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STATISTICAL SURVEY OF THE HOUSING CHARACTERISTICS AND EVALUATION OF SHIELDING FACTORS IN THE SURROUNDINGS OF FRENCH NUCLEAR SITES

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Abstract — Throughout France, a statistical survey is being conducted of housing located around nuclear sites. Four housing types are considered: old and recent single family, old and recent multi-family. For each site and housing type, the characteristics of the standard building and the standard apartment are recorded. These data are used to define a representative sample of buildings in the surroundings of each site. Through computer codes, using Monte Carlo methods, the kerma rates outside and inside a building are calculated. The results of the survey, concerning the nuclear sites situated in the Rhône valley, the Loire valley and in the North and the East of France are described. Representative samples of buildings and their shielding factors are presented for three sites.

INTRODUCTION

When a release of radioactive materials occurs during a nuclear power plant accident, the population living downwind is exposed to radiation emitted from the radioactive cloud and from deposited radionuclides. People sheltering in dwellings is one of the protection measures which can reduce population exposure. Shielding factors depend on building structures. In France a statistical survey of housing characteristics is being conducted in the surroundings of nuclear power plant sites. The results of the survey concerning nuclear sites situated in the Rhône valley, the Loire valley and in the North and East of France are described as well as the shielding factors for representative samples of buildings for three sites.

GENERAL METHODOLOGY

Statement of the problem

In the event of an atmospheric release of radionuclides due to an accident, the housing characteristics likely to have an influence on protection are those characteristics which, generally speaking, determine the potential of exchanges with the outdoor environment. That is:

- geometric data on the housing volume and its exposed surfaces (especially the most permeable elements, i.e. doors, windows and roofs);
- data concerning the construction materials and the various techniques which may have been used for making the walls, the roofs and the floors.

In principle, one possibility would consist of collecting the primary data necessary for the study by means of field surveys. This would involve complete knowledge (surfaces and volumes, structure analysis) of thousands of dwellings. Even so, the slowness, the difficulty and the cost of such a procedure have led to research into other means of obtaining the knowledge necessary for a thorough analysis of housing and of shielding factors. Within the research conducted in France, we opted for a historical and quantitative methodology. The guideline of the process, therefore, consists in considering the existing dwellings in terms of groups defined by their age, and for each we evaluate the characteristics relevant to shielding.

Chosen approach

The basis of any historical approach includes the question of sources. In addition to the information from the census of 1982 and a general knowledge of the history of construction, we called on several surveys, old or contemporary, and also, concerning the post-war era, the data and studies related to new construction. We have been able, in particular, to use a remarkable tax survey of 1938-1942 which describes statistically on a very fine geographical scale the surfaces and materials of the total number of dwellings of the time. This general data base was completed by exploring specific records. We sampled from the records of state aided construction (i.e. a large part of the production between 1950 and 1975), and used data on the regional production of materials until 1960.

Some questions remained for which the records give no consistent answers. For these points, we finally decided to launch specific surveys, making every effort to centre these on elements easily accessible and rapidly observable on significant numbers of buildings. For example, we determined the ratio of contiguity in single family houses by cadastral studies and field studies concerning 200 to 400 houses per site. Contiguity is the extent to which a dwelling is joined to others by common walls. Thus a detached house is not contiguous, while a house in the middle of a terrace is highly contiguous. In the same way, the sizes of façades and the proportion of doors and windows were submitted to evaluation using concurrently the data from the records, the accessible studies and the specific surveys.

The structure of the potential sources of exposure largely contributed to the definition of the geographical scale of the analysis. To represent the environment of nuclear. sites we chose the departement which is a territorial sub-division measuring 100 to 150 km in its largest dimension and containing generally 80,000 to 250,000 housing units, rarely more.

Knowledge of the relevant characteristics led us to distribute the dwellings in a departement into four basic categories which result from two dualities:

(i) the old and the recent,
(ii) single family and multi-family housing.

(i) *The old and the recent*
Within the types of French housing, two important and relatively homogeneous elements exist: construction prior to 1914, and construction post 1960. The history of construction in France has allowed us to consider only two classes, the year 1948 being chosen as a limit between the old and the recent.

(ii) *Single family and multi-family housing*
From a standpoint concerning building types, one can generally separate single family and multi-family housing. In order, once again, to simplify the model for the analysis, we decided to split the intermediary category considering as single family, buildings holding 1 or 2 households, and as multi-family, buildings holding 3 or more households.

Presentation of the results

For each departement, intermediary charts with comments give the composition of the number of housing units (or households) in terms of the four basic categories, and show, for the average housing of each category, the surfaces of walls, floor, roof, doors and windows.

Moreover, we established three matrices named 'materials' for the walls, the floors and the roofs, and for which it is clear that 'materials' relates to a composite technology. An example concerning the walls of the Loiret departement is shown in Table 1.

BRIEF SUMMARY OF THE RESULTS

Actually, 25 departements have been studied, covering the Rhône valley, the Loire valley, the North and the East (Figure 1). Six other departements are under study and before the end of 1987, the housing conditions in the surroundings of all the French nuclear plants will have been evaluated.

Table 1. Walls in the Loiret departement.

Material	Old single family housing			Old multi-family housing			Recent single family housing			Recent multi-family housing			General Housing		Distribution Surfaces	
	(%)	N	S	(%)	N	S	(%)	N	S	(%)	N	S	N	(%)	S	(%)
Stone	88	70.7	6.7	89	15.2	0.6	3	2.6	0.3	4	2.2	0.1	90.7	38.3	7.7	39
Hollow brick	0	0	0	0	0	0	39	33.1	3.5	29	15.8	0.7	48.9	20.6	4.2	21.3
Concrete	0	0	0	0	0	0	3	2.6	0.3	35	19.0	0.9	21.6	9.1	1.2	5.7
Bondstone	1	0.8	0.1	0	0	0	51	43.3	4.6	31	16.8	0.7	60.9	25.8	5.4	27.4
Wood	1	0.8	0.1	3	0.5	0	0	0	0	0	0	0	1.3	0.6	0.1	0.5
Rammed earth	1	0.8	0.1	0	0	0	0	0	0	0	0	0	0.8	0.3	0.1	0.4
Brick	9	7.2	0.7	8	1.4	0.1	4	3.4	0.3	1	0.5	0	12.5	5.3	1.1	5.7
Total	100	80.3	7.7	100	17.1	0.7	100	85.0	9.0	100	54.3	2.4	236.7	100	19.8	100

N = Number of housing units in thousands (10^3 units).
S = Surface of walls in millions of m^2 (10^6 m^2).

General trends

Certain characteristics emerging from the study of the different sites allow generalisations to be made. On the whole, we notice that the recent groups:

are made of a lighter type of construction (the partition walls of the recent single family as well as multi-family units are approximately 20 cm thick compared with 40 to 60 cm for traditional constructions made of stone or rammed earth);
have slightly larger doors and windows;
contain single family dwellings which are slightly shorter (1.3 to 1.5 floors instead of 1.5 to 2) and much fewer contiguous houses (in general, 10 to 30% of recent housing instead of 50 to 80% in the past).

Therefore, even if we consider the number of large multi-family dwellings built in the 1960's, the general trend in construction is mostly unfavourable in respect of shielding factors. This tendency has increased during the most recent period, where the production of new housing includes as a national average 2/3 of single family housings, with ratios of contiguity declining even more.

Volumes and surfaces

In all the zones studied, the only one to show a marked multi-family character corresponds to the Alps and the Rhône valley. Yet even there the multi-family character is not uniform: only five departements out of ten have a proportion of multi-family houses near or over 50%. Considering the clear preponderance of the single family and, most of the time, the old units, even in very urban regions such as the North, the short comment hereafter will be exclusively related to this type of housing.

It is the ground surface area which determines the global profile of the average building. Considering the relative uniformity of the inhabitable surfaces in their geographic distribution one might expect that the number of floors would be correlated with the ground surface area. In this respect, the very limited correlation factor which appears in Figure 2 must be discussed. In fact, the low value results mainly from the departements situated in the North-East border, where the size of housing, rare for France, creates constructions which both are high and large in their ground dimensions.

The hypothesis of a relatively constant height of storey leads to the fact that the quantity of exterior vertical walls per floor depends on a variety of factors: ground surface, tendency to contiguity, intensity of the contiguity (on 1 or 2 sides, partial or total disappearance of the gables) etc. Certain factors among these constitute linked variables, as is typically the case for the contiguity ratio and the contiguity intensity. The results show significant correlations between: (1) the surface of exterior vertical walls and the ground surface (Figure 3), and (2) the surface of exterior vertical walls and the ratio of contiguous houses (Figure 4).

Materials

The lifespan of a number of types of housing spreads over a very long period. The global inertia has been even more marked through the slow and progressive character of the penetration of the new technologies used in recent construction: certain departements had considerable stone production

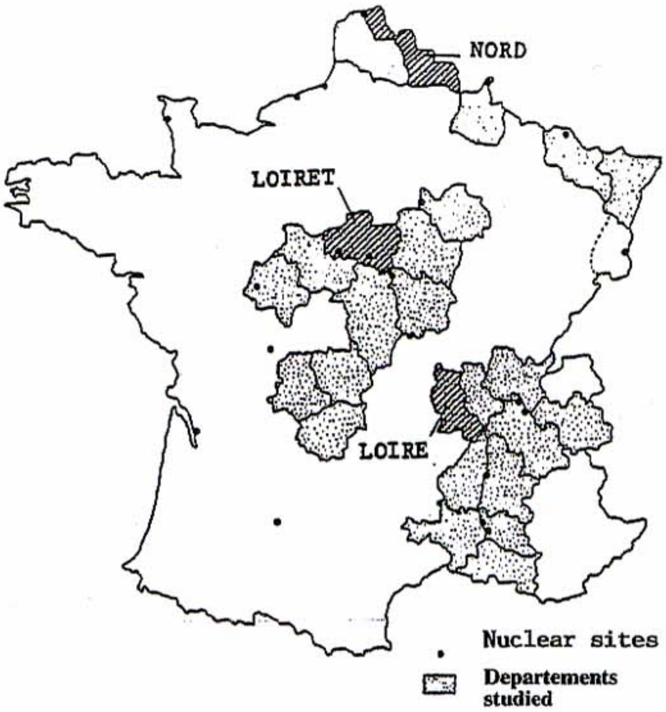

Figure 1. Nuclear sites and departements studied (April 1987).

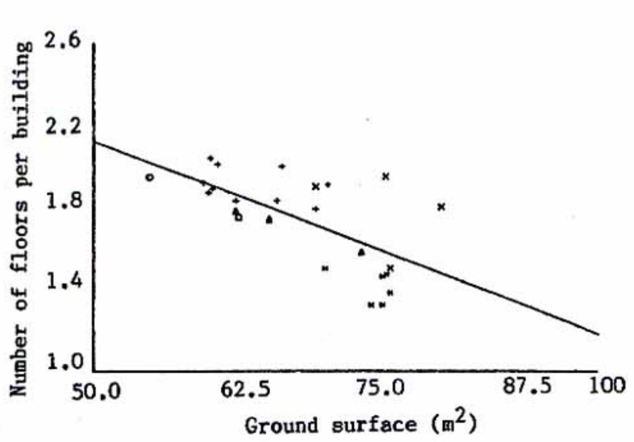

Figure 2. Number of floors per building relative to ground surface. Old single family housing. Correlation coefficient = −0.658. a = −0.019. b = 3.067. Key: +, Rhone valley. Δ, Limousin. *, Loire valley. □, North. x, North-east.

until 1960 or marginal but persistent tendencies to the maintenance of very old technologies such as timber framed construction. In a country where approximately half of all the dwellings existing in 1982 were built before 1948, this situation gives considerable importance to the old materials.

This is especially the case for walls, for which it is normal to find that 40 to 60% are made of stone in most departements. Among other materials liable to be locally important, or even dominant, in the old houses, are brick (North, Alsace) or earth (region of Lyon, Normandie) just by themselves or associated with timber framing (Alsace, Normandie).

In the recent period, it is obviously concrete in its various forms (hollow blocks, solid panels) which is the most frequently used material. Nevertheless, the presence of brick, which became hollow thus following the path of concrete blocks, is apparent in the regions where this material was used traditionally (North, Alsace).

The materials used for the roofs, and to a lesser extent the floors, have changed more frequently.

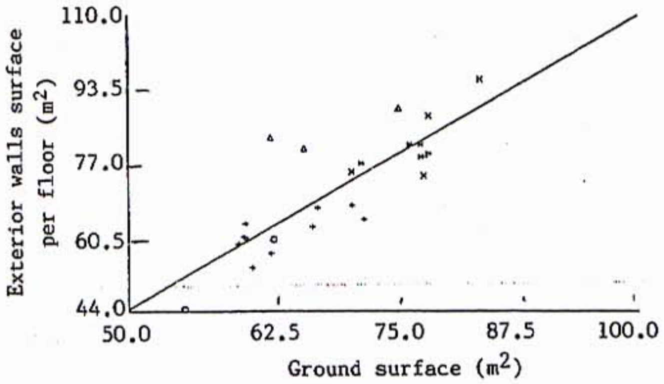

Figure 3. Exterior walls surface per floor relative to ground surface. Old single family housing. Correlation coefficient = 0.829. a = 1.306. b = −20.75. Key as Figure 2.

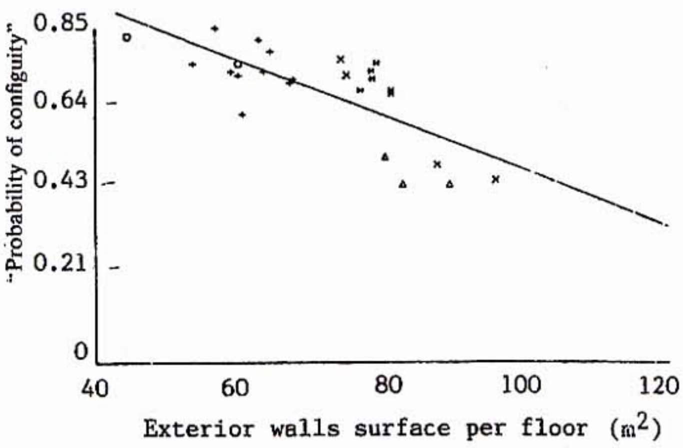

Figure 4. Probability of contiguity relative to exterior walls surface per floor. Old single family housing. Correlation coefficient = −0.744. a = −0.007. b = 1.195. Key as Figure 2.

The 30 year long cycle, which generally corresponds to the lifetime of the roofing materials, has allowed inversions between different materials compatible with the support. We therefore observe the presence, sometimes not insignificant, of recent roofing materials within the group of old houses. On the whole the most dominant mode is still the terracotta tile. The flat roof, so cherished by the modern architect, has become of significant importance merely in multi-family housing.

Three illustrative departements

The variety of cases which we have encountered may be illustrated through three departements: the Loire, the Loiret and the Nord.

Loire: In this industrial departement bordered to the East by the Rhône valley, the old and the multi-family housing predominates.

The old multi-family dwellings which are made of stone, correspond for the most part to 'workers' apartment houses' with particularly small housing units. The recent multi-family housing is formed of relatively large buildings.

In the single family housing, the heights and contiguity ratios have evolved in terms comparable with the general average values. The old single family housing has the characteristics that a significant number of houses are built with rammed earth.

Loiret: Here most of the dwellings are recent; but the departement of Loiret has maintained the tradition of predominantly single family housing, even in an urban environment.

In single family housing, the contiguity ratios have changed in conformity with the general average values, but the height of houses has always been particularly low. The tradition is one of a stone construction with a roof divided between tile and slate. In the recent period, the tendency is toward hollow blocks (brick or concrete) and slate.

For multi-family housing the recent group alone has a significant importance; about 50% of it is formed of state aided housing projects.

Nord: In this industrial departement, very densely urbanised, housing is characterised by a slight preponderance of the old (in spite of a reconstruction effort which lasted long after the destruction in 1940-1944) and with a large predominance of the single family type (in the old but also in the recent).

Both in the workers' housing projects and in the old town centres the tradition of construction corresponds to contiguous brick houses roofed with tiles. These houses may be very high in the centre of towns and in the wealthier areas. With heights just slightly reduced and groups of houses just a little less numerous, the habits inherited from the past have largely been upheld; the North and its neighbour the Pas-de-Calais are no doubt the only two French départements (outside the Paris area) where one finds a majority of contiguous recent single family housing units.

In multi-family housing only the recent group is of significant importance. This group represents almost 65% of state aided housing and it is formed of fairly long buildings with a relatively low height.

DETERMINATION OF A SAMPLE OF REPRESENTATIVE BUILDINGS FOR EACH SITE

General principle

For each of the four basic categories an average building is established. It is defined as a parallelepiped, whose ground surface is determined, and for which one plan dimension (the width between the two main façades) has been best evaluated during cadastral studies. Triangled roofs are represented by a section of parallelepiped whose exposed surface is equivalent.

The description of the size of the building is completed with an evaluation of the density of interior partitions, including the distinction between heavy and light walls. This evaluation is based on a specific empirical study, which also enables us to specify, for the old and the recent, the most common dimensions of the pieces of façade taken between two perpendicular sections (i.e. the portions of façades corresponding to an inhabitable room).

To describe the diverse variant characteristics of a site, we then consider the technologies and materials liable to have been used in the construction of the two main surfaces in contact with the exterior: the vertical walls and the roofs.

Single family housing is certainly the case justifying the most accurate approach, due both to the numbers concerned and the dependence of the surfaces exposed on various parameters. In fact, the quantity of exterior walls is determined in particular by the state of contiguity or not, while the variation in the number of floors (generally 1 or 2, sometimes 3, rarely more) may have a significant influence on the exposure through the roofs.

For multi-family housing, the image of the parallelepiped is particularly suited to the representation of recent buildings. However, areas with a high density of old buildings and especially in the urban centres prior to the 19th century, the real forms are often irregular: then the average building becomes an imaginary figure again. In categorising buildings both in the old environments and in the recent urbanisations, contiguity (i.e. the absence of exposed gables) is assumed. Generally this is the actual condition for old buildings while in recent ones contiguity is less frequent. However, it is important to note that the length of the recent multi-family housings combined with the general lack of windows in the gables, lead to a fairly low importance of the permeability through the gables. To evaluate the height, we adopt the integer closest to the average number of floors determined for each category.

In order to classify the diverse variants of each housing category by rank of decreasing probability, we calculate the probability associated with the 'k' house located in the 'd' departement:

$$P(k,d) = P_m(d).P_n(d).P_i(d).P_j(d).P_h(d)$$

where:

- P_m = probability for a situation of contiguity or not,
- P_n = probability for a number of floors,
- P_i = probability for the walls' materials,
- P_j = probability for the roofs' materials,
- P_h = probability for apartments in housing type:

and for multi-family housing types P_m and P_n are equal to 1.

Each of these probabilities (P_m, P_n, P_i, P_j, P_h) is the proportion of housing units having the considered characteristic. The probability P(k,d) of the dwelling k is thus assumed to be the ratio of housing units with the characteristics m,n,i,j,h in the departement d. The cumulative apartment ratio is the sum of the probabilities P(k,d) of the buildings in the sample.

There is a maximum of 336 configurations for each single family housing type, if we consider that all the technologies may exist, and also that there are no incompatibilities. The assumptions on contiguity and number of floors for each multi-family housing type reduce the number of variants to 56 configurations.

The samples of buildings

The number of variants existing in the Loire, Loiret and Nord departements are respectively 193, 220 and 252. All the variants which have a probability greater than 0.01 are considered in the sample. The distribution of each housing type appears in Table 2 as well as the cumulative apartment ratio represented in each sample. The omitted variants represent respectively 18%, 22% and 18% of the housings in the Loire, Loiret and Nord departements. The parameter frequencies in each sample (contiguity, number of floors, walls and roof materials) comply with the values obtained in the survey, and the variants which are not considered are infrequent.

Table 2. Number of buildings in each sample.

Sample	Loire	Loiret	Nord
Old single family	7	8	8
Recent single family	5	10	6
Old multi-family	4	2	2
Recent multi-family	5	6	4
Total	21	26	20
Cumulative apartment ratio	0.82	0.78	0.82

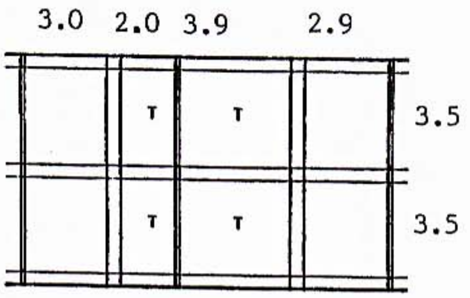

Figure 5. Contiguous old single family house for Loire. Wall thickness 0.5 m. Partition thicknesses: perpendicular to front 0.14 m; parallel to front 0.48 m. Aperture area ratio 0.16.

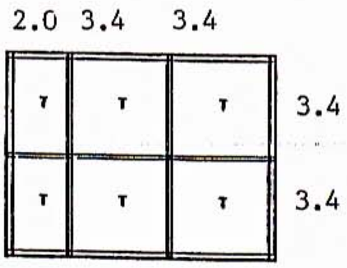

Figure 6. Recent single family house for Loiret. Wall thickness 0.23 m. Partition thicknesses 0.15 m. Aperture area ratio 0.12.

Examples of dwelling models are presented in Figures 5-8 for each housing type.

The single family houses of the samples have one or two floors, except in Nord where one variant of old house has three floors. The height from floor to floor is respectively equal to 3 m and 2.75 m for old and recent houses.

The old multi-family buildings have three floors except in Loire where one variant with rammed earth walls has two floors. There are one or two apartments on each floor, and the height from floor to floor is 3.1 m. The number of floors in recent multi-family buildings is respectively five in Loire and Loiret and four in Nord. There are two or three apartments on each floor and the height from floor to floor is 2.75 m.

The average thicknesses and surface densities of building materials are presented in Table 3. Some of these materials do not appear in the samples: wood, steel, plate and schist slate.

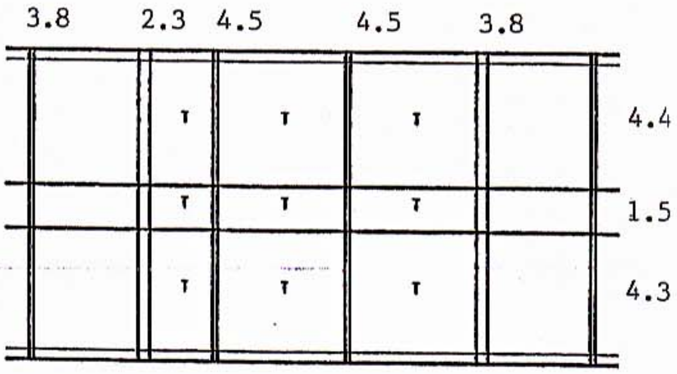

Figure 7. Old multi-family building for Loire. Wall thickness 0.41 m. Partition thicknesses: perpendicular to front 0.18 m; parallel to front 0.15 m. Aperture area ratio 0.14.

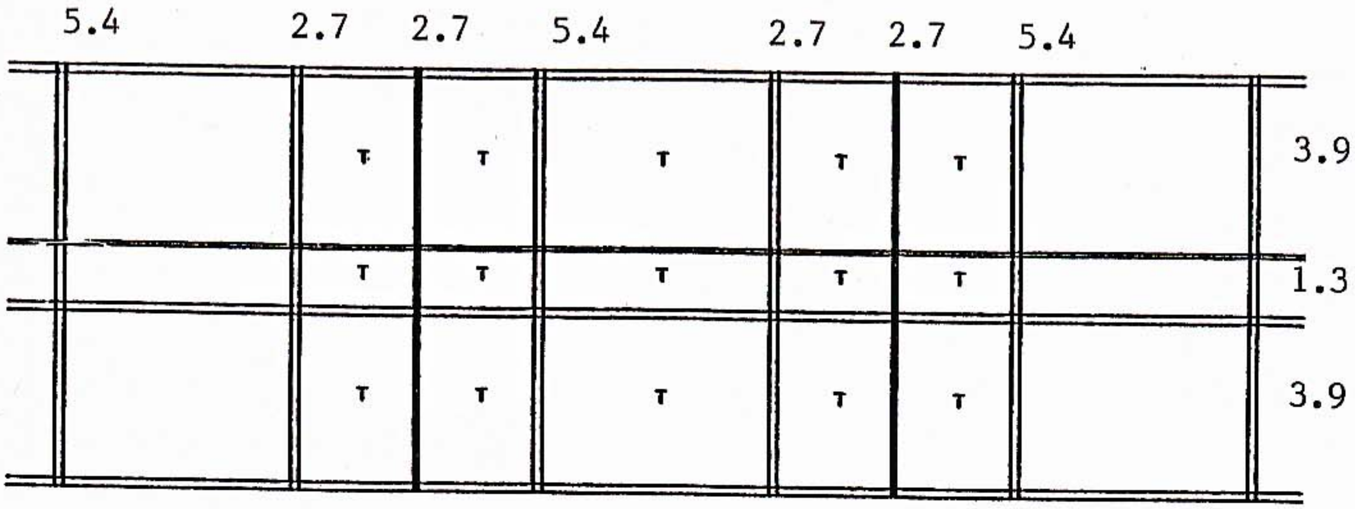

Figure 8. Recent multi-family building for Loire. Internal and external walls thicknesses 0.20 m. Light partition thickness 0.10 m. Aperture area ratio 0.23.

SHIELDING FACTORS

Method

Three steps are considered: photon fields outside the dwelling, photon fields in apartments, and shielding factors evaluation. In the two first steps Monte Carlo methods are used to simulate the photon transport. In the first step the kerma rates at one metre above the ground are calculated[1]. In the second step, the mean kerma rate on each floor is determined[2,3]. Then the shielding factor is the quotient of the mean kerma rate on a floor by the kerma rate in open air. A mean shielding factor for the dwelling is calculated from the values obtained on each floor.

Table 3. Average thickness and average surface densities of building technologies (*25 recent, 30 old).

Building structure	Material	Thickness (cm)	Surface density ($g.cm^{-2}$)
Wall	Hollow brick	23	20.7
	Wood	25	22.5
	Bondstone	23	28.75
	Concrete	20	47.0
	Brick	25-35	43-59.5
	Rubble stone	50	82
	Freestone	41	67
	Rammed earth	53	84.8
Roofing material and framework	Asbestos-cement	1.7	3
	Iron plate	0.4	3
	Slate	3	6.6
	Zinc	6.5	7
	Wood	13	9
	Tiles	7	11.6
	Schist slate	12	19
	Flat roof	23	54
Floor and ceiling	1st floor	25	59
	Intermediate floor	25-30*	40
	Ceiling under roof	25-30*	20

Results

In each housing category of a sample, two interesting dwellings can be considered: the most probable houses which are defined with the most frequent characteristics (Table 4), and the worst shielded houses (Table 5) which are defined by some unfavourable characteristics. In comparing shielding factors the greatest differences appear between dwellings with light wall materials (hollow brick, bondstone) and dwellings with heavy wall materials (stones, rammed earth or brick). For single family houses another important parameter is the external surfaces exposed to open air; contiguous houses have better shielding factors than single houses. Roof materials have an influence only on the top floor of houses and buildings. Other parameters such as building width, aperture area ratio, inhabitable surface, can change the shielding factors slightly.

Old single family houses have the same characteristics (contiguity and heavy wall materials) in the three sites. The mean shielding factors of this housing type have practically the same value (Table 6). On the other hand recent single family houses present a great variation between the Nord departement and the two other sites. In Nord contiguity remains preponderant for both recent and old single family types while contiguous houses are

Table 4. Shielding factors for the most probable houses or buildings.

Housing type	Site	House type	Floor number	Wall	Roof	Shielding factor 0.5 MeV	5 MeV
Old single family	Loire	Contiguous	2	Stone	Tile	0.06	0.16
	Loiret	Contiguous	1	Stone	Tile	0.06	0.21
	Nord	Contiguous	2	Brick	Tile	0.07	0.19
Recent single family	Loire	Single	2	Bondstone	Tile	0.13	0.39
	Loiret	Single	1	Bondstone	Slate	0.12	0.45
	Nord	Contiguous	2	Brick	Tile	0.08	0.23
Old multi-family	Loire	Contiguous	3	Stone	Tile	0.04	0.13
	Loiret	Contiguous	3	Stone	Slate	0.06	0.15
	Nord	Contiguous	3	Brick	Tile	0.05	0.16
Recent multi-family	Loire	Contiguous	5	Concrete	Flat roof	0.07	0.13
	Loiret	Contiguous	5	Concrete	Flat roof	0.06	0.12
	Nord	Contiguous	4	Brick	Tile	0.09	0.16

infrequent in Loire and Loiret. Shielding factors variation between sites is small for multi-family buildings: old types with heavy wall materials are better shielded than the recent ones which have lighter wall materials. However apartment shielding factors are greater on the top floor than on the ground floor. The mean value for each site depends on the distribution of housing type, but the recent single family frequency has a great influence: this type is the most frequent in Loiret (35%) and the least frequent in Loire (16%).

The best shielded apartment for the three samples is at the ground floor of an old multi-family building, and the worst shielded apartment is, in Loire and Loiret, a recent single family house, while in Nord it is on the top floor of a recent multi-family building. Naturally, these ranges of variation depend on samples which are composed of building models defined only by the most important housing characteristics.

CONCLUSION

The methodology used to make the statistical survey of housing is based on research of historical records. Only some important parameters are determined by measurements on land registry or local observations. Nevertheless the collected data allow definition of dwelling models which represent the housing diversity, and determination of representative building samples in the surroundings of nuclear sites. They can then be used to determine shielding factors and their variation according to the main parameters: thickness and density of walls, contiguity.

The old dwellings which are characterised by heavy wall materials and high frequency of contiguity are better shielded than recent buildings. Because of light wall materials and low frequency of contiguity, the recent single family is the worst shielded dwelling type. Old multi-family housing is the best shielded for the three sites.

The worst mean shielding factors are obtained in Loiret in relation to the statistical weight of the recent single family house. On the other hand single family housing in Nord is characterised by contiguity, so this site has better mean shielding factors than in Loiret. In Loire, the relative great

Table 5. Shielding factors for the worst shielded houses or buildings in the dwelling samples.

Housing type	Site	House type	Floor number	Wall	Roof	Shielding factor 0.5 MeV	Shielding factor 5 MeV
Old single family	Loire	contiguous	2	Bondstone	Tile	0.08	0.24
	Loiret	Single	1	Stone	Slate	0.08	0.27
	Nord	Single	1	Brick	Tile	0.09	0.36
Recent single family	Loire	Single	2	Hollow brick	Tile	0.17	0.46
	Loiret	Single	1	Hollow brick	Slate	0.17	0.51
	Nord	Single	2	Brick	Tile	0.09	0.30
Old multi-family	Loire	Contiguous	3	Brick	Tile	0.04	0.15
	Loiret	Contiguous	3	Stone	Slate	0.06	0.15
	Nord	Contiguous	3	Brick	Slate	0.06	0.17
Recent multi-family	Loire	Contiguous	5	Hollow brick	Flat roof	0.10	0.21
	Loiret	Contiguous	4	Hollow brick	Slate	0.09	0.23
	Nord	Contiguous	4	Bondstone	Tile	0.11	0.21

Table 6. Mean shielding factors per dwelling and variation ranges of apartment shielding factors, for the three sites.

Sample	Loire 0.5 MeV	Loire 5 MeV	Loiret 0.5 MeV	Loiret 5 MeV	Nord 0.5 MeV	Nord 5 MeV
Old single family	0.07	0.21	0.07	0.21	0.08	0.23
Recent single family	0.12	0.38	0.13	0.43	0.08	0.26
Old multi-family	0.04	0.14	0.06	0.15	0.06	0.17
Recent multi-family	0.08	0.17	0.08	0.18	0.09	0.17
Mean	0.08	0.25	0.10	0.32	0.08	0.24
Best shielded apartment	0.03	0.05	0.05	0.07	0.05	0.08
Worst shielded apartment	0.17	0.46	0.17	0.51	0.14	0.37

frequency of old multi-family housing types and the low frequency of recent single family housing types lead to more favourable shielding factors than in Loiret.

Shielding factors are presented in the study for two initial photon energies which are assumed representative of the average energy (0.5 MeV) and the maximum energy (5 MeV) of photons emitted by a fission product mixture; the shielding factors corresponding to these energies may then be similarly interpreted as average and maximum values. This is true probably for the maximum value, but the mean value depends both on the energy spectra and the relation of shielding factors to photon energy.

In order to extend the study, further work is needed in the following areas:

(i) The considered characteristics of the materials (wall thickness, etc) are assumed to correspond to national averages; supplementary work should be devoted to regional differences.

(ii) Housing models are based on systematic simplifications; it should be useful to compare some actual dwellings with models.

(iii) Only two assumptions have been treated concerning initial photon energy; supplementary calculations are needed to determine more actual shielding factor averages.

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