

ARTICLE

The consumption of locally-produced foodstuff: an important parameter of the radiological exposure for population living in the vicinity of French nuclear facilities

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Abstract – Either in normal or post-accidental situations, the ingestion of locally-produced foodstuffs, potentially contaminated, is one of the main exposures to the population living in the vicinity of nuclear facilities. For this reason, the French Institute for Radioprotection and Nuclear Safety has developed a specific methodology and has carried out surveys on dietary habits of some populations concerned. This study presents the methodology used for local food surveys, the amount consumed and how much food is produced locally. The results from the 6 surveys already done show that food surveys even if conducted with a specific aim as impact assessments provide further in-depth understanding of the food habits of local residents. There are still local specific population groups that have a high level of “home-consumption” for products more sensitive to contamination. For leafy vegetables and milk (products highly sensitive to contamination), home-consumption rates vary widely from one region to another from 76 to more than 90% and from 1 to 17% respectively. Specifically for the Andra survey carried out in a rural area in the North-East of France, self-sufficiency had reached 100% for a few products (game meat for example).

Keywords: radiological exposure / food consumption / locally-produced foodstuff / food survey / statistical analysis

1 Context

The contamination of the environment by a radioactive release (in normal or accidental situations) should affect locally-produced foodstuffs. One of the main radiological exposures pathways of people living in the vicinity of a nuclear site is the potential intake of radionuclides linked to the ingestion of locally produced foodstuff contaminated by the radioactive releases. This exposure and dosimetric impact of populations is proportional to the contamination level of the foodstuffs and to the ingested quantities (Parache *et al.*, 2011a, 2011b; Renaud *et al.*, 2015). Otherwise, the different kinds of agricultural products are more or less sensitive to the radioactive contamination of the environment. Leafy-vegetables for example are well-known to present the highest contamination levels in case of atmospheric release. So the quantities consumed of each kind of foodstuff must be considered. The categories of foodstuffs considered in national

survey do not match at all with those which must be discriminated for their radiological sensitivity, as leafy-vegetables for example. Moreover, these national surveys do not provide information about the part of the consumption which is locally produced. And this part depends strongly of the kind of foodstuff locally produced, so to the kind. Finally, some of them are outdated.

Doses from food ingestion depend mainly on:

- locally sourced food in the population’s diet (degree of self-sufficiency, in the broadest sense);
- the nature of the food produced locally (leafy vegetables, dairy products...);
- the season in which the radioactive release occurs in the case of accident.

Regarding the doses received shortly after the occurrence of an accident, special attention should be paid to the proportion of fresh produce (leafy vegetables and dairy products) consumed in the diet (regarding the short period of decrease of some radionuclides). Indeed, during this period, the contribution of other food products (meat, canned milk,

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soft cheeses, cereal products...) is low and will become progressively significant later. National surveys currently available for France (Bertrand, 1993; Volatier, 2000; Lafay, 2009) are not very informative on this matter and the available data are now often outdated. Given the variety of diets across France, it would be appropriate to conduct investigations locally, around the different nuclear sites with a focus on local agricultural products themselves as well as their distribution channels.

The objective of this study is to describe the dietary habits of the most exposed population living near a nuclear site (up to several tens of kilometres): the population likely to have a high consumption of locally-produced foodstuff potentially contaminated either by authorized routine releases or in case of (or after) an accident.

2 Material and method

For local surveys conducted by IRSN (Fig. 1 and Tab. 1), self-sufficiency is defined as the consumption of foodstuffs produced locally or picked by the consumer and of foodstuffs from local sources (less than or equal to 50 km). These foods are fruits and vegetables from privately owned garden and orchards, meat and poultry from individual farms, sea food products, hunting and gathering. Insofar as we are interested in pollution which may occur in localized areas, it seemed necessary to include, in addition to home-consumption food, food purchased from local farms or redistributed by local producers as poultry products or milk or cheese. Seasonal variations also play a major role in the consumption of foodstuffs from local sources. The consumption of vegetables and dairy products and seasonal variations in production and consumption of these products must be also taken into account. Concerning national surveys and those designed especially for populations living near nuclear facilities, the method of consumer notebooks is usually chosen (Durand *et al.*, 2006).

Each survey concerns a sample of 150 to 200 people who disposes a kitchen garden or orchard or barnyard or is consumer of local food products. (Descamps and Guillet, 2003). A specific protocol has been developed to correspond at this aim. This protocol takes into account: (1) the informative nature of the results obtained for the first study (Parache, 2010), (2) national trends in the population's food habits (Bertrand, 1993; Volatier, 2000; Lafay, 2009), and (3) the necessity to ensure that the protocol could be reproduced in the future and in other places. This approach consists in several stages: (a) defining the population group to be surveyed and the area covered by the study, (b) choosing the survey period and seasonal variations in home-consumption habits, (c) providing information to the inhabitants surveyed and drawing up a survey questionnaire in the form of a weekly home-consumption notebook and (d) the survey and statistical processing of the collected data.

The membership of families in the survey protocol considered to be time consuming (intelligence daily questionnaire) based on two essential elements: (1) time for exchanges and explanation to the families, (2) the checking of the collected information in collaboration with family to avoid an unusable questionnaire. This type of survey needs also the expertise and human relationships abilities. To take into

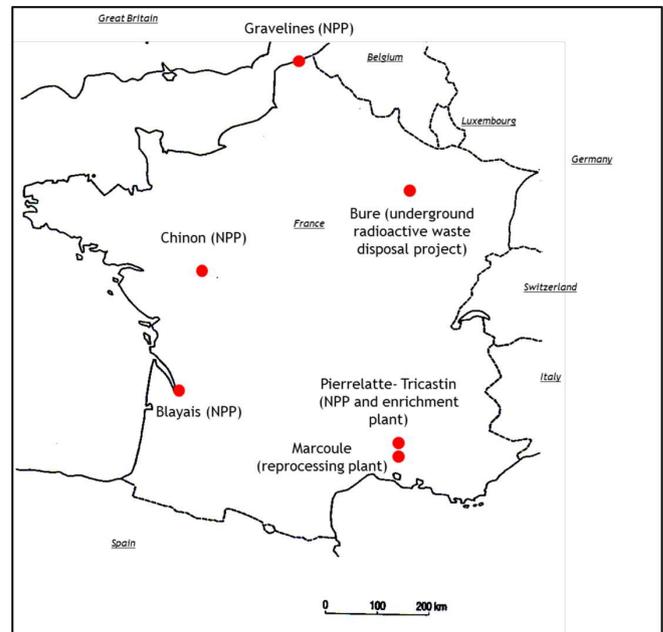


Fig. 1. Location at which surveys were conducted.

account all foods mentioned in consumer notebooks in foodstuff categories used for impact assessments, some adjustments were made (Tab. 2).

3 Results

3.1 Food ration (Fig. 2 and Tab. 3)

Figure 2 presents the quantities consumed of each kinds of foods, provided by the different surveys. The results are consistent. The different kinds of foodstuff are consumed with the same proportions and contribute with similar proportion to the whole consumption. However, quite important variations can be observed. It is notably the case for fruit-vegetables with consumption rates ranging from 50 (Gravelines) to 165 kg/y (Tricastin), and fruits (45 kg/y and 100 kg/y for Gravelines and Tricastin respectively). Inversely, the consumption of potatoes is higher close to Gravelines (75 kg/y) than in the vicinity of Tricastin (40 kg/y). These gaps are linked to well-known differences between the agricultural practices and food habits of the two corresponding regions. It appears also that the total quantity of seafood (fish, shellfish and crustaceans) consumed by people living close to the sea (Gravelines, Blayais) is about 35 to 40 kg/y whereas it is only 12 to 22 kg/y in other sites (located away from the sea).

And finally, the food ration varies from 543 kg/y (Chinon) to 700 kg/y (Tricastin). Table 3 presents the mean values of the quantities consumed for each foodstuff categories on the basis of the results of the different surveys. The minimum (min) and maximum (max) values and the name of the surveys corresponding to the min and max values are also given for information. Indeed, for vegetables products (root and fruits specifically) and fruits products, the gaps between min and max values are about a factor 2 and more.

Table 1. Food surveys conducted by IRSN near French nuclear sites.

Survey	Location	Date	Collaboration (financial or technical)	Response rate (%)**	Number of people surveyed
Chinon	Loire Valley	Summer 2008	EDF, ADEME	72	217 (88 households)
Tricastin*	Rhone Valley	Summer 2004	AREVA, ADEME	51	182 (76 households)
Marcoule	Rhone Valley	Summer 2010	CEA	90	216 (83 households)
Gravelines	North sea	Summer 2011	ADEME, CLI	80	252 (82 households)
Blayais	Gironde Valley	Summer 2012	ADEME	93	315 (119 households)
OPE-Bure	Est of France	Summer 2013	ANDRA	89	308 (106 households)

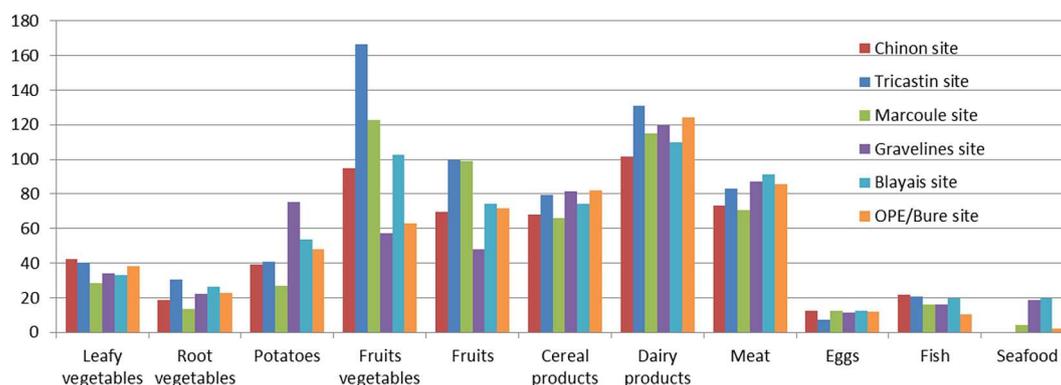
* The Tricastin survey also aimed to see seasonal changes in feeding practices. The survey has been conducted during the summer and fall 2004 and during the winter and spring 2005. To compare, only the results of the summer 2004 will be presented here.

** The response rate is the percentage of people from the sample who have answered.

Table 2. Correspondence between foodstuff categories used for impact assessments and those from the treatment of local surveys.

Foodstuff categories IRSN	Foodstuff categories from the treatment
Leafy vegetables	Fresh leafy vegetables + wild asparagus + aromatic plants
Root vegetables	Fresh root vegetables
Potatoes	Potatoes
Fruit vegetables	Fresh fruit vegetables + dried vegetables
Fruits	Fresh fruits + nuts + dried fruits + fruit preserves and jams
Mushrooms	Mushrooms and wild mushrooms
Cereal products	Rice + bread and rusk + other cereals
Milk	Milk
Other milk products	Cheese + butter + other milk products
Meat	Beef, veal, sheep and pork meat + sausage + wild animals + poultry + rabbits + snails
Eggs	Eggs
Fish	Fish
Seafood (shellfish and crustaceans)*	Shellfish and crustaceans

* For Marcoule, Gravelines, Blayais and Bure surveys (for Chinon and Tricastin sites, seafood category is with fish category).

**Fig. 2.** Food intake (kg/y.person) for population living near the Chinon, Marcoule, Tricastin, Gravelines, Blayais and Bure sites.

3.2 Self-sufficiency (Tabs. 4 and 5)

In these studies, it was confirmed that targeted population of the survey have high rates of home-consumption, of around 70 to more than 90% for different food categories (Tab. 4). Home consumption of some specific natural food products can reach a rate of 100% (wild animals and mushrooms, fresh water fish for example) (Appendix 1). For plant crops, the

results are of the same order of magnitude at these sites, with the exception of fruiting vegetables and fruits, consumed and locally-produced in significantly larger quantities by the population of Tricastin (Tabs. 3 and 4). On the other hand, home-consumption rates are higher in Bure in the case of meat, eggs and especially dairy products (17% for milk). The population surveyed near the Chinon, Marcoule, Gravelines and Blayais sites averages between those of Tricastin and that

Table 3. Mean, min and max values of the quantity consumed for each foodstuff categories from the different local surveys, and name of the surveys corresponding to the min and max values in kg/y.

Foodstuff category	Mean	Min	Survey	Max	Survey
Leafy vegetables	36	28	Marcoule	42	Chinon
Root vegetables	22	14	Marcoule	30	Tricastin
Potatoes	47	27	Marcoule	76	Gravelines
Fruit vegetables	101	57	Gravelines	167	Tricastin
Fruits	77	48	Gravelines	99	Tricastin
Mushrooms	9	3	Gravelines	20	Blayais
Cereal products	75	66	Marcoule	82	Bure
Milk products	117	102	Chinon	131	Tricastin
Meat	82	71	Marcoule	91	Blayais
Eggs	11	7	Tricastin	13	Chinon/Marcoule
Fish	17	10	Bure	22	Chinon
Seafood (shellfish and crustaceans)*	11	2	Bure	20	Blayais

* For the following sites: Marcoule, Gravelines, Blayais and Bure. The distinction fish / shellfish and crustaceans was not done in previous surveys

Table 4. Home-consumption rate (% of the total solid or liquid intake) for each foodstuff categories from the different local surveys.

Foodstuff cat.	Chinon	Tricastin	Marcoule	Gravelines	Blayais	Bure
Leafy vegetables	86	90	76	88	87	79
Root vegetables	80	85	66	81	81	69
Potatoes	93	90	80	87	80	64
Fruit vegetables	88	92	87	64	84	47
Fruits	42	82	74	27	52	45
Mushrooms	17	100	58	9	88	74
Cereal products	0	0	0	0	0	0
Milk	5	0	0	0,4	4	17
Other milk products	0,3	0	1	1	1	4
Meat	27	25	13	26	27	32
Eggs	70	54	52	76	73	82
Fish	7	12	4	50	23	10
Shellfish and crustacean	–	–	0	77	29	0
<i>Wine</i>	85	79	94	0,1	94	3
<i>Tap water</i>	2	0	7	2	4	3

Table 5. Mean, min and max values of the quantity home-consumed for each foodstuff categories from the different local surveys, and name of the surveys corresponding to the min and max values in kg/y.

Foodstuff cat.	Mean	Min	Survey	Max	Survey
Leafy vegetables	30	21	Marcoule	36	Tricastin
Root vegetables	17	9	Marcoule	26	Tricastin
Potatoes	39	22	Marcoule	65	Gravelines
Fruit vegetables	82	29	Bure	153	Tricastin
Fruits	45	13	Gravelines	81	Tricastin
Cereal products	0	0	<i>All</i>	0	<i>All</i>
Milk products	4	0	Tricastin	14	Bure
Meat	21	9	Marcoule	27	Bure
Eggs	8	4	Tricastin	10	Bure
Fish	3	1	Marcoule	8	Gravelines
Seafood (shellfish and crustaceans)*	5	0	Marcoule/Bure	14	Gravelines

* For the following sites: Marcoule, Gravelines, Blayais and Bure. The distinction fish / shellfish and crustaceans was not done in previous surveys.

Table 6. Consumption and home consumption values used for the gardener village reference group (Mean, min, max and 95th percentile values of the quantity consumed and home-consumed for each foodstuff categories).

Foodstuff		Min. (g/d)	Max. (g/d)	Mean (g/d and kg/y)		Standard deviation	95th percentile (g/d and kg/y)	
Leafy vegetables	Consumption	6.9	221.4	99.92	37	47.05	194.02	71
	Home-consumption	0	188.7	77.72	28	49.42	176.56	91%
Root vegetables	Consumption	0	293.5	62.16	23	52.98	168.12	61
	Home-consumption	0	178.6	42.63	16	42.76	128.15	76%
Fruit vegetables	Consumption	38	493.3	171	62	82.45	335.88	123
	Home-consumption	0	417.9	80.57	29	78.3	236.63	70%
Fruits	Consumption	0	582.4	184	67	104.74	393.48	144
	Home-consumption	0	424.6	82.9	30	74.05	231	59%
Potatoes	Consumption	0	644.4	130.9	48	81.02	292.97	107
	Home-consumption	0	555.6	83.64	31	90.63	264.90	90%
Milk	Consumption	0	965.52	208.02	76	173.32	554.66	203
	Home-consumption	0	705.88	34.36	–	114.23	262.82	47%
Meat	Consumption	0	133.88	46.03	17	33.15	112.33	41
	Home-consumption	0	102.93	10.57	–	24.02	58.61	52%
Cheese	Consumption	7.94	121.54	46.1	17	24.78	95.66	35
	Home-consumption		71.54	4.4	–	13.72	31.84	33%

of Bure. The home-consumption is finally more important for people living close to the sea (Blayais and Gravelines): respectively 26 and 64% of home-consumption of seafood (fish, shellfish and crustacean) against 4 to 12% for people in sites located away from the sea. This finding could be compared with local production in each of the five regions (Parache, 2011; Parache *et al.*, 2011b; Parache, 2012, 2013, 2014; Leclerc, 2014) and (Andra, 2018; Leclerc *et al.*, 2014).

In its report on the gardens (Schwartz *et al.*, 2013), the ADEME explains that gardening concerns 51% of rural families. This practice concerns only 20% of families living in a city of more than 100 000 inhabitants. This helps to explain the levels of home-consumption of fruit, vegetables and potatoes observed in local surveys. According to this report, nowadays, retired people are more likely to use gardening than before. Among the farmers, 74% have a kitchen-garden and the total rises to 93% for farmers aged between 55 and 65 years in contrast to workers and employees, with averages respectively 40% and 25%. The rurality of the population has no influence on the home-consumption of fruit and vegetables (Parache-Durand and Grandjean, 2015). However, it can affect the home-consumption of livestock products (meat, milk and eggs). The very rural nature of Bure site, could explain the observed levels for home-consumption of these products. In many cases, rates of home-consumption vary from one food category to another. The region of origin is also of importance.

Table 5 presents the mean values of the home-consumed quantities for each foodstuff categories on the basis of the results of these different surveys. The minimum and maximum are also given for information. For leafy vegetables, the gap between min and max values is less than a factor of 2. For eggs, it is about 2. And for all other foodstuff categories, the gaps are between factors of 3 to 8. It is linked to a very high home-consumption rate of fruit vegetables and fruits from the Tricastin survey and to a high home-consumption rate of seafood products from the Gravelines survey.

3.3 Use of statistical analysis

Sensitives analysis can be made on human behaviour considering statistical analysis.

Beyond the use of food survey results as mean values in risk and impact assessment, the use of other results from a statistical analysis if available can be useful. If the sample size is large enough, some statistical analysis had allowed extracting statistical distribution of data, standard deviation and percentiles. Indeed, some very specific behaviour as high consumer of vegetables or dairy products can be pointed out for upper bound impact in risk assessments.

In the case of Bure survey, for example, 95th percentile values as specified in Table 6, are used to represent realistic but specific behaviour as high consumer of dairy products or kitchen garden products (raw data presented in Appendix 1).

4 Conclusion

These studies show that food surveys, even if conducted with the specific aim of dosimetric impact assessments, provide further in-depth understanding of the food habits of small groups representative of a mainly rural population. Taking into account local supply systems reach to more realistic data compared to national data. These surveys show that there are still local specific population groups that have a high level of “self-consumption” for local or regional products. This home-consumption includes specifically foodstuff among the more sensitive to a radioactive contamination. Furthermore, the acquisition of “local” data compared to “national scale” data, provides accuracy of the scenarios studied (taking into account variations or regional characteristics, for example) and thus promotes the credibility of impact assessment studies. Finally, local food surveys show that the season and the region can have a strong influence on the degree

of self-sufficiency and, consequently, the impact that would be received by certain categories of population living near those industrial sites in case of an accident or for authorized routine releases. This is a limitation of this article which does not present any figures concerning this aspect. But one of the surveys carried out concerned the four seasons and showed that there was variability according to the production seasons (Parache, 2010). Specifically, during the summer, the consumption of fruits and fruit-vegetables was much more important.

Current practices in health risk assessment for impact studies shows that in the absence of such specific data, the practitioner who wishes to introduce the concept of self-consumption in its exposure scenarios, most often choose between two extremes: 100% or 0% of self-consumption, and this for all food categories. Yet, the results gained through this study confirm the variability of this important parameter of the sensitivity of population exposed. Despite the changing of eating habits (supermarkets, ready meals), there are still groups of people with high consumption practices whose variability is due both to the categories of food and to the geographic area.

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Appendix 1 Results for Bure survey (Parache, 2014).

Food products	HOME-CONSUMPTION (g)					
	Min.	Max.	Average	Median	coefficient of variation	Standard variation
Fresh leafy vegetables	0.00	188.73	77.72	71.43	0.64	49.42
Fresh roots vegetables	0.00	178.64	42.63	31.25	1.00	42.76
Fresh fruit vegetables	0.00	417.86	80.57	71.43	0.97	78.03
Other vegetables						
dried vegetables	0.00	0.00	0.00	0.00	—	0.00
potatoes	0.00	555.56	83.64	75.00	1.08	90.63
mushrooms of Paris	0.00	0.00	0.00	0.00	—	0.00
wild mushrooms	0.00	68.68	6.82	0.53	2.01	13.70
wild asparagus and other wild plants	0.00	3.39	0.13	0.00	4.23	0.57
aromatic plants	0.00	25.00	4.63	3.23	1.07	4.97
Fresh fruits	0.00	424.59	82.90	71.43	0.89	74.05
Other fruit and honey						
nuts	0.00	14.61	0.21	0.00	7.41	1.58
dried fruits	0.00	0.00	0.00	0.00	—	0.00
fruit preserves and jams	0.00	53.85	4.77	0.00	1.99	9.50
honey	0.00	27.78	2.79	0.53	2.01	5.62
Meat, Eggs and Fish						
beef - veal - horse	0.00	102.93	10.57	0.00	2.27	24.02
sheep	0.00	39.11	0.90	0.00	6.14	5.52
pork	0.00	125.00	12.75	0.00	2.27	28.98
delicatessen	0.00	122.50	4.46	0.00	3.52	15.71
game	0.00	89.19	13.87	4.87	1.43	19.90
poultry	0.00	203.39	22.87	0.00	1.72	39.38
rabbits	0.00	76.92	6.51	0.00	2.14	13.96
snails	0.00	92.31	2.82	0.00	3.82	10.75
eegs	0.00	93.51	26.38	24.24	0.80	21.03
sea fish	0.00	0.00	0.00	0.00	—	0.00
river fish	0.00	68.57	2.87	0.00	3.14	9.00
shellfish and crustaceans	0.00	0.00	0.00	0.00	—	0.00
Other foods						
cow cheeses	0.00	71.54	4.40	0.00	3.12	13.72
goat cheeses	0.00	84.75	0.96	0.00	8.63	8.31
sheep cheeses	0.00	0.00	0.00	0.00	—	0.00
butters	0.00	0.00	0.00	0.00	—	0.00
oil	0.00	0.00	0.00	0.00	—	0.00
other fat	0.00	17.86	0.17	0.00	10.25	1.74
bread and rusks	0.00	0.00	0.00	0.00	—	0.00
other cereals: flour - semolina - pasta	0.00	0.00	0.00	0.00	—	0.00
chocolate	0.00	0.00	0.00	0.00	—	0.00
rice	0.00	0.00	0.00	0.00	—	0.00
salt	0.00	0.00	0.00	0.00	—	0.00
sugar	0.00	0.00	0.00	0.00	—	0.00
Liquid						
Milk (cow)	0.00	705.88	34.36	0.00	3.32	114.23
other dairy products	0.00	0.00	0.00	0.00	—	0.00
wine and liqueurs	0.00	88.76	1.82	0.00	6.05	11.02
beers	0.00	0.00	0.00	0.00	—	0.00
fruit juices and sugary drinks	0.00	116.55	7.83	0.00	2.68	20.97
tap water	0.00	1866.67	26.52	0.00	7.63	202.23
mineral water	0.00	0.00	0.00	0.00	—	0.00
tea - coffee - herbal teas	0.00	6.49	0.06	0.00	10.25	0.63