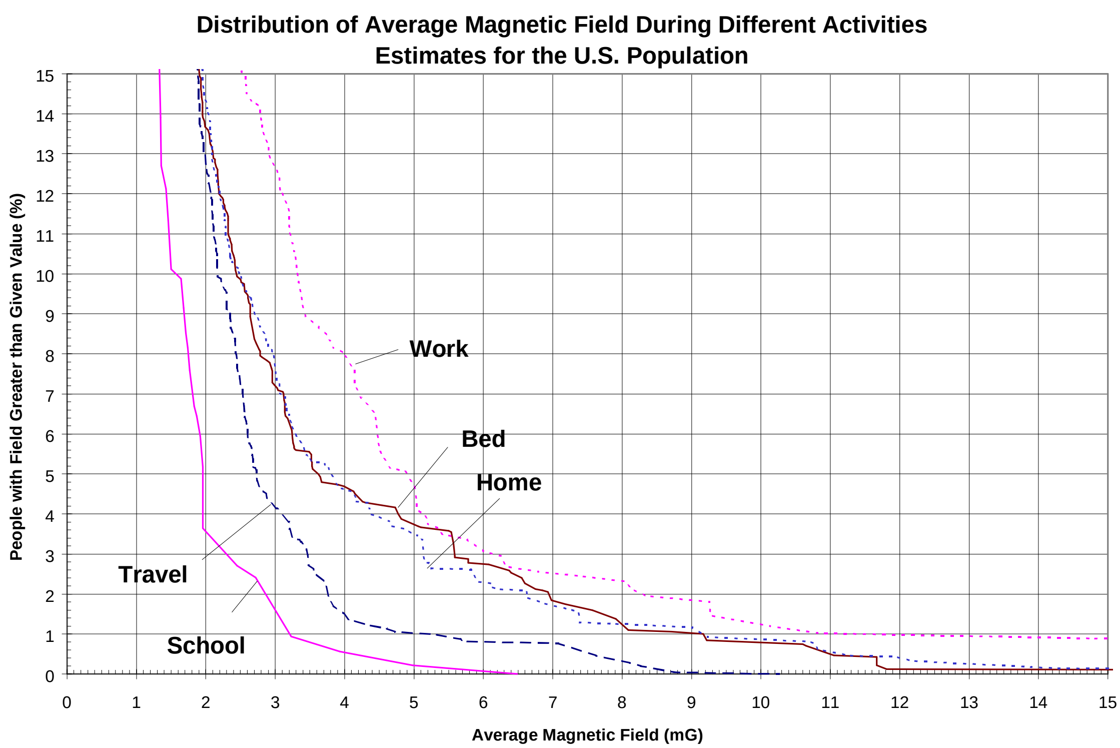

Figure 5-25 Same as Figure 5-24 but with an Expanded Vertical Scale. Distribution of Average Magnetic Fields Measured During Periods of Different Activities

Table 5-7 Descriptive Statistics for Different Activity Periods

Parameter	Home not in Bed	In Bed	Work	School	Travel	24-Hour
Number of Valid Data Sets	1011	996	525	139	765	1012
1st Percentile	0.10 mG	0.01 mG	0.14 mG	0.13 mG	0.13 mG	0.18 mG
5th Percentile	0.20 mG	0.08 mG	0.24 mG	0.18 mG	0.29 mG	0.27 mG
10th Percentile	0.27 mG	0.12 mG	0.30 mG	0.29 mG	0.41 mG	0.35 mG
25th Percentile	0.44 mG	0.24 mG	0.60 mG	0.35 mG	0.66 mG	0.51 mG
50th Percentile	0.75 mG	0.48 mG	0.99 mG	0.60 mG	0.98 mG	0.87 mG
75th Percentile	1.39 mG	1.24 mG	1.78 mG	1.01 mG	1.46 mG	1.41 mG
90th Percentile	2.49 mG	2.44 mG	3.32 mG	1.64 mG	2.18 mG	2.38 mG
95th Percentile	3.89 mG	3.63 mG	5.00 mG	1.77 mG	2.73 mG	3.38 mG
99th Percentile	9.50 mG	9.19 mG	13.5 mG	3.55 mG	5.43 mG	6.16 mG
Mean	1.29 mG	1.11 mG	1.73 mG	0.82 mG	1.22 mG	1.25 mG
Standard Deviation	2.54 mG	2.06 mG	3.09 mG	0.70 mG	0.99 mG	1.51 mG
Geometric Mean	0.80 mG	0.52 mG	1.03 mG	0.64 mG	0.96 mG	0.89 mG
Geometric Standard Deviation	2.50	3.52	2.57	2.06	2.03	2.18

5.7 Other Quantities Recorded During Different Activity Periods

5.7.1 Time Above Given Field Values

The length of time during which the field exceeded a number of specified field levels was analyzed for each activity period. For each specified field level the distribution of exposure times above that level was calculated from the measurements on the 1,012 people, applying the weights described in Section 5.1. Since the duration of each period of activity was less than 24 hours and varied from person to person, the exposure time was expressed in percentage of the period of activity. The results are shown in Figure 5.26 and 5.27 for the period “in bed”, in Figure 5.28 and 5.29 for the period “at home not in bed”, in Figure 5.30 and 5.31 for the period “at work”, in Figure 5.32 and 5.33 for the period “in school”, and in Figure 5.34 and 5.35 for the period “during travel”.

Figure 5.26 shows, for example, that 50% of the people spend more than 50% of the time in bed at fields greater than 0.5 mG. Figure 5.7, with an expanded scale, allows observing time above the highest specified field levels. For example, Figure 5.27 shows that about 1% of the people spend more than 2.5% of the time in bed at fields greater than 16 mG.

In order to compare different activities, the distributions of the times above the (arbitrarily chosen) level of 16 mG were plotted for all the different periods in Figure 5.36.

The U.S. population estimated maximum magnetic fields during different activities are shown in Figure 5.37. Only the 10% largest field values are shown.

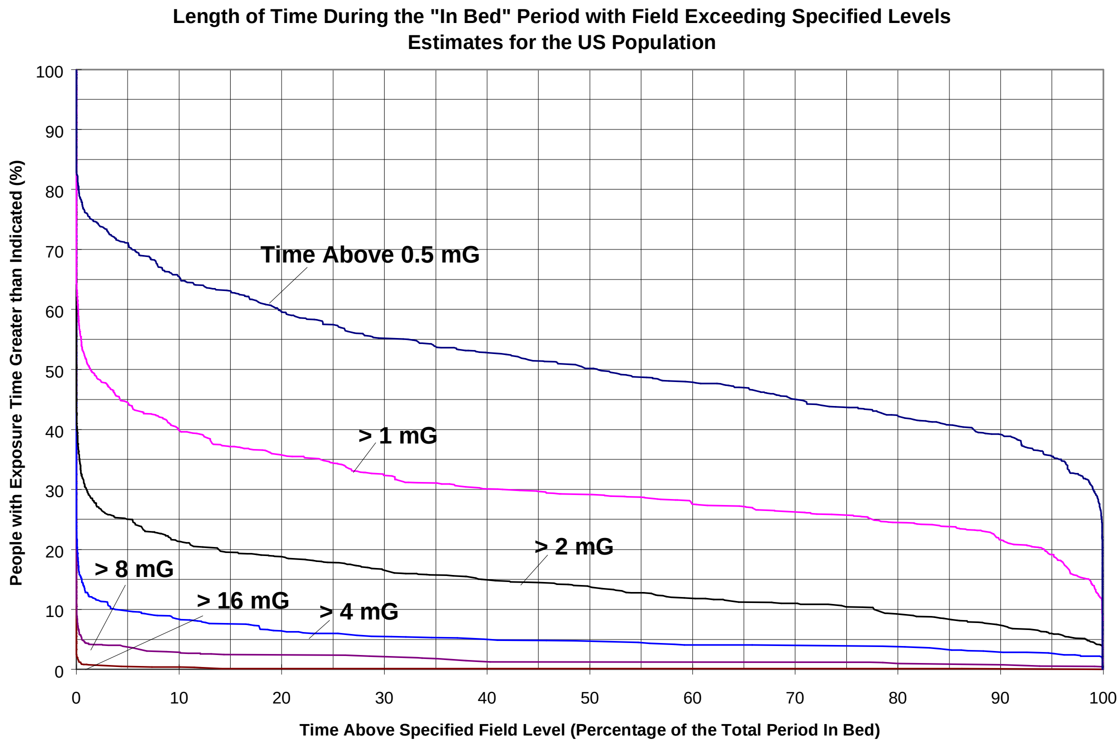

Figure 5.26 Estimated U.S. Population Distributions of Times Above Specified Field Levels during the “In Bed” Period

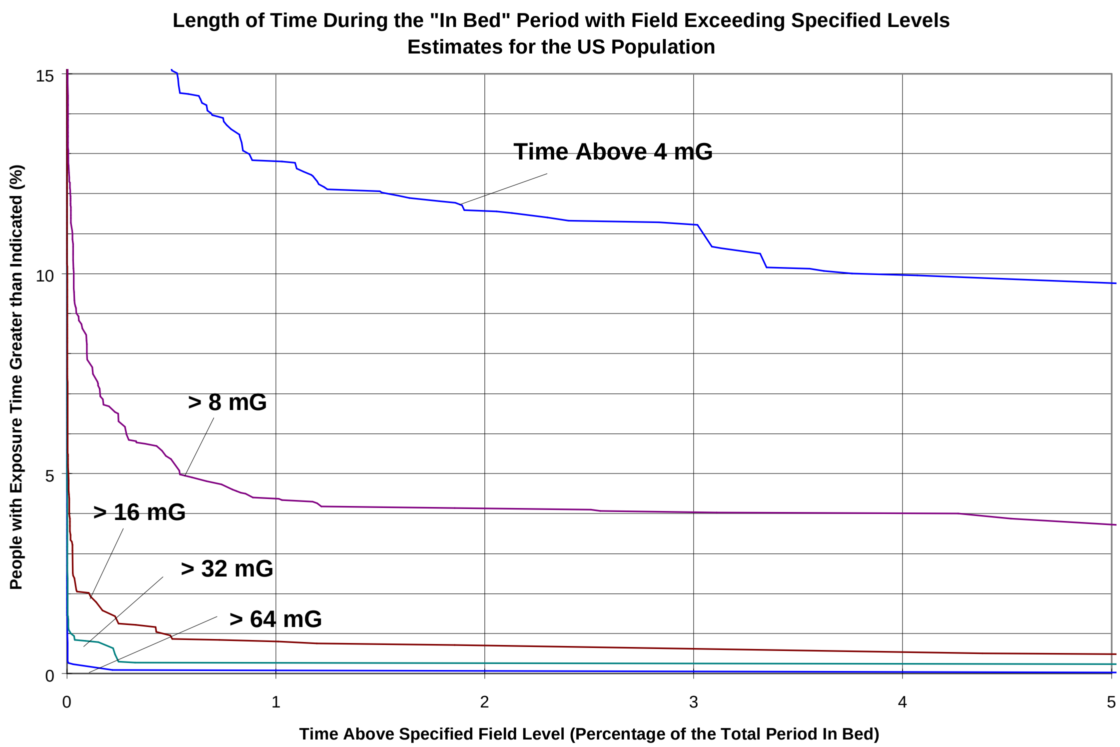

Figure 5.27 Same as Figure 5.26, but with Expanded Scales. Estimated U.S. Population Distributions of Times Above Specified Field Levels During the “In Bed” Period.

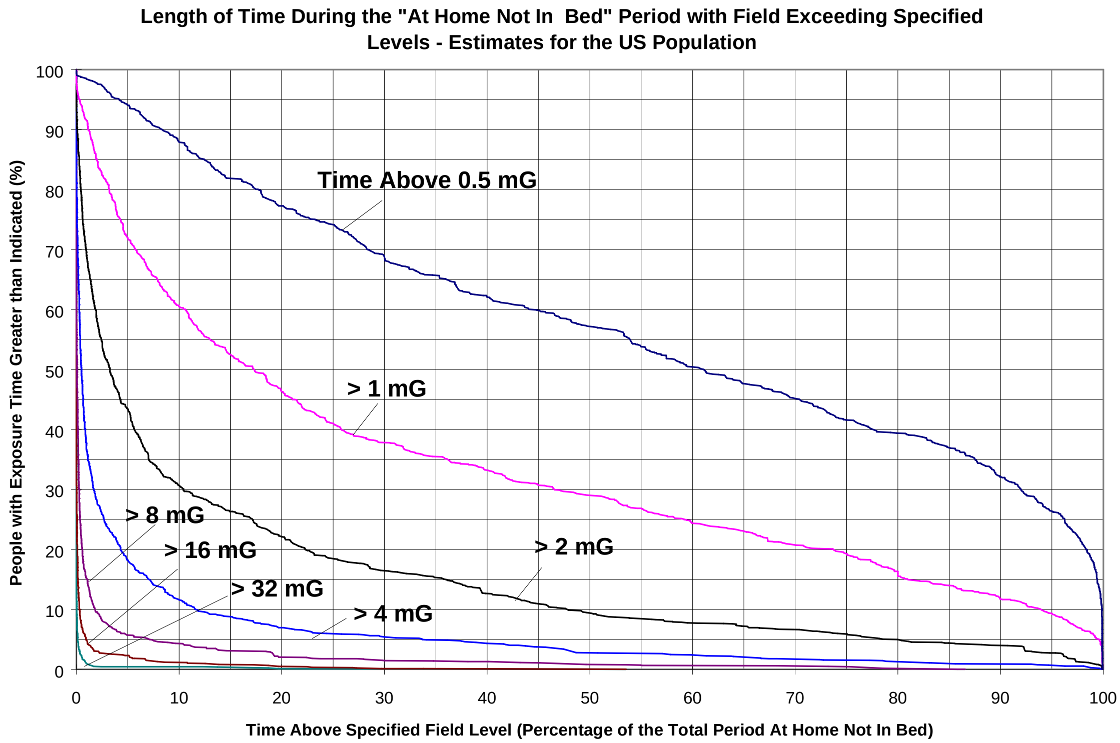

Figure 5.28 Estimated U.S. Population Distributions of Times Above Specified Field Levels during the "At Home Not In Bed" Period

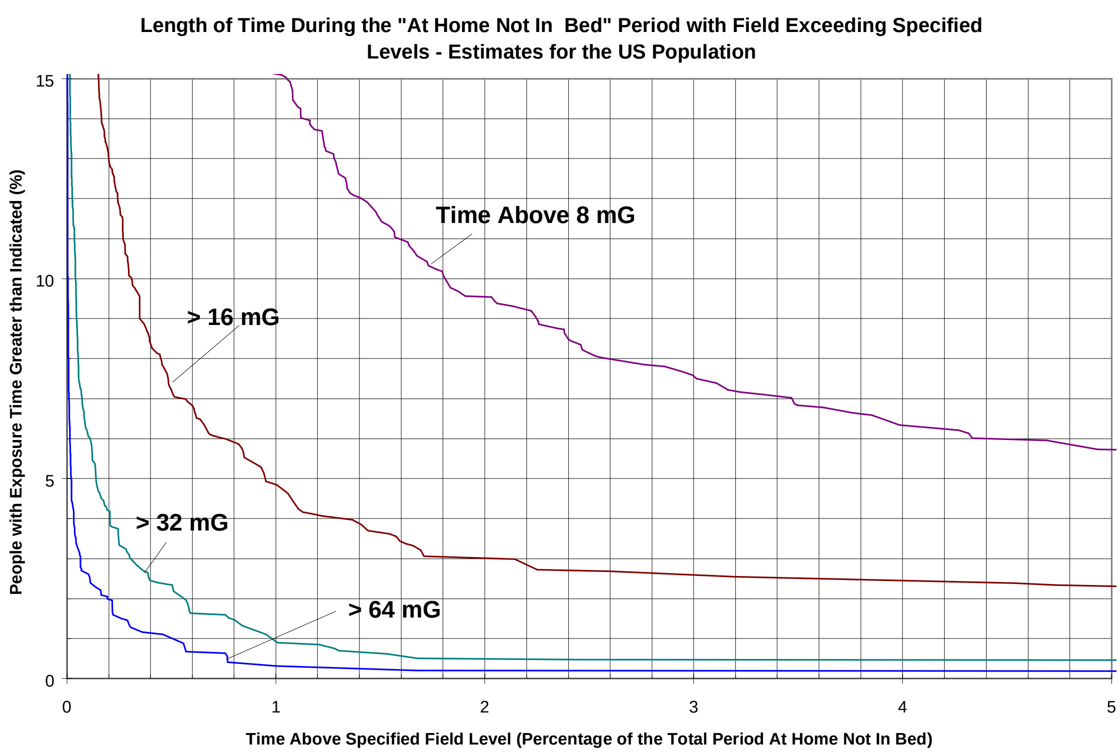

Figure 5.29 Same as Figure 5.28, but with Expanded Scales. Estimated U.S. Population Distributions of Times Above Specified Field Levels while "At Home Not In Bed"

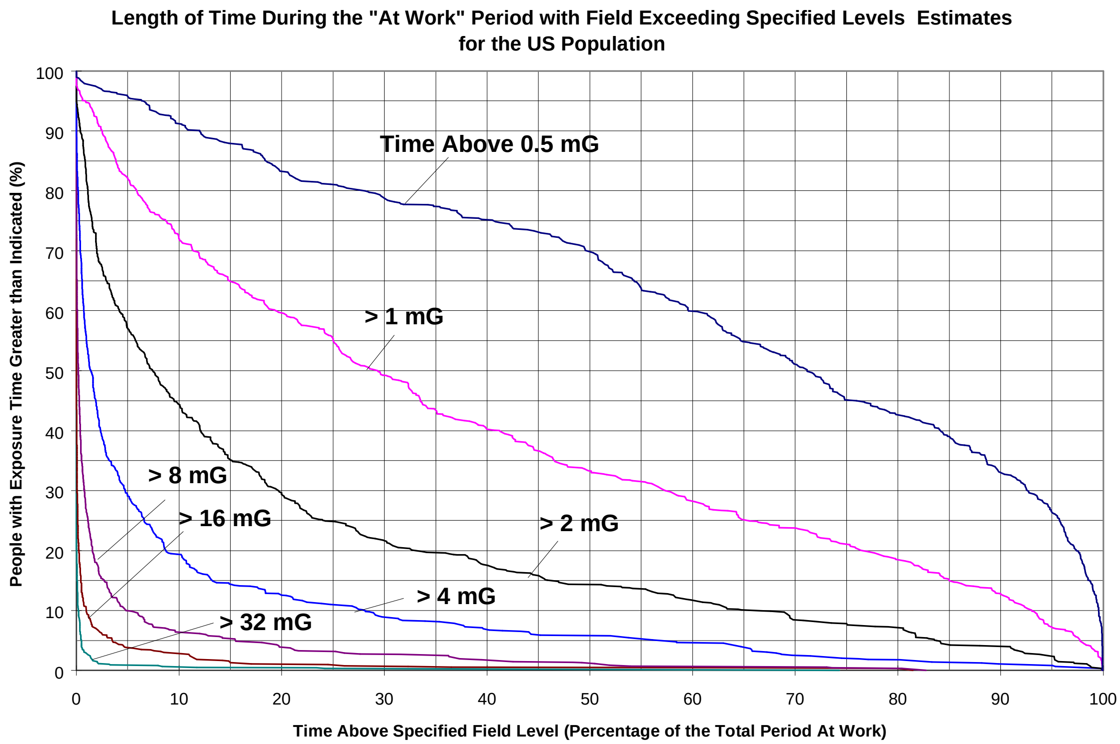

Figure 5.30 Estimated U.S. Population Distributions of Times Above Specified Field Levels during the “At Work” Period

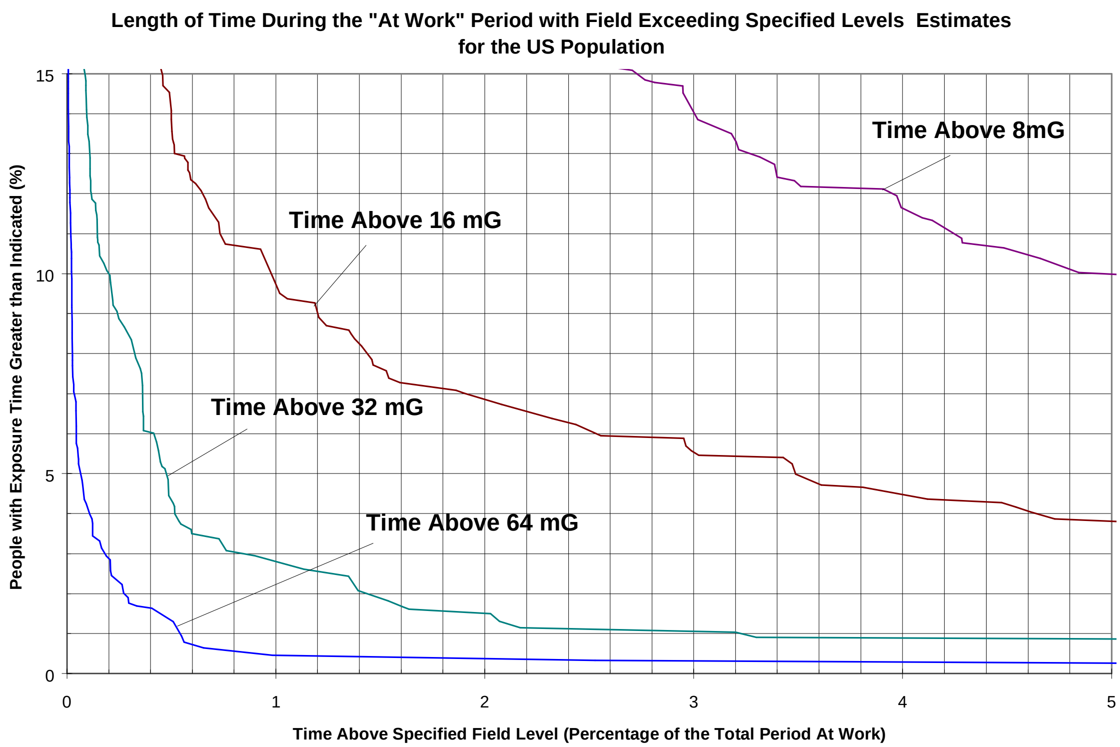

Figure 5.31 Same as Figure 5.30, but with Expanded Scales. Estimated U.S. Population Distributions of Times Above Specified Field Levels during the “At Work” Period.

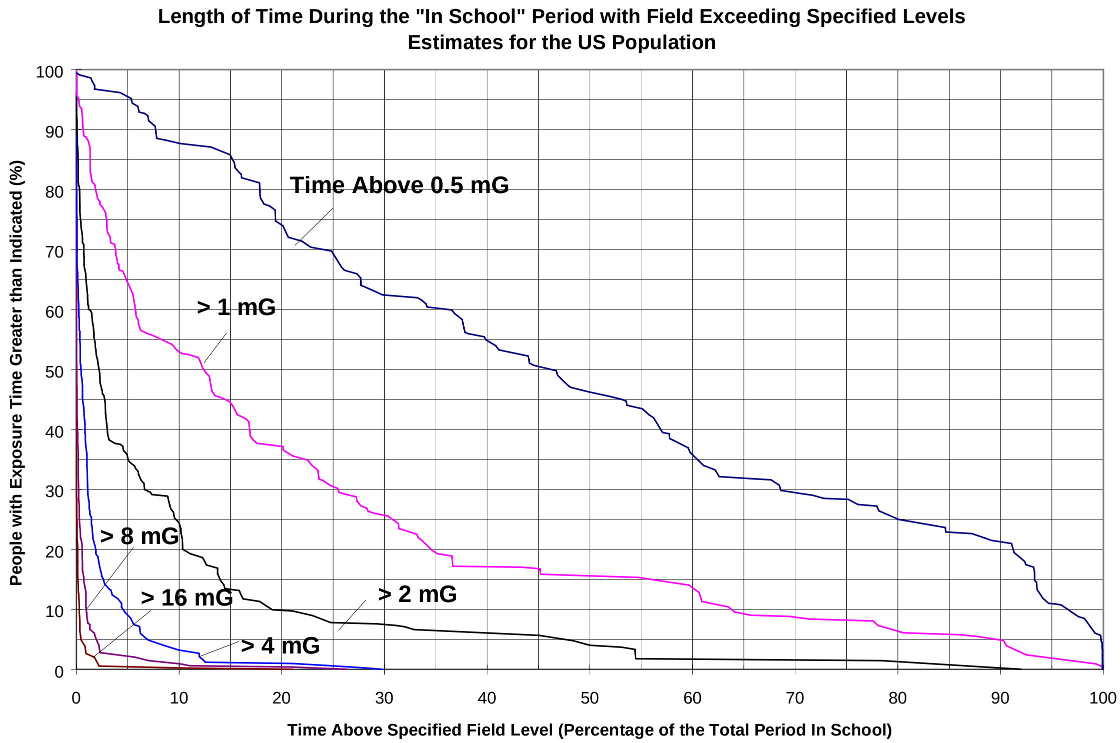

Figure 5.32 Estimated U.S. Population Distributions of Times Above Specified Field Levels during the “In School” Period

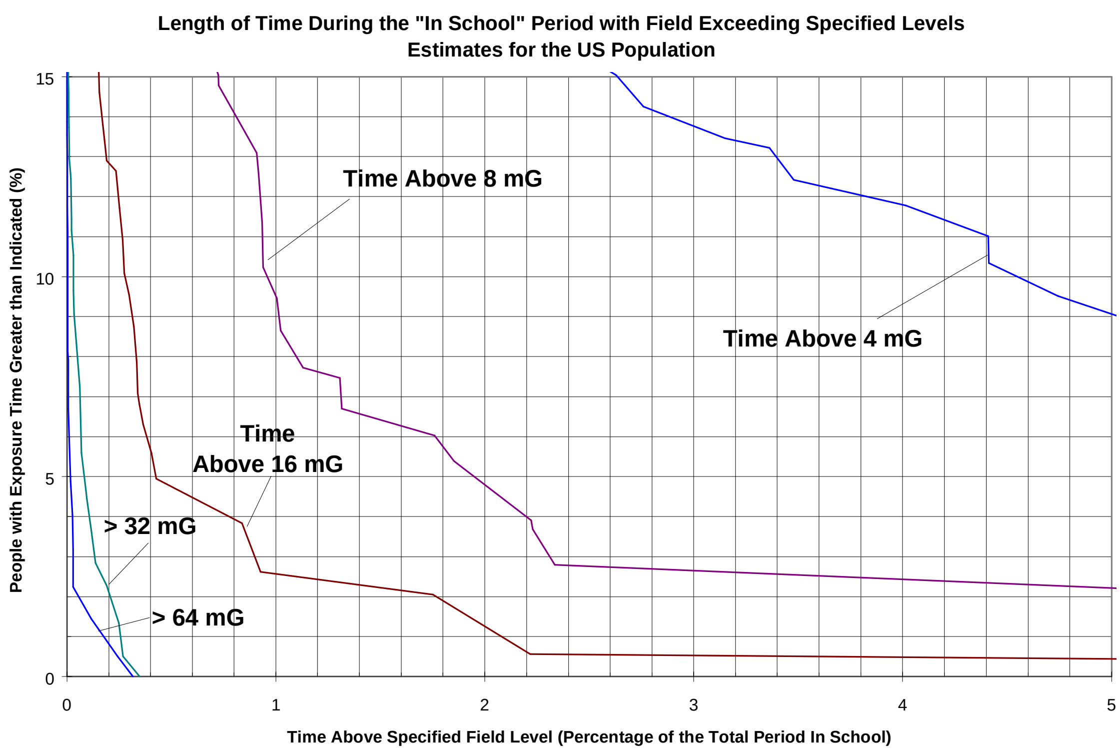

Figure 5.33 Same as Figure 5.32, but with Expanded Scales. Estimated U.S. Population Distributions of Times Above Specified Field Levels during the “In School” Period.

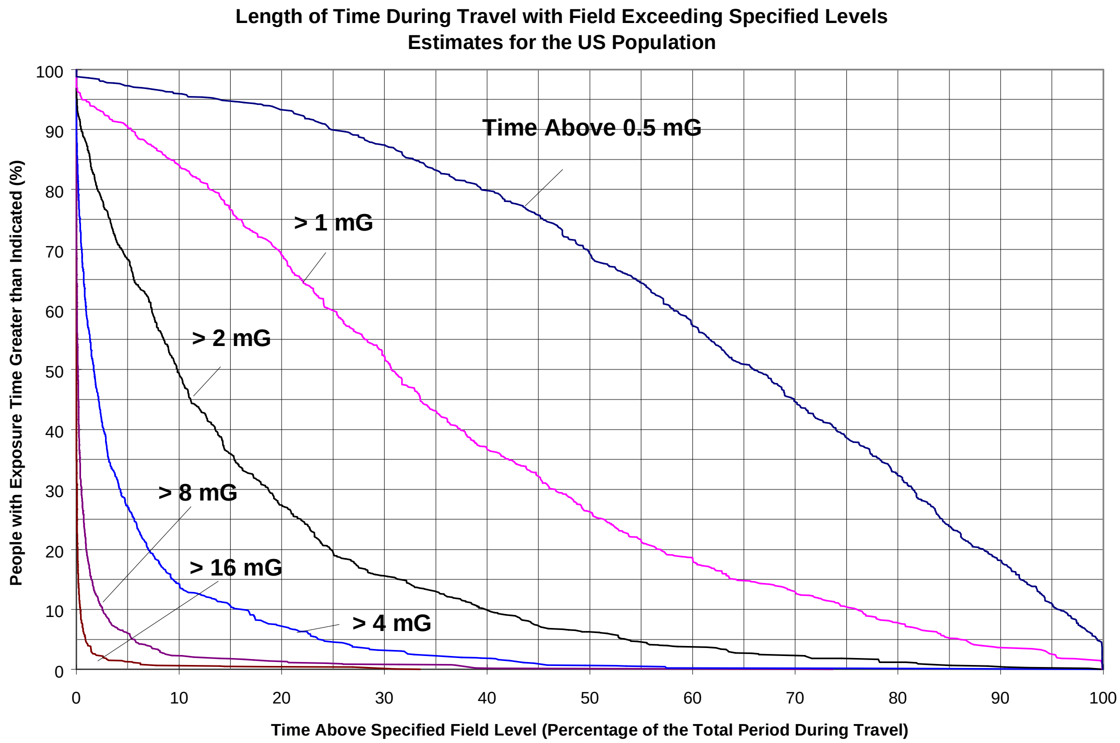

Figure 5.34 Estimated U.S. Population Distributions of Times Above Specified Field Levels “During Travel”

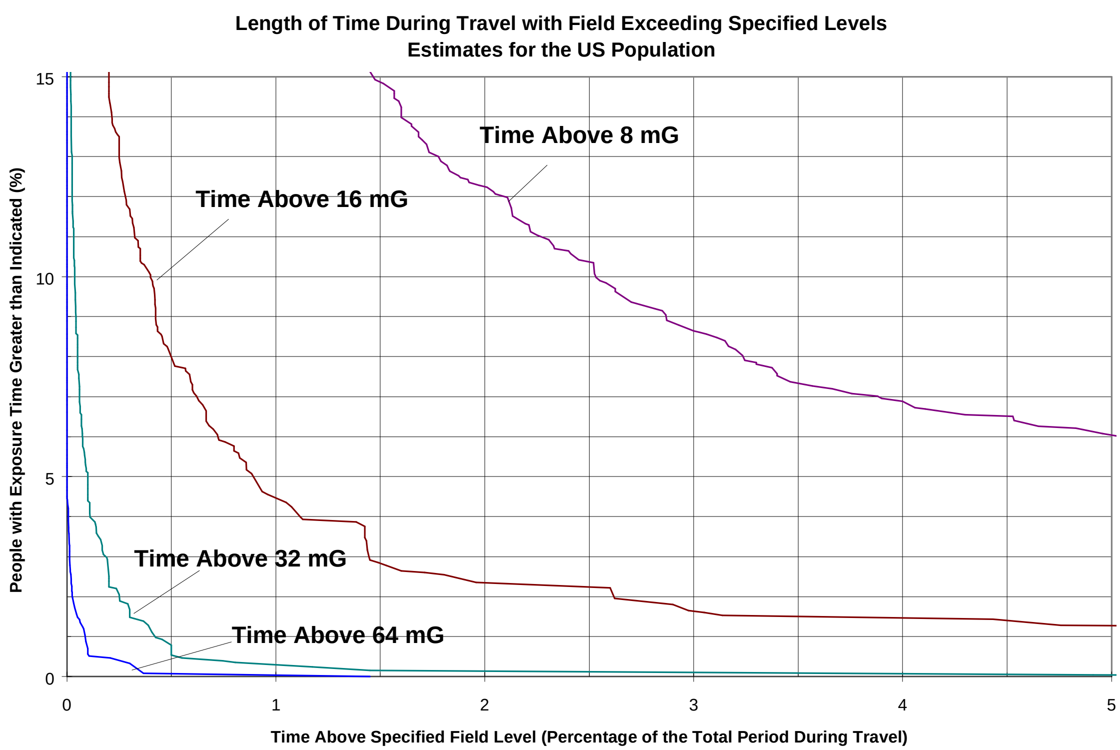

Figure 5.35 Same as Figure 5.34, but with Expanded Scales. Estimated U.S. Population Distributions of Times Above Specified Field Levels “During Travel”

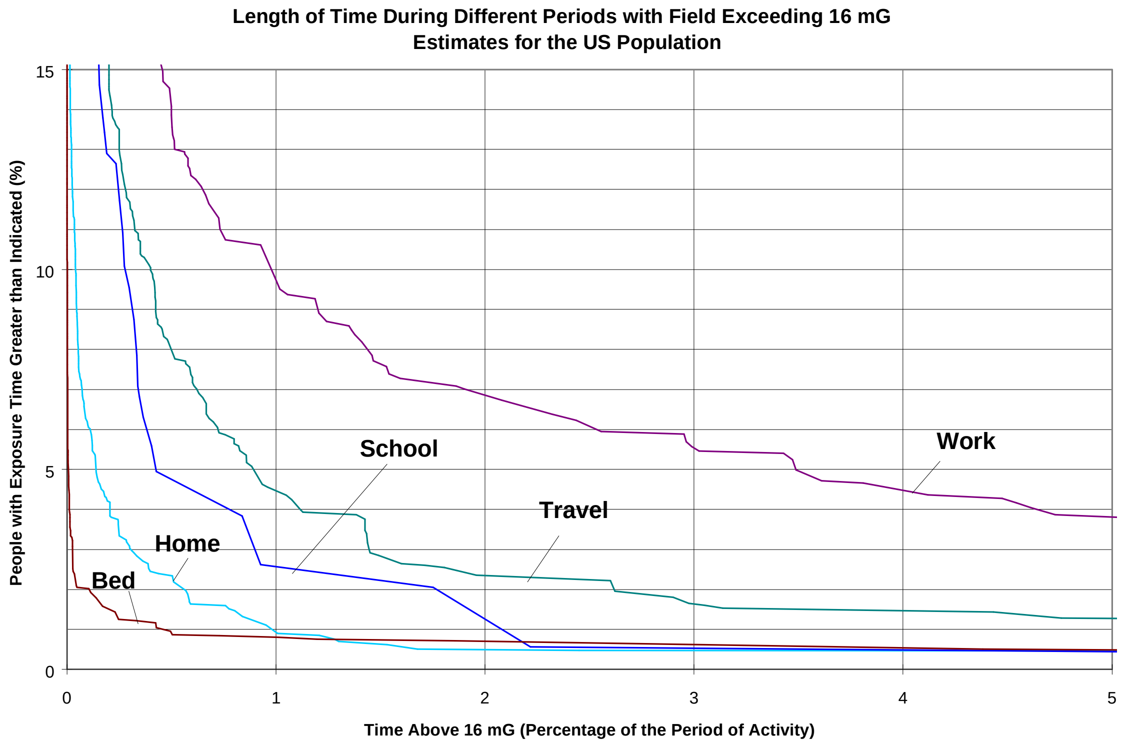

Figure 5.36 Estimated U.S. Population Distributions of Times Above 16 mG for Different Activity Periods.

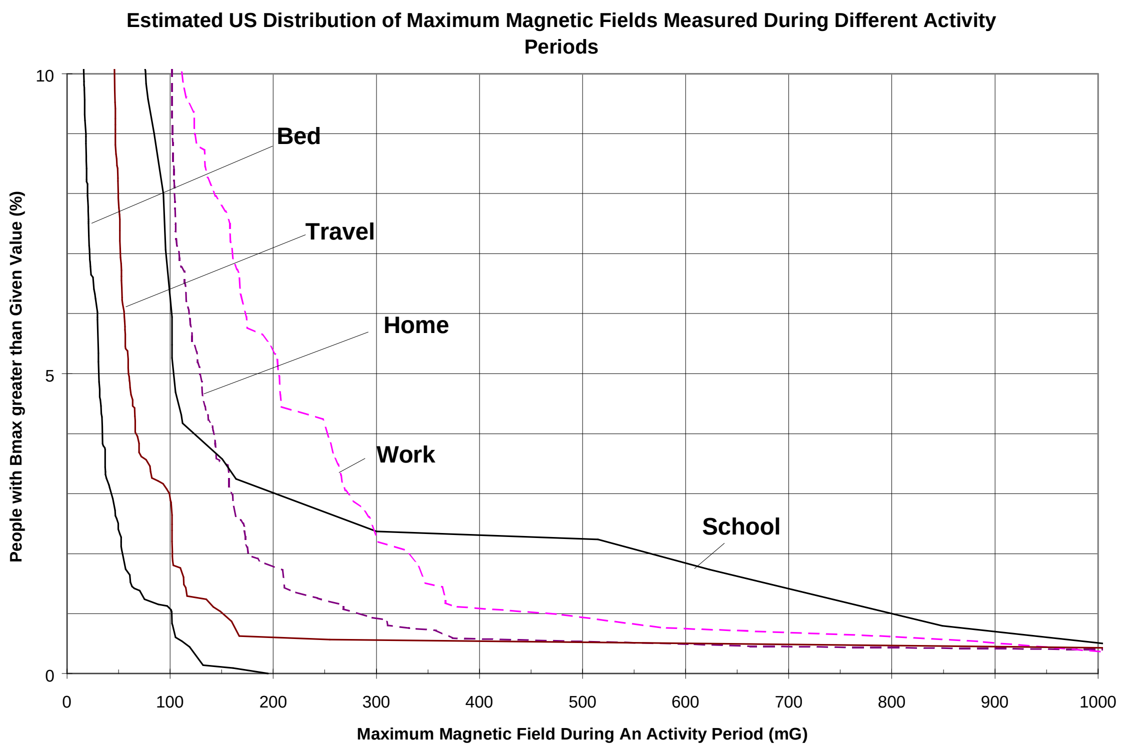

Figure 5.37 Estimated U.S. Population Distribution of Maximum Magnetic Field During Different Activities.

5.7.2 Number of Sudden Field Changes

The number of sudden field changes greater than 2.5 mG, 5 mG, and 10 mG were counted for each activity period within the 24 hour recording period. Since activity periods varied in duration, the number of field changes per hour was calculated. The U.S. population estimates of the distributions of the number of sudden field changes per hour were calculated and plotted for each activity period in Figure 5.38 (in bed), 5.39 (at home not in bed), 5.40 (at work), 5.41 (in school), and 5.42 (during travel). A comparison between data for different activities is shown in Figure 5.43 which shows the number of field changes per hour greater than 10 mG.

Because of the high sampling rate (one record every 0.5 seconds), a sudden field change is more likely to be caused by the application or removal of an electrical load. Since, switching electrical loads may cause transient magnetic fields [3], the number of field changes is, in essence, a proxy for the number of transients. An exception may be provided by the time during travel. Because of the relatively higher speed of traveling by car than by foot, it is possible that a sudden change in reading corresponds to moving in or out of the zone of influence of a source like a power line.

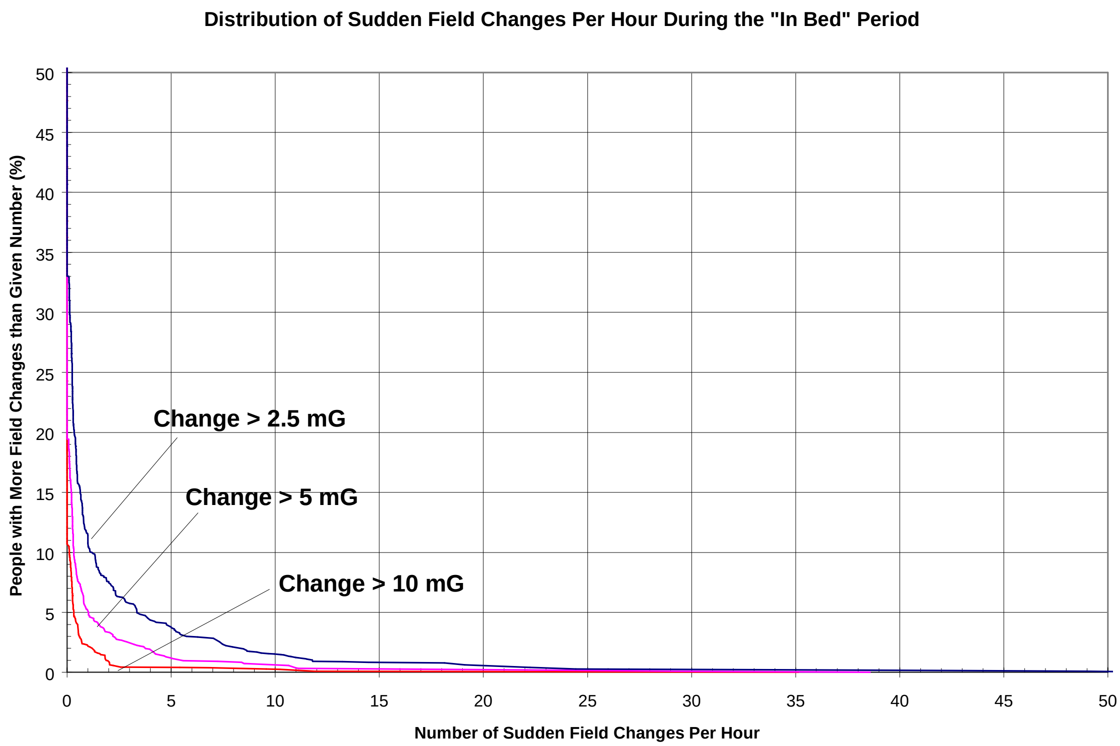

Figure 5.38 Distribution of the Number of Sudden Field Changes per Hour Greater than Given Amounts for the Period “In Bed”

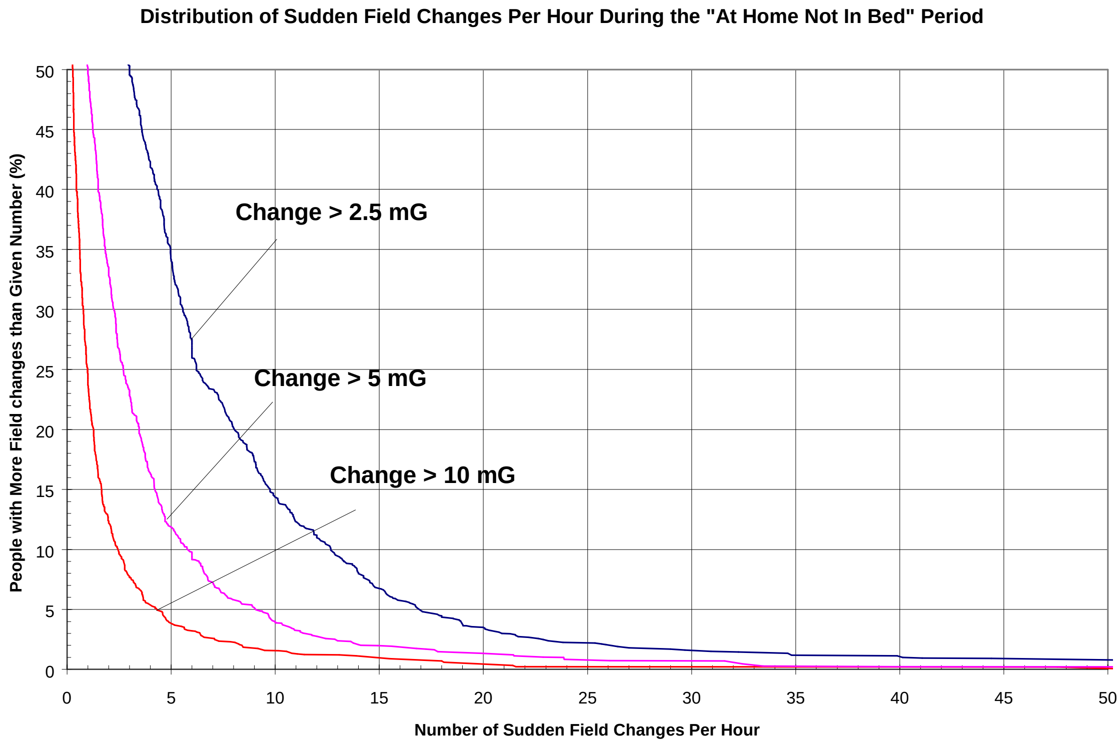

Figure 5.39 Distribution of the Number of Sudden Field Changes per Hour Greater than Given Amounts for the Period “At Home Not In Bed”

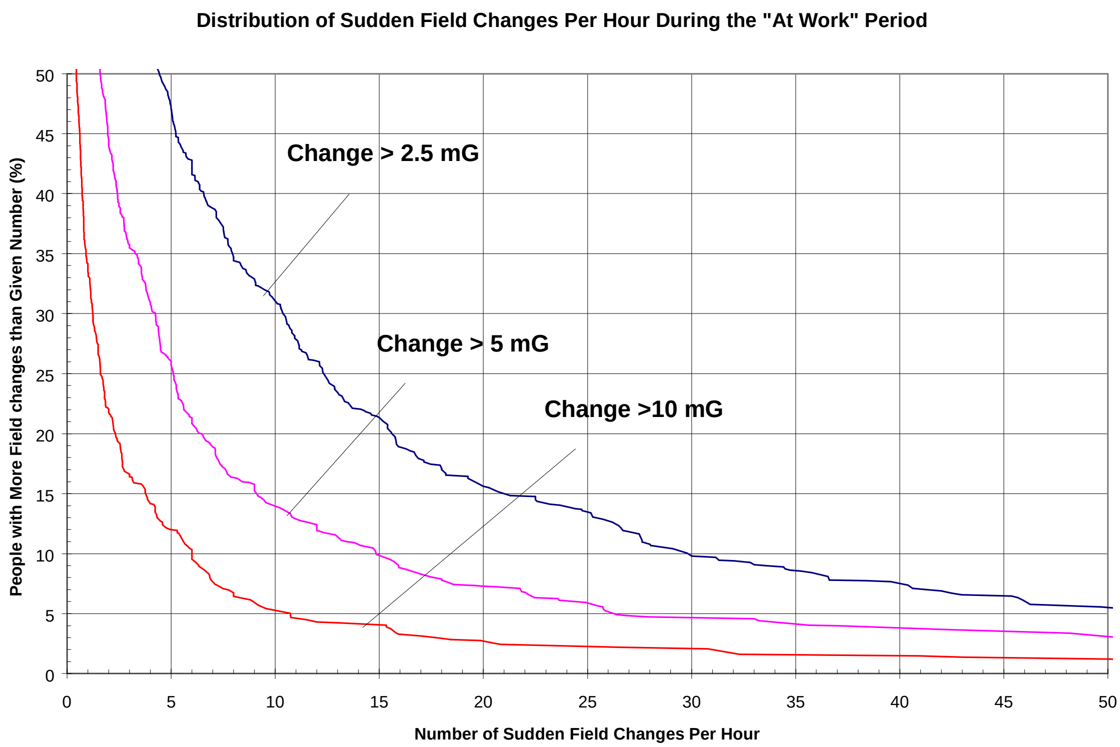

Figure 5.40 Distribution of the Number of Sudden Field Changes per Hour Greater than Given Amounts for the Period “At Work”

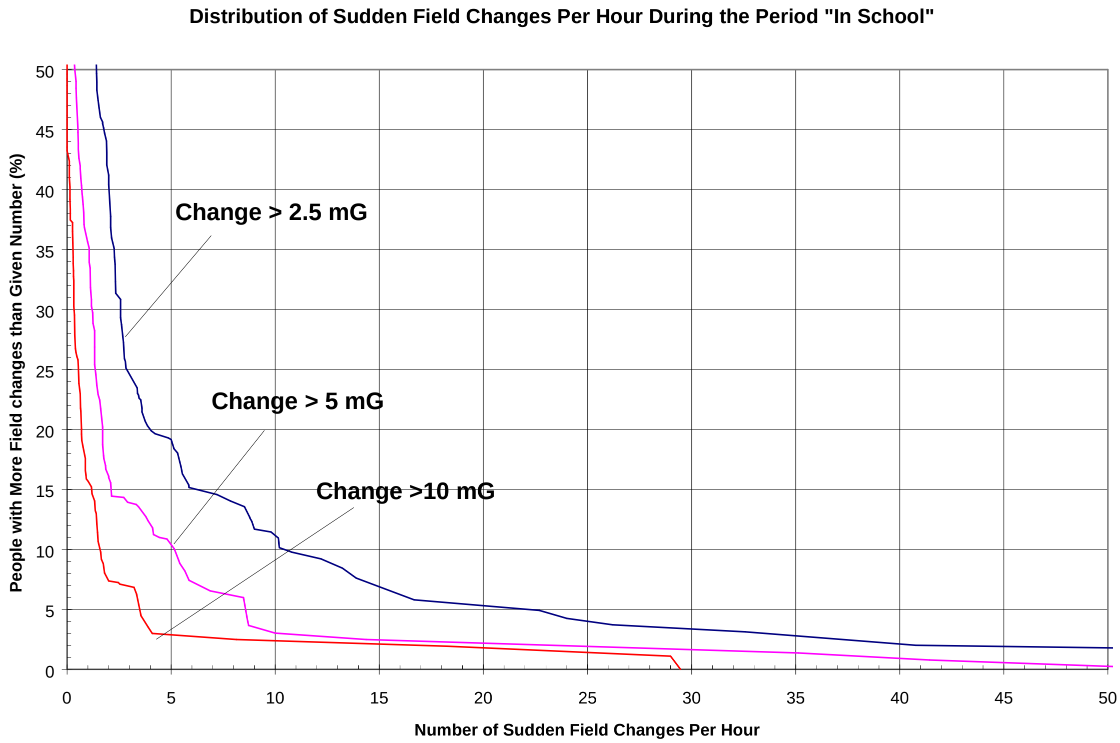

Figure 5.41 Distribution of the Number of Sudden Field Changes per Hour Greater than Given Amounts for the Period “In School”

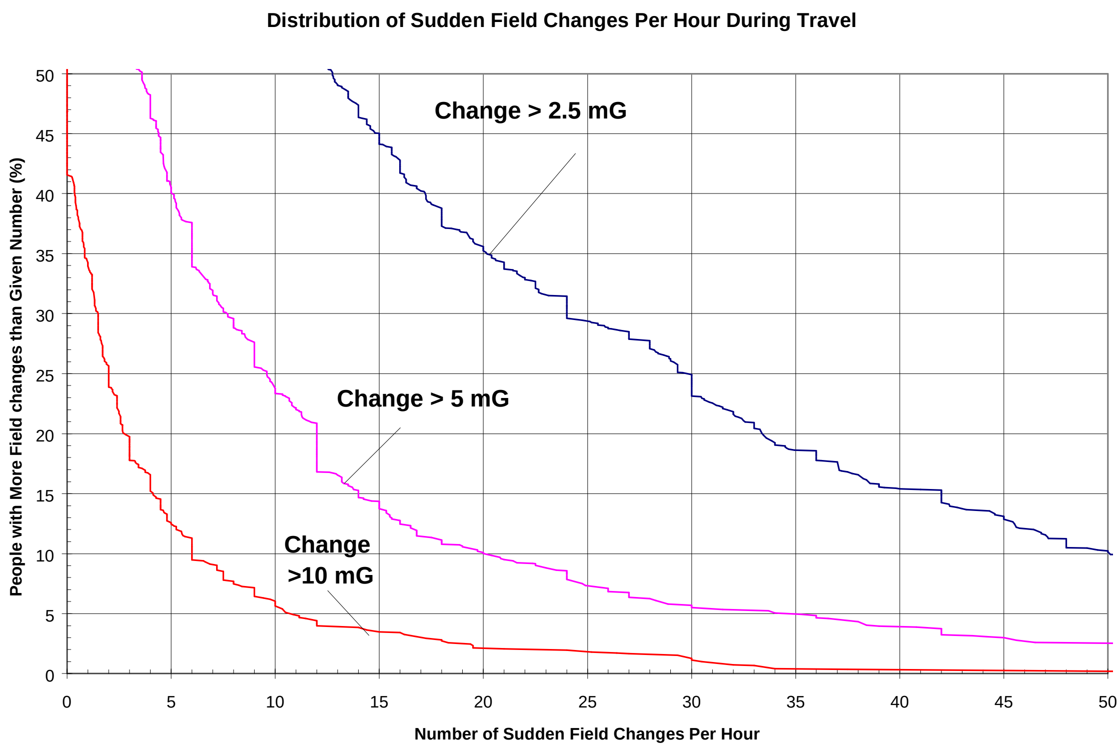

Figure 5.42 Distribution of the Number of Sudden Field Changes per Hour Greater than Given Amounts for the Period “During Travel”

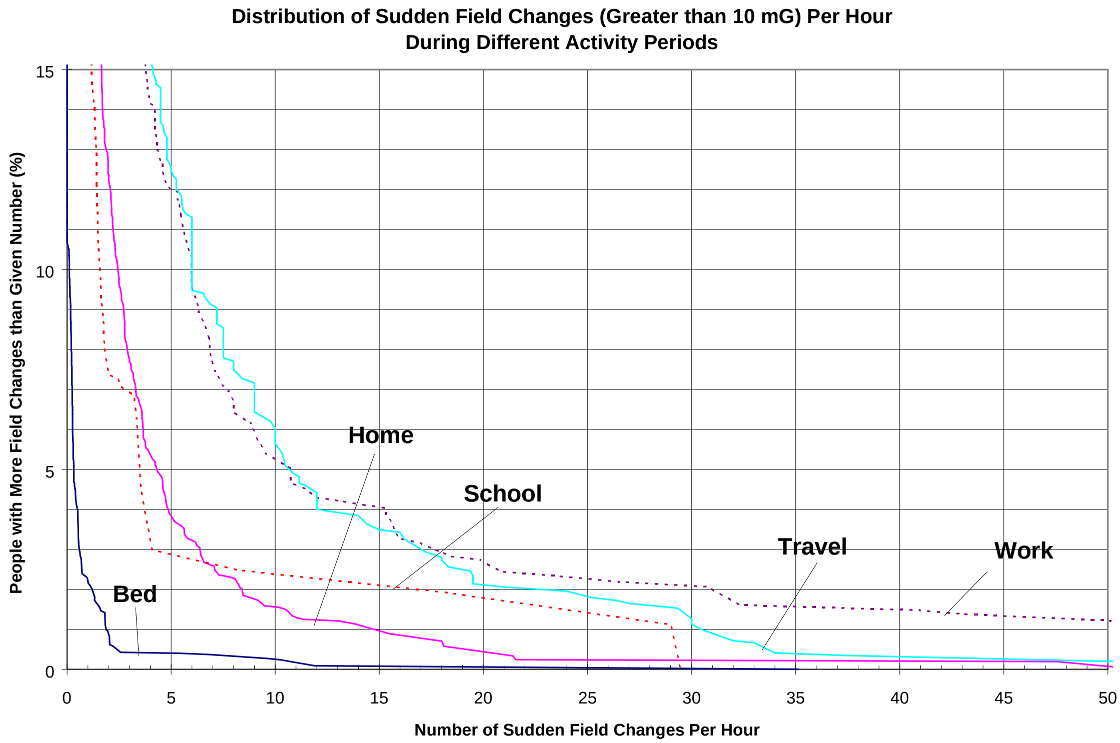

Figure 5.43 Distribution of the Number of Sudden Field Changes per Hour Greater than 10 mG for Different Activities

5.7.3 Length of Time with Constant Field

The total duration of all the periods during which the field was constant in all three axes and greater than 2 mG was calculated for each activity period within the 24 hour recording period. Since activity periods varied in duration, the duration of constant field was expressed in minutes per hour. The U.S. population estimates of the distributions of the duration of constant field were calculated and plotted for each activity period in Figure 5.44. A comparison between data for different activities indicates that the chances for long periods of constant field are higher during the period “in bed”, followed by the periods” at home not in bed” and “at work”.

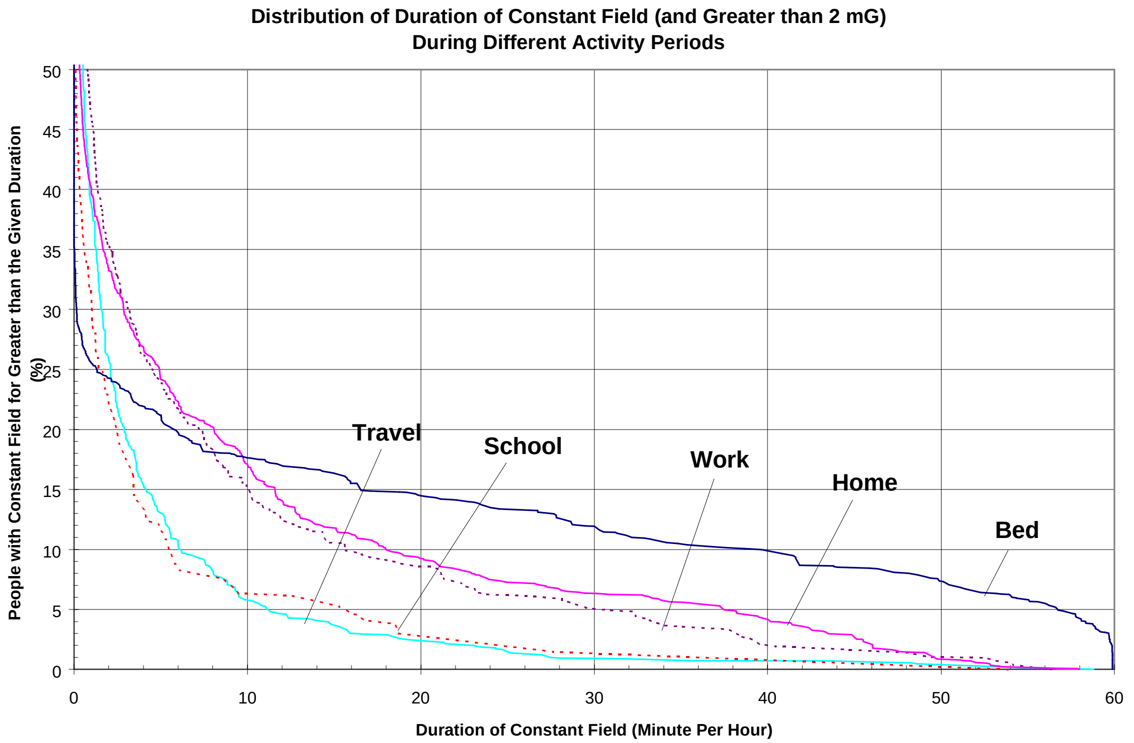

Figure 5.44 Distribution of the Duration of Periods with Constant Field for Different Activities

5.7.4 Intermittence

The average field change between consecutive records (please note that the recording rate is one record every 0.5 second) was expressed in three different ways: as a percentage of 1 mG, as a percentage of the standard deviation, and as a percentage of the average. The estimated distributions of these three indices of intermittence for different activity periods are shown in Figures 5.45 to 5.47. The activity periods with the largest absolute values of the intermittence are “travel” and “work” while the intermittence is lowest for the “in bed” period. The same ranking occurs if the intermittence is expressed as a percentage of the average field during the period of activity. However, when the intermittence is referred to the standard deviation, the “in bed” period has some of the largest values (apparently because the standard deviation is often very low).

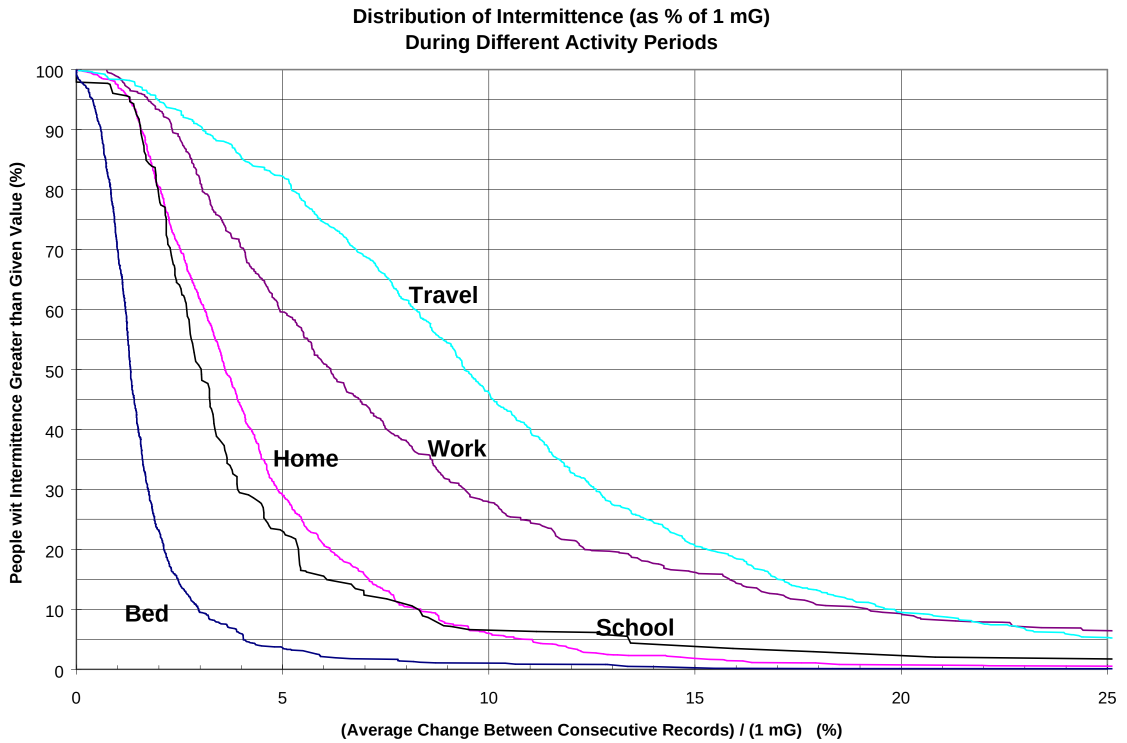

Figure 5.45 Distribution of Intermittence (Expressed in Percentage of 1 mG) for Different Activities

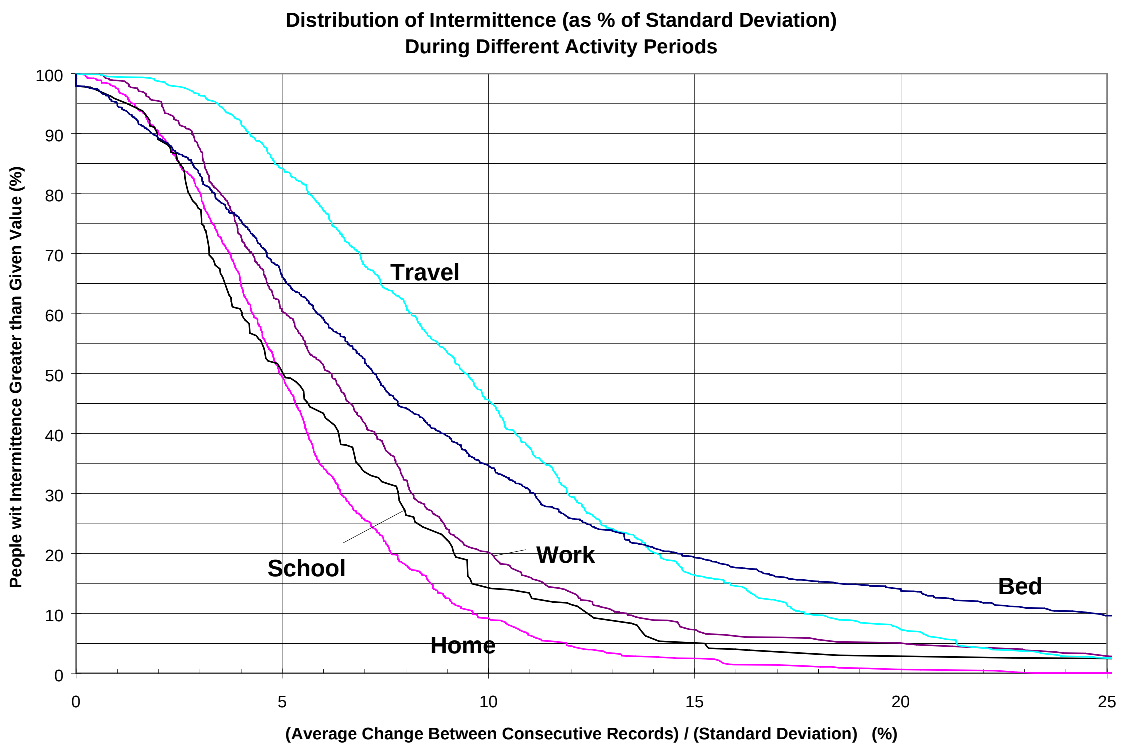

Figure 5.46 Distribution of Intermittence (Expressed in Percentage of the Standard Deviation) for Different Activities

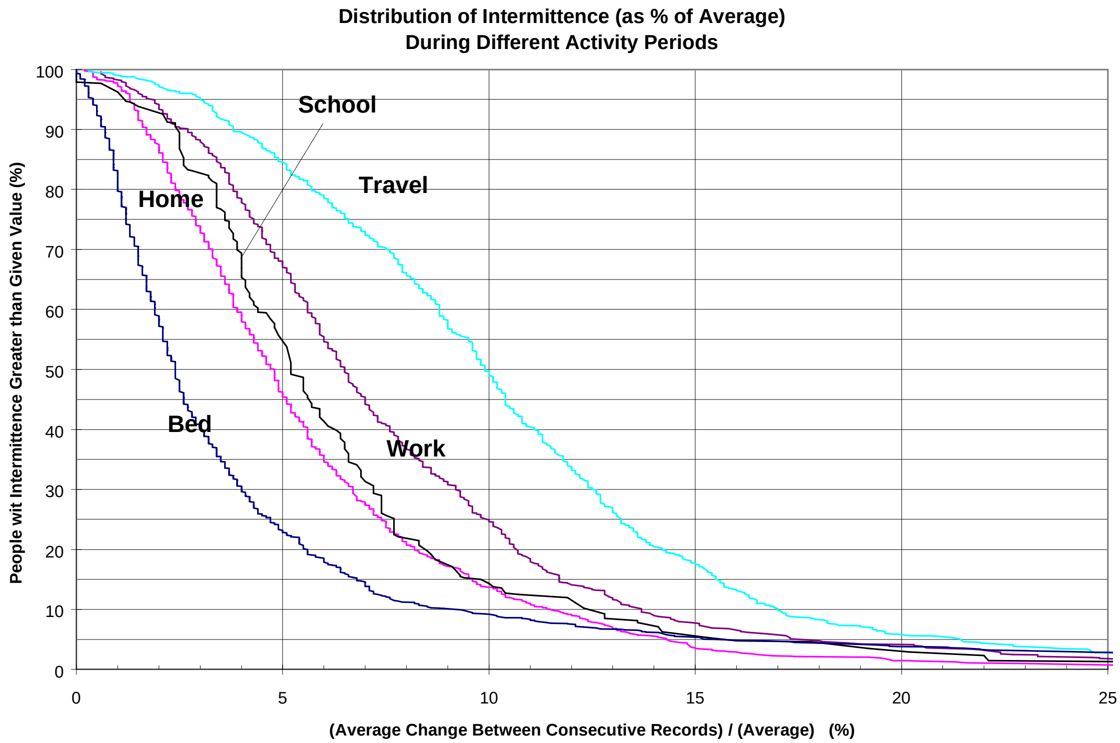

Figure 5.47 Distribution of Intermittence (Expressed in Percentage of the Average) for Different Activities

5.7.5 Correlation between Exposures during Different Activities

Correlation coefficients were calculated between average magnetic field obtained during different activity periods: bed, home not in bed, work, travel, other, and the entire 24-hour period. The data used for the calculations were those of the 525 people who spent at least one hour at work during a 24-hour period. The correlation coefficients are shown in Table 5-8. The table shows that the average field for the 24-hour period is well correlated with the average magnetic fields measured in bed, at home not in bed, and at work, but none of these three period has a generalized dominant effect on the 24-hour average, although that may happen for selected individuals. There is little correlation between bed and home not in bed. There is no correlation between residential and work exposure.

Table 5-8 Correlation Coefficients between TWAs during Different Activity Periods

	Exposure Metric: TWA					
	Bed	Home	Work	Travel	Other	24-Hour
Bed	1.00	0.33	0.00	0.04	0.06	0.66
Home		1.00	0.04	0.08	0.03	0.64
Work			1.00	0.05	0.09	0.60
Travel				1.00	0.06	0.09
Other					1.00	0.12
24-Hour						1.00

Tables 5-9 to 5-14 show the correlation coefficients between exposures during different activity periods, using different metrics: time above 4 mG, time above 16 mG, maximum field, number of sudden field changes, time with constant field, and intermittence .

Table 5-9 Correlation Coefficients between Exposures during Different Activities

	Exposure Metric: Time Above 4 mG					
	Bed	Home	Work	Travel	Other	24-Hour
Bed	1.00	0.76	0.03	0.18	0.00	0.75
Home		1.00	0.08	0.30	0.05	0.77
Work			1.00	0.27	0.03	0.62
Travel				1.00	0.01	0.39
Other					1.00	0.11
24-Hour						1.00

Table 5-10 Correlation Coefficients between Exposures during Different Activities

	Exposure Metric: Time Above 16 mG					
	Bed	Home	Work	Travel	Other	24-Hour
Bed	1.00	0.93	0.00	0.00	0.00	0.77
Home		1.00	0.09	0.03	0.00	0.81
Work			1.00	0.10	0.01	0.62
Travel				1.00	0.01	0.07
Other					1.00	0.03
24-Hour						1.00

Table 5-11 Correlation Coefficients between Exposures during Different Activities

	Exposure Metric: Maximum field					
	Bed	Home	Work	Travel	Other	24-Hour
Bed	1.00	0.01	0.01	0.08	0.06	0.05
Home		1.00	0.01	0.02	0.02	0.40
Work			1.00	0.02	0.01	0.72
Travel				1.00	0.01	0.32
Other					1.00	0.37
24-Hour						1.00

Table 5-12 Correlation Coefficients between Exposures during Different Activities

	Exposure Metric: Number of Field Changes Greater than 10 mG					
	Bed	Home	Work	Travel	Other	24-Hour
Bed	1.00	0.03	0.01	0.05	0.00	0.05
Home		1.00	0.01	0.00	0.02	0.35
Work			1.00	0.03	0.01	0.90
Travel				1.00	0.02	0.25
Other					1.00	0.01
24-Hour						1.00

Table 5-13 Correlation Coefficients between Exposures during Different Activities

	Exposure Metric: Time with Constant Field Greater than 2 mG					
	Bed	Home	Work	Travel	Other	24-Hour
Bed	1.00	0.55	0.00	0.12	0.06	0.80
Home		1.00	0.00	0.13	0.08	0.73
Work			1.00	0.04	0.05	0.36
Travel				1.00	0.09	0.21
Other					1.00	0.19
24-Hour						1.00

Table 5-14 Correlation Coefficients between Exposures during Different Activities

	Exposure Metric: Intermittence (Average Change between Consecutive Records)					
	Bed	Home	Work	Travel	Other	24-Hour
Bed	1.00	0.00	0.01	0.03	0.06	0.00
Home		1.00	0.01	0.02	0.03	0.94
Work			1.00	0.00	0.17	0.32
Travel				1.00	0.03	0.04
Other					1.00	0.04
24-Hour						1.00

5.8 Effect of Parameters on the Average Magnetic Field during Personal Exposure Measurements

5.8.1 Effect of Gender on 24-Hour Average Field

The 1,012 participants were divided by gender. The sample included 522 females and 490 males. Their 24-hour average fields, properly weighted to make estimates for the U.S. population, provided the distributions shown in Figure 5.48 and, with an expanded vertical scale, in Figure 5.49. The data are also shown in Table 5.15.

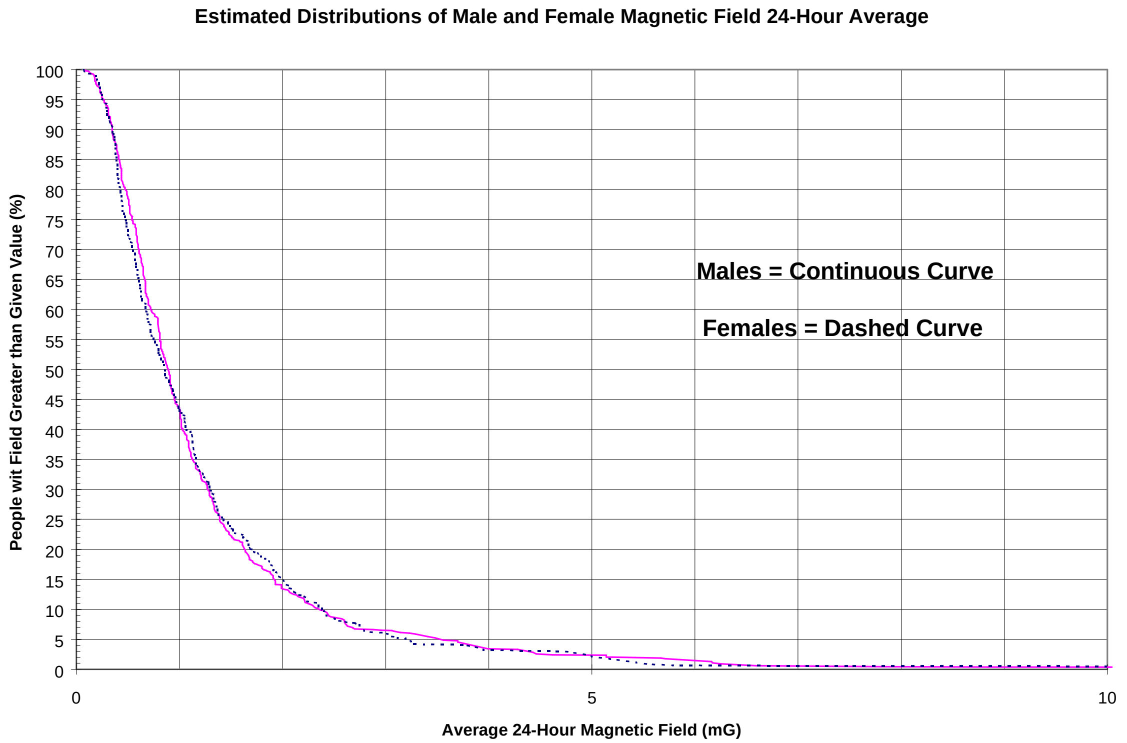

Figure 5.48 Estimated Distributions of 24-Hour Average Magnetic Field for Males and Females.

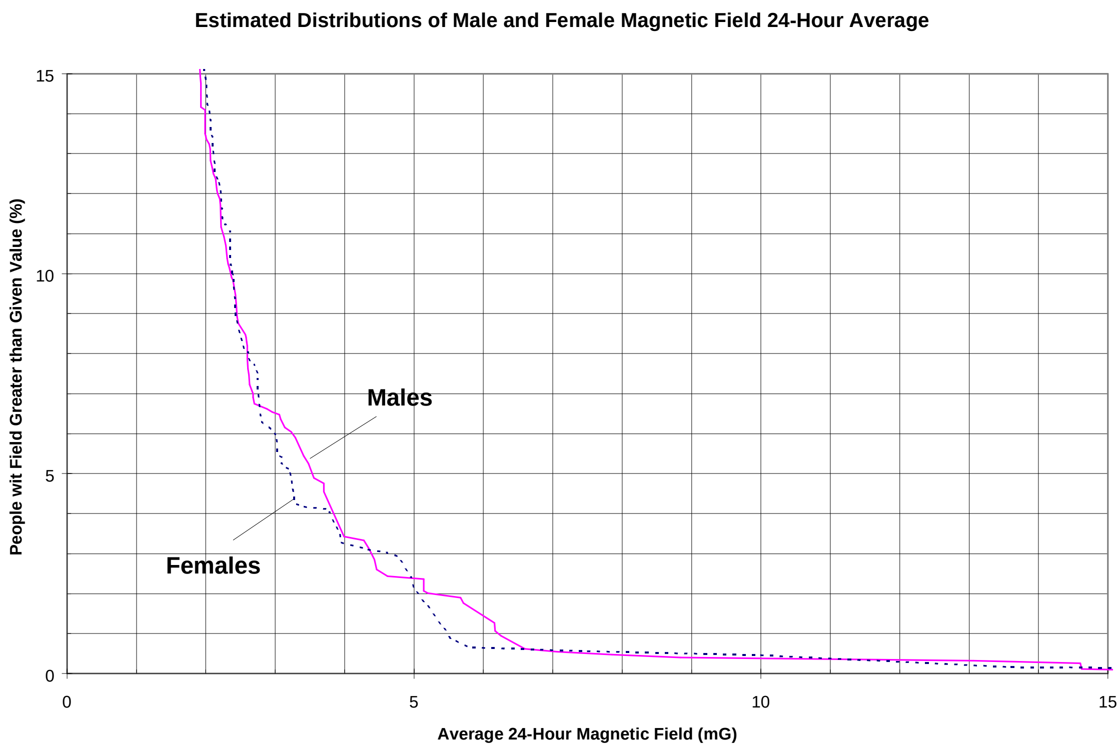

Figure 5.49 Same as Figure 5.48 but with an Expanded Vertical Scale. Estimated Distributions of 24-Hour Average Magnetic Field for Males and Females.

5.8.2 Effect of Age on 24-Hour Average Field

The 1,012 participants were divided by age: 28 pre-schoolers (0-4 year old), 110 school-age children (5-17 year old), 716 working age people (18-64 year old), and 158 retirement age people (65 year old or older). Their 24-hour average fields, properly weighted to make estimates for the U.S. population, provided the distributions shown in Figure 5.50 and, with an expanded vertical scale, in Figure 5.51. The data are also shown in Table 5.15.

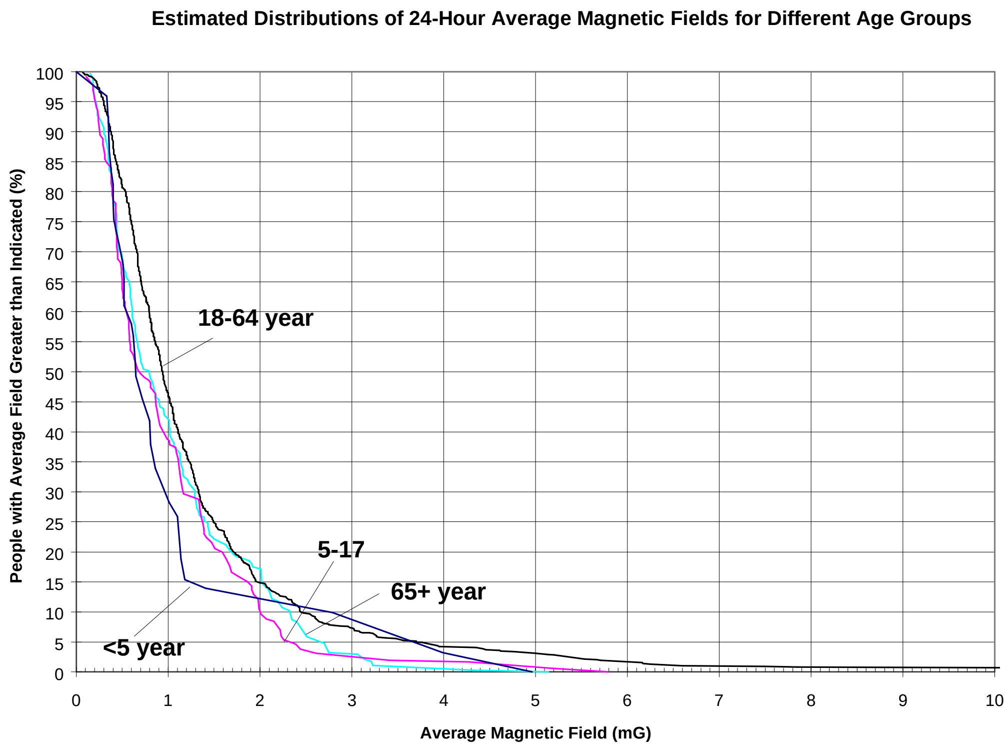

Figure 5.50 Estimated Distributions of 24-Hour Average Magnetic Field for People Belonging to Different Age Groups

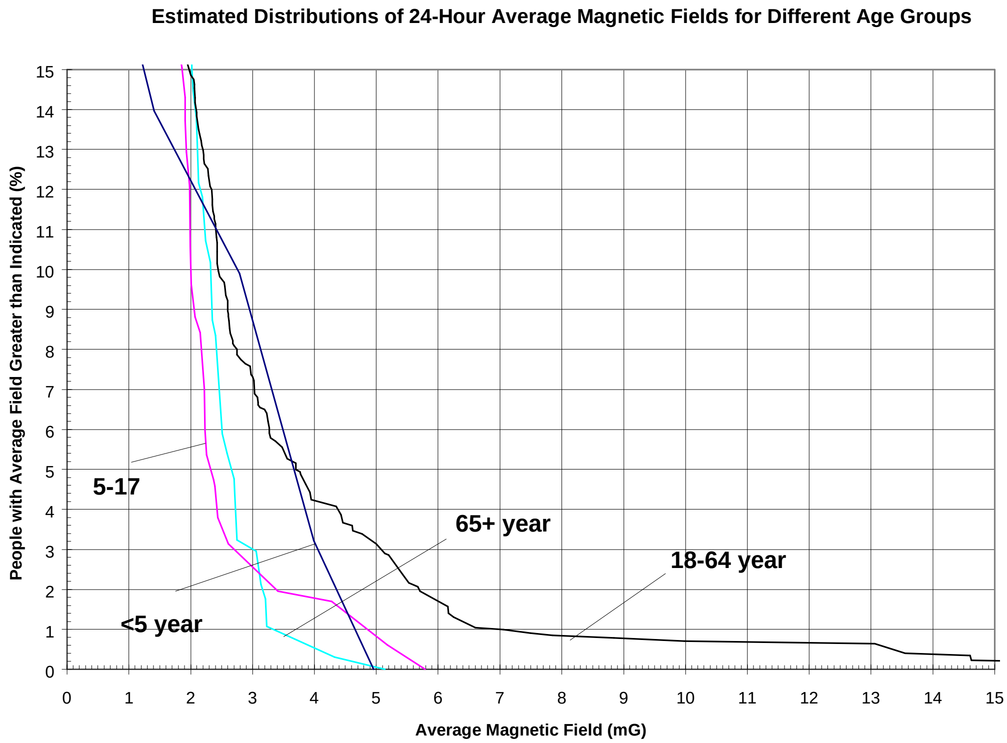

Figure 5.51 Same as Figure 5.50 but with an Expanded Vertical Scale. Estimated Distributions of 24-Hour Average Magnetic Field for People Belonging to Different Age Groups

5.8.3 Effect of Region on 24-Hour Average Field

The 1,012 participants were divided by region: 227 in the Northeast, 257 in the Midwest, 322 in the South, and 206 in the West. Their 24-hour average fields, properly weighted to make estimates for each region, provided the distributions shown in Figure 5.52 and, with expanded scales, in Figure 5.53. The data are also shown in Table 5.15.

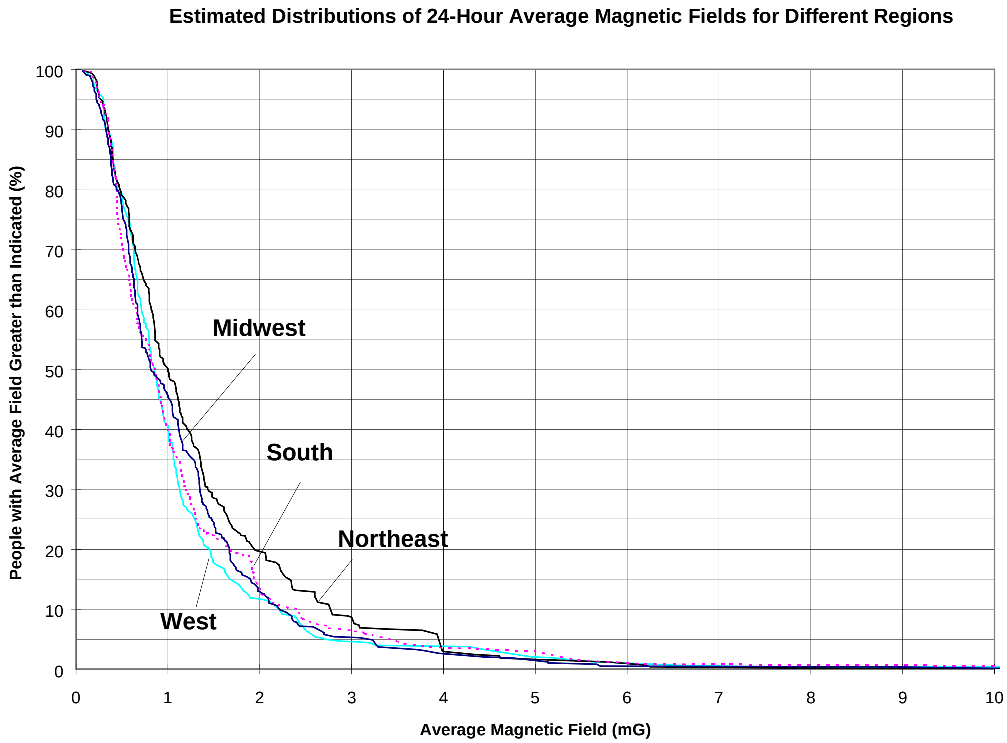

Figure 5.52 Estimated Distributions of 24-Hour Average Magnetic Field for People in Different Regions

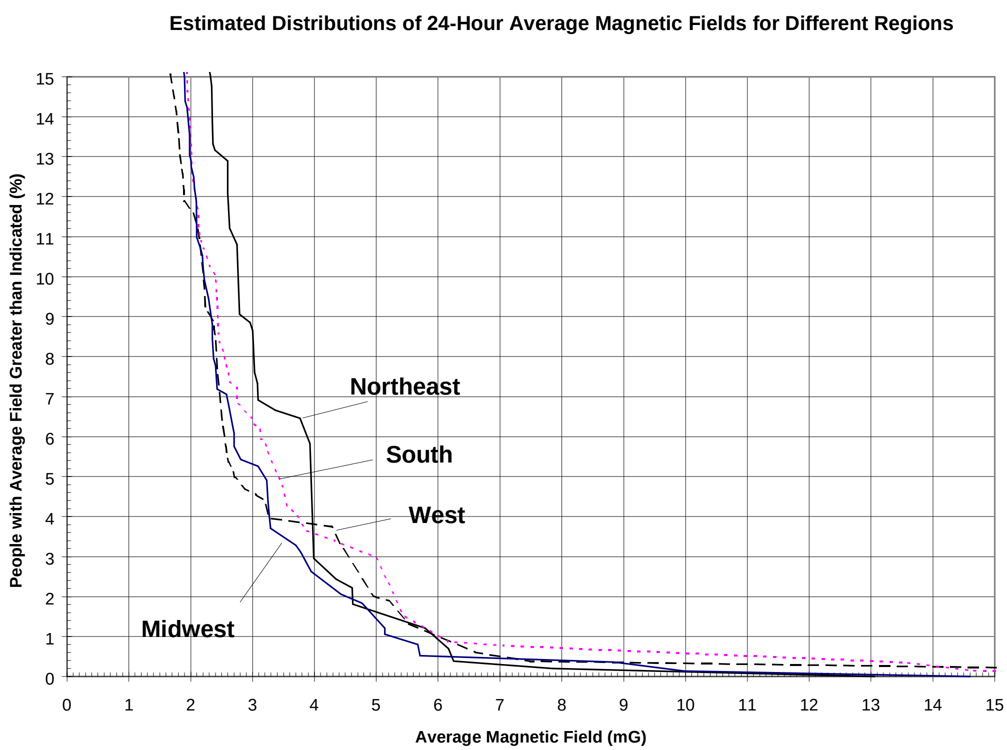

Figure 5.53 Same as Figure 5.52 but with an Expanded Vertical Scale. Estimated Distributions of 24-Hour Average Magnetic Field for People in Different Regions

Table 5-15 Percentile Values and Other Parameters of the Distributions of Average Magnetic Field of Different Groups Differentiated by Gender, Age, or Region

		24-Hour Average Magnetic Field Distributions Percentile Values (mG)								
		1st	5th	10th	25th	50th	75th	90th	95th	99th
By Gender	Males	0.17	0.27	0.35	0.54	0.89	1.39	2.36	3.54	6.22
	Females	0.19	0.25	0.35	0.47	0.86	1.42	2.38	3.21	5.48
By Age Group	Pre-School		0.33	0.35	0.42	0.65	1.11	2.76	3.67	
	School Age	0.12	0.21	0.25	0.43	0.68	1.37	2	2.32	4.86
	Working Age	0.18	0.3	0.38	0.6	0.94	1.49	2.45	3.7	6.97
	Retirement Age	0.18	0.21	0.3	0.44	0.79	1.41	2.32	2.66	3.33
By Region	Midwest	0.13	0.22	0.33	0.51	0.65	1.48	2.22	3.19	5.26
	Northeast	0.19	0.27	0.35	0.58	1	1.66	2.77	3.95	5.95
	South	0.18	0.26	0.35	0.46	0.86	1.31	2.4	3.42	6.03
	West	0.15	0.3	0.33	0.57	0.85	1.29	2.2	2.71	6.01

		Mean	Standard Deviation	Geometric Mean	Geometric Standard Dev.
By Gender	Males	1.25	1.41	0.9	2.16
	Females	1.25	1.6	0.88	2.21
By Age Group	Pre-School	1.12	1.17	0.8	2.11
	School Age	1.03	0.9	0.76	2.19
	Working Age	1.37	1.76	0.97	2.17
	Retirement Age	1.07	0.84	0.8	2.16
By Region	Midwest	1.19	1.18	0.87	2.2
	Northeast	1.36	1.26	1	2.2
	South	1.24	1.58	0.86	2.21
	West	1.22	1.83	0.87	2.1

5.8.4 Effect of Type of Occupation on Work Exposure

525 participants indicated in the diary that they spent some time at work during the 24-hour measurement period. Of these, 501 reported their occupation. In addition to these 501 people, another 103 adults who participated to Phase I of this project recorded magnetic field during work and reported their occupation. The average magnetic field measured during the work period was analyzed by category of occupation (described in Table 4-5). The distributions of magnetic field are shown in Figure 5.54 and, with expanded scales, in Figure 5.55. The data are also shown in Table 5.16.

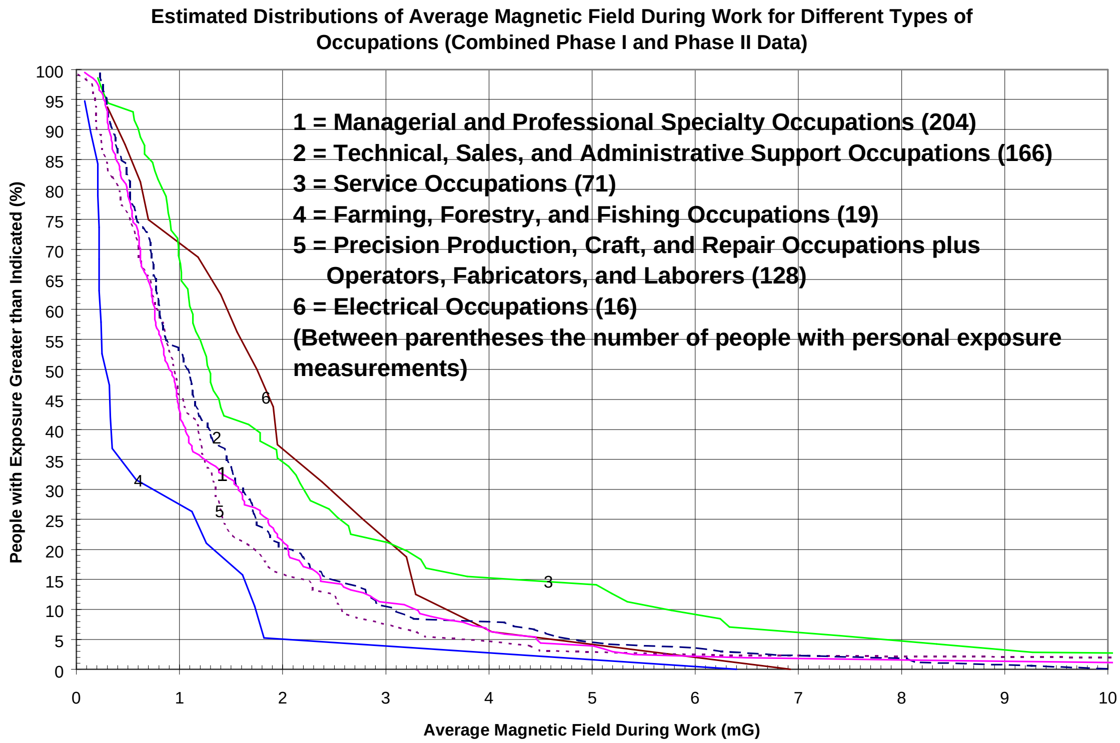

Figure 5.54 Estimated Distributions of Average Field During Work for People with Different Occupations

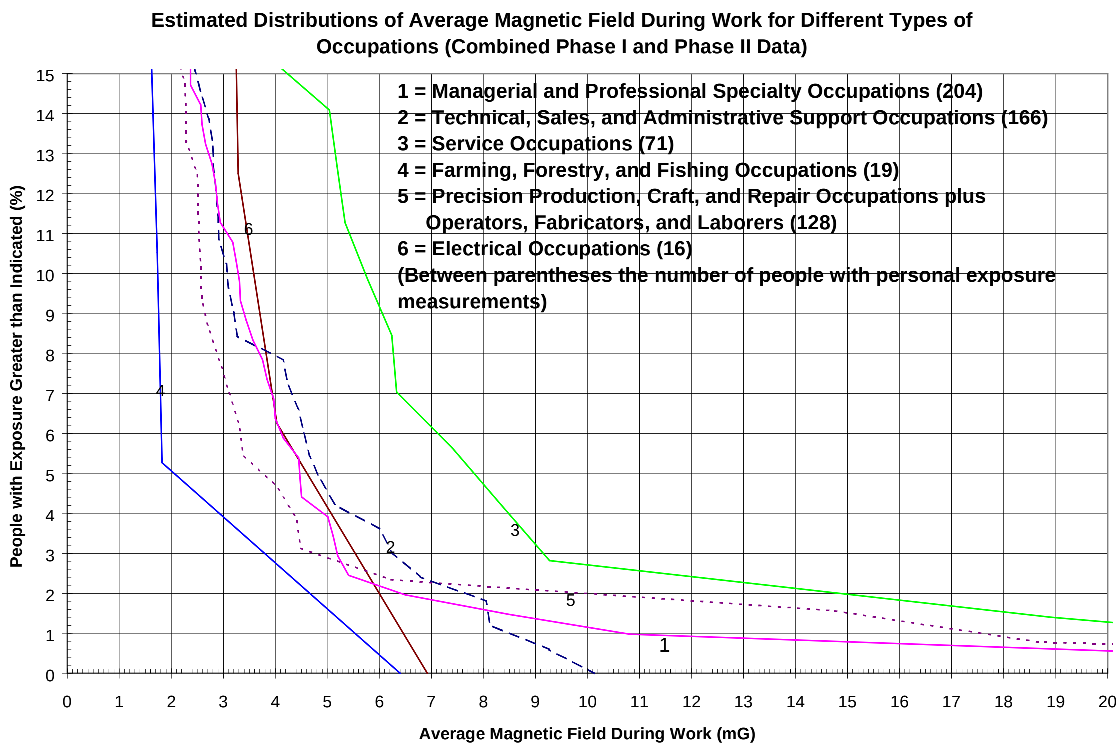

Figure 5.55 Same as Figure 5.54 but with an Expanded Vertical Scale. Estimated Distributions of Average Field During Work for People with Different Occupations

Table 5-16 Parameters of the Distributions of Average Magnetic Field During Work for Different Types of Occupations

Description	Number of People Surveyed	Mean (mG)	Standard Deviation (mG)	Geometric Mean (mG)	Geometric Standard Deviation
Managerial and Professional Specialty Occupations	204	1.64	2.82	0.99	2.47
Technical, Sales, and Administrative Supports Occupation	166	1.58	1.67	1.09	2.30
(Protective, Food, Health, Cleaning, and Personal) Service Occupations	71	2.74	4.42	1.59	2.55
Farming, Forestry, and Fishing Occupations	19	0.91	1.41	0.45	2.97
Precision Production, Craft, and Repair Occupations, and Operators, Fabricators, and Laborers	128	1.73	4.15	0.89	2.80
Electrical Occupations (see note)	16	2.15	1.62	1.61	2.25

Note: Electrical occupations are those classified as such by Dr. Samuel Milham in his study of leukemia mortality in men occupationally exposed to EMF [6]. The electrical occupations include: electronic technicians, radio and telegraph operators, electricians, linemen (power and telephone), television and radio repairmen, power-station operators, aluminum workers, welders and flame cutters, motion-picture projectionists, electrical engineers, streetcar and subway motormen.

5.8.5 Effect of Residence Characteristics (Residence Type, Floor Area, Bedroom Floor, Water Pipes) on Residential Exposure

The participants described in a questionnaire some of the characteristics of their homes. This has made it possible to analyze the data to determine whether any of the recorded characteristics is related to magnetic field exposure. To study the effect of residence type, floor area, and water pipes, the residential exposure was defined as the average field during the combined periods “at home not in bed” and “in bed”. To study the effect of bedroom floor, only the period “in bed” was considered.

The data were analyzed for different types of residences. The results are shown in the form of box and whisker plots in Figures 5.56 to 5.59 and are reported in Tables 5-17 to 5.20.

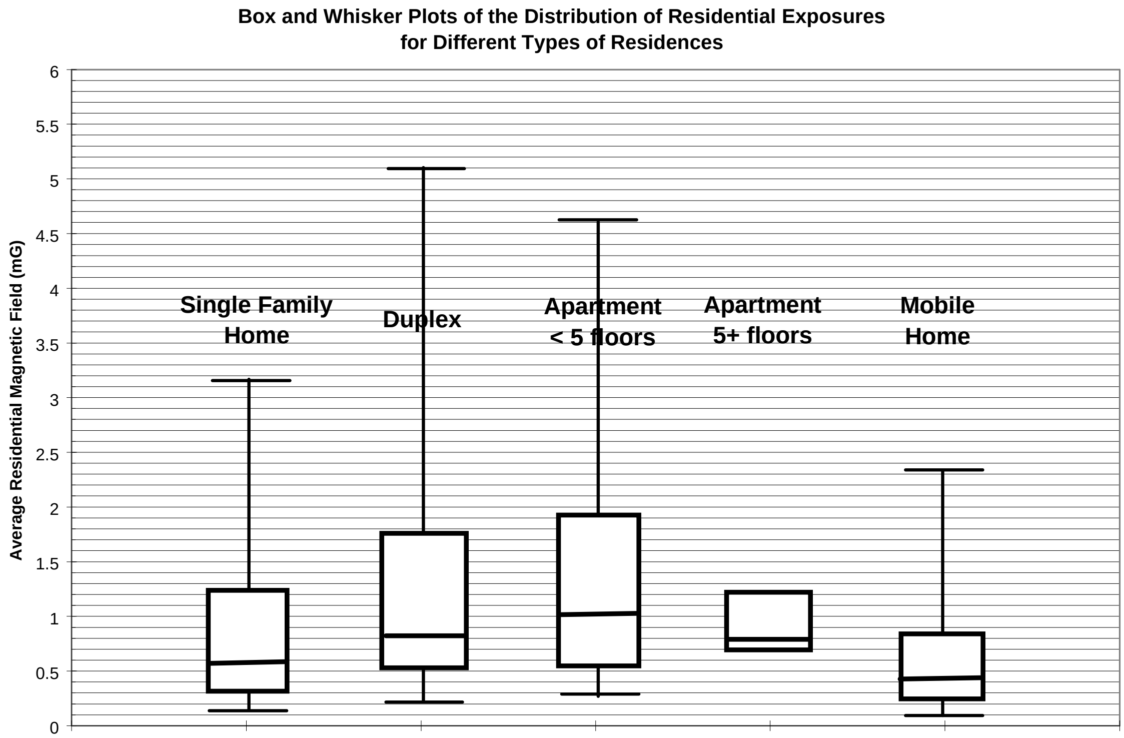

Figure 5.56 Box and Whisker Plots of the Distribution of Average Residential Field for Different Types of Residences. The boxes show the 25% to 75 % range, the whiskers show the 5% to 95 % range. The median values are shown by bars inside the boxes.

Table 5.17 Residential Exposure versus Residence Type

						Percentiles (mG)				
	Number	Mean	St Dev	Geo Mean	Geo. St Dev	5th	25th	50th	75th	95th
Single family home	701	1.08	1.73	0.65	2.66	0.16	0.34	0.60	1.28	3.15
Duplex	46	2.12	4.93	1.04	2.76	0.22	0.53	0.84	1.79	5.10
Apartment (<5 floors)	143	1.62	1.95	1.09	2.34	0.30	0.59	1.02	1.92	4.60
Apartment (5+ floors)	13	0.98	0.43	0.89	1.53		0.71	0.81	1.25	
Mobile home	65	0.76	0.94	0.49	2.46	0.11	0.27	0.44	0.87	2.34
Unknown and other	44	1.29	1.34	0.83	2.58	0.18	0.44	0.83	1.57	3.88
Total	1012	1.19	1.98	0.71	2.66	0.17	0.37	0.68	1.38	3.56

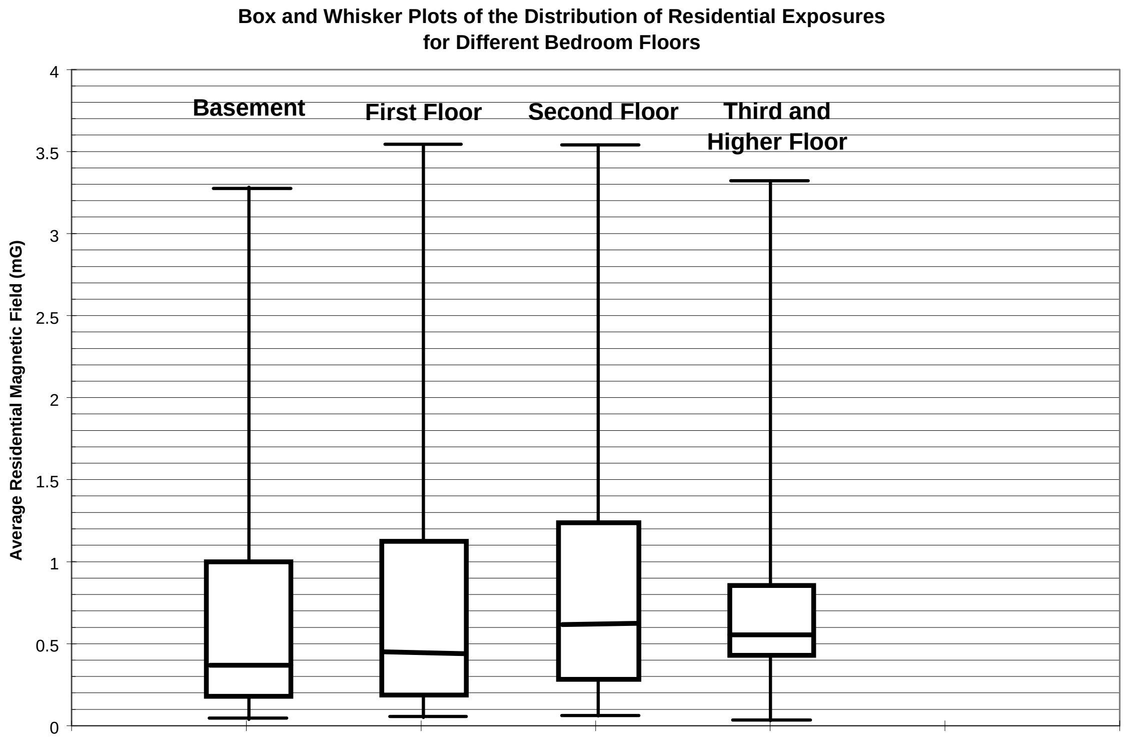

Figure 5.57 Box and Whisker Plots of the Distribution of Average Residential Field for Different Bedroom Floors. The boxes show the 25% to 75 % range, the whiskers show the 5% to 95 % range. The median values are shown by bars inside the boxes.

Table 5.18 Bed Time Exposure versus Bedroom Floor

						Percentiles (mG)				
	Number	Mean	St Dev	Geo Mean	Geo. St Dev	5th	25th	50th	75th	95th
Basement	27	0.83	0.93	0.45	3.37	0.07	0.21	0.39	1.01	3.25
First Floor	586	1.11	2.50	0.47	3.71	0.07	0.21	0.45	1.12	3.53
Second Floor	300	1.10	1.47	0.58	3.36	0.09	0.30	0.63	1.33	3.53
Third or Higher Floor	38	0.98	1.27	0.58	2.92	0.05	0.43	0.58	0.88	3.31
No Response	45	1.10	1.28	0.60	3.33	0.12	0.27	0.51	1.55	3.30
Total	996	1.09	2.12	0.51	3.56	0.08	0.23	0.49	1.20	3.52

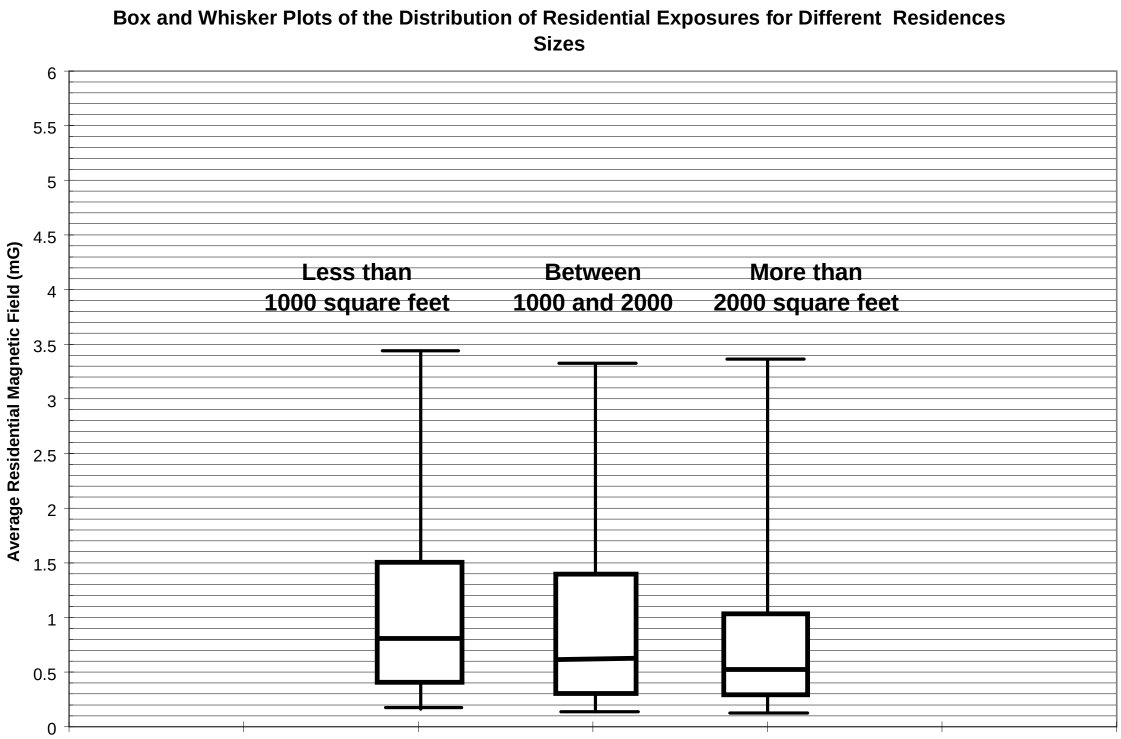

Figure 5.58 Box and Whisker Plots of the Distribution of Average Residential Field for Different Residence Sizes. The boxes show the 25% to 75 % range, the whiskers show the 5% to 95 % range. The median values are shown by bars inside the boxes.

Table 5.19 Residential Exposure versus Residence Size

						Percentiles (mG)				
	Number	**Mean**	**St Dev**	**Geo Mean**	**Geo. St Dev**	**5th**	**25th**	**50th**	**75th**	**95th**
Less than 1000 Square Feet	238	1.39	2.63	0.84	2.50	0.19	0.44	0.82	1.54	3.43
Between 1000 and 2000	527	1.16	1.91	0.68	2.74	0.17	0.35	0.62	1.40	3.32
More than 2000 Square Feet	190	0.97	1.24	0.60	2.53	0.15	0.32	0.54	1.08	3.37
No Response	57	1.39	1.38	0.92	2.54	0.19	0.48	0.96	1.65	4.18
Total	1012	1.19	1.98	0.71	2.66	0.17	0.37	0.68	1.38	3.56

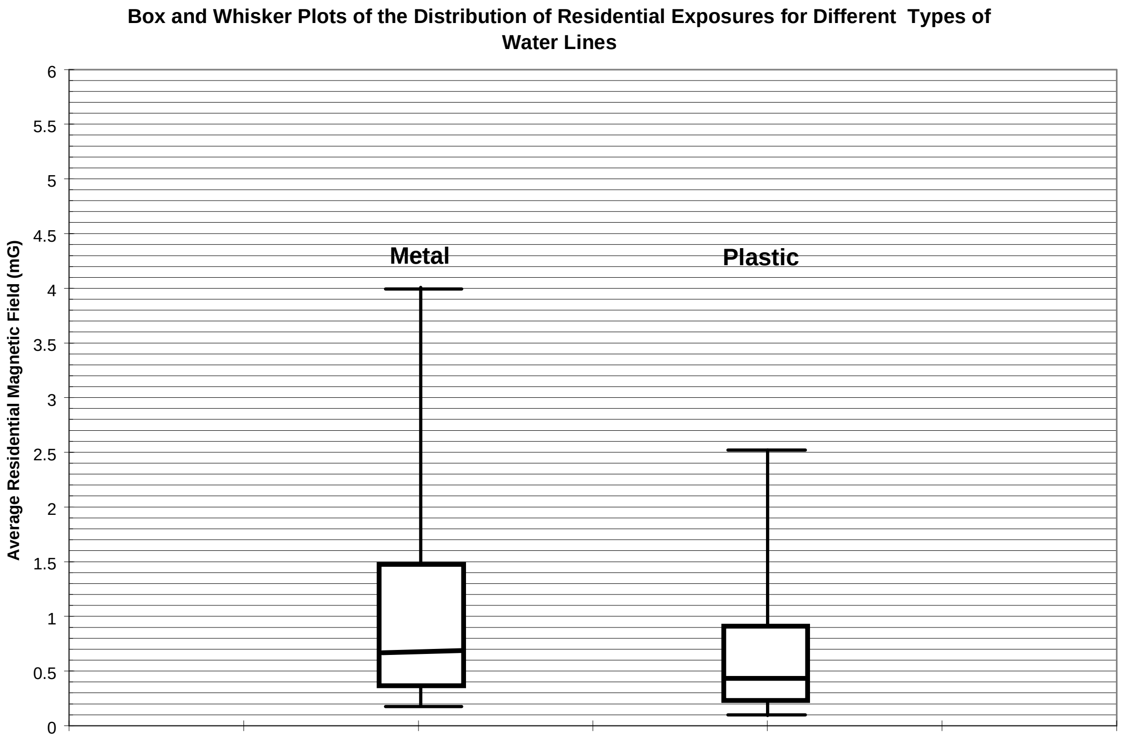

Figure 5.59 Box and Whisker Plots of the Distribution of Average Residential Field for Different Water Line Types. The boxes show the 25% to 75 % range, the whiskers show the 5% to 95 % range. The median values are shown by bars inside the boxes.

Table 5.20 Residential Exposure versus Water Line Type

	Number	Mean	St Dev	Geo Mean	Geo. St Dev	Percentiles (mG)				
						5th	25th	50th	75th	95th
Metal	556	1.24	1.52	0.78	2.57	0.19	0.40	0.71	1.50	3.99
Plastic	215	0.95	2.40	0.52	2.75	0.11	0.27	0.48	0.93	2.52
Both	27	0.82	1.03	0.53	2.41	0.12	0.30	0.47	0.93	2.33
No Response	214	1.35	2.56	0.81	2.62	0.19	0.41	0.81	1.55	3.62
Total	1012	1.19	1.98	0.71	2.66	0.17	0.37	0.68	1.38	3.56

5.8.6 Effect of Proximity to Power Lines on Residential Exposure

The participants reported in a questionnaire the distance between overhead power lines and their homes and the type of power line, which the participants could choose among different sketches that were submitted to them. This has made it possible to analyze the data to determine whether any of the recorded characteristics is related to magnetic field exposure. Residential exposure was defined as the average field during the combined periods “at home not in bed” and “in bed”.

The results of the analysis are shown in the form of box and whisker plots in Figures 5.60 and 5.61 and are reported in Tables 5.21 and 5.22.

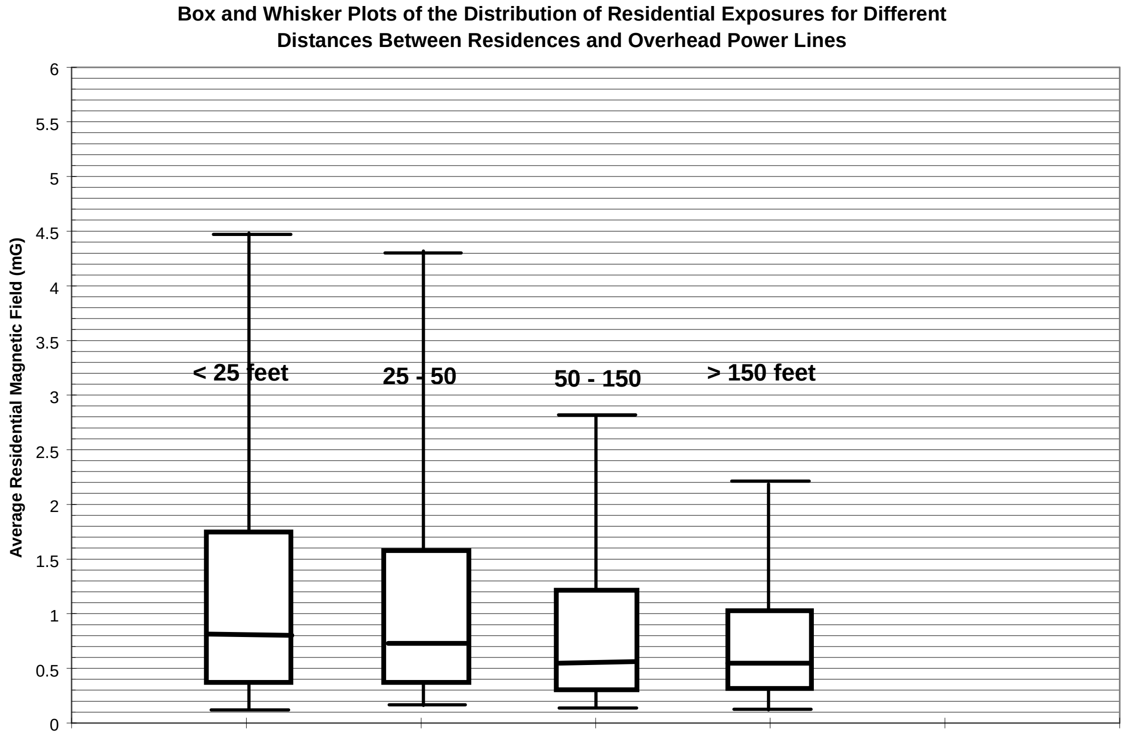

Figure 5.60 Box and Whisker Plots of the Distribution of Average Residential Field for Different Distances to Overhead Power Lines. The boxes show the 25% to 75 % range, the whiskers show the 5% to 95 % range. The median values are shown by bars inside the boxes.

Table 5.21 Residential Exposure versus Distance to Overhead Power Line

						Percentiles (mG)				
	Number	Mean	St Dev	Geo Mean	Geo. St Dev	5th	25th	50th	75th	95th
Less than 25 ft	134	1.74	4.11	0.86	2.87	0.15	0.41	0.82	1.77	4.48
25 - 50 ft	324	1.28	1.55	0.81	2.61	0.19	0.40	0.76	1.60	4.28
50 - 150 ft	306	0.99	1.20	0.61	2.68	0.15	0.33	0.59	1.22	2.82
Other 0-150 ft	5									
More than 150 ft	196	0.93	1.32	0.61	2.37	0.15	0.35	0.58	1.04	2.21
No Response	47	1.30	1.32	0.85	2.52	0.19	0.43	0.85	1.58	3.85
Total	1012	1.19	1.98	0.71	2.66	0.17	0.37	0.68	1.38	3.56

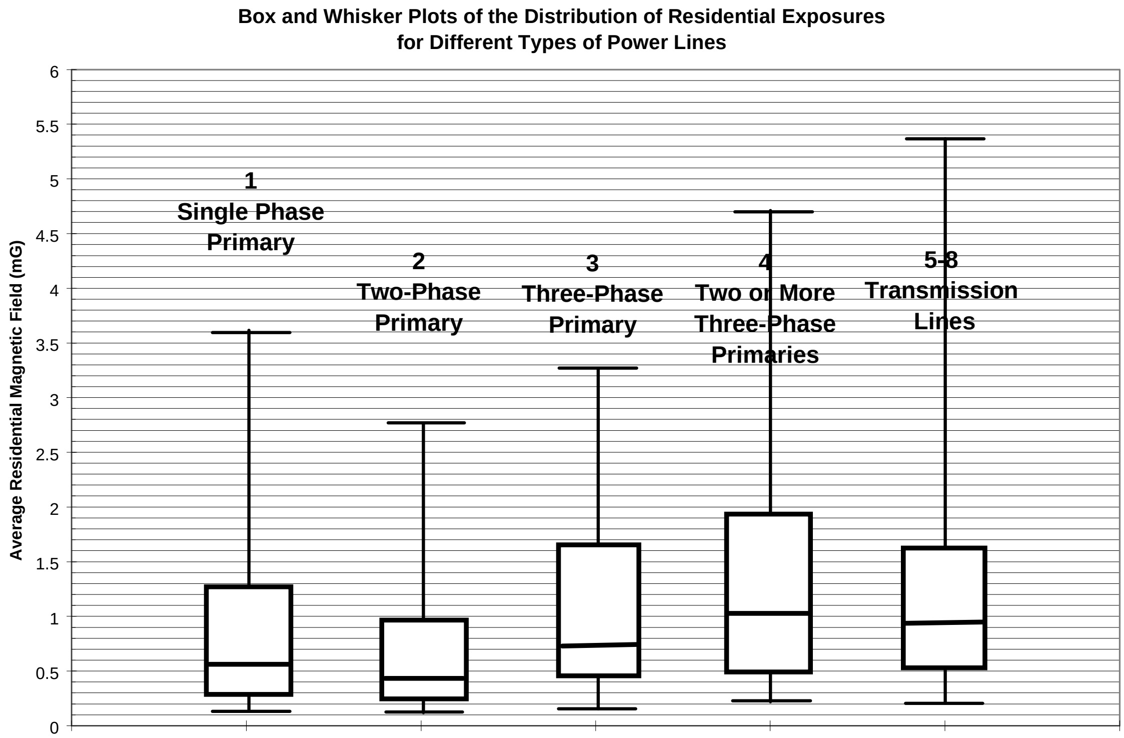

Figure 5.61 Box and Whisker Plots of the Distribution of Average Residential Field for Different Types of Power Lines. The boxes show the 25% to 75 % range, the whiskers show the 5% to 95 % range. The median values are shown by bars inside the boxes.

Table 5.22 Residential Exposure versus Type of Overhead Power Line

						Percentiles (mG)				
	Number	Mean	St Dev	Geo Mean	Geo. St Dev	5th	25th	50th	75th	95th
Single Phase Primary	274	1.19	2.36	0.65	2.82	0.16	0.31	0.57	1.29	3.60
Two Phase Primary	138	0.84	1.00	0.53	2.56	0.13	0.29	0.47	0.99	2.78
Three Phase Primary	183	1.36	2.64	0.83	2.55	0.18	0.48	0.76	1.65	3.28
Two Three Phase Primaries	104	1.63	1.93	1.05	2.68	0.23	0.52	1.07	1.96	4.70
Transmission Line	59	1.52	1.61	0.99	2.49	0.21	0.53	0.94	1.63	5.34
Unknown Type	11									
Total	769	1.25	2.15	0.73	2.73	0.17	0.37	0.69	1.49	3.80