Interdisciplinary and participatory research for sustainable management of arsenic pollution in French collective gardens: collective process of risk manufacture

C. Dumat[1,2]*, Jing Tao Wu[3], A. Pierart[2,4], L. Sochacki[1]

[1]CERTOP (UMR CNRS 5044, UT2, UT3), Université Paul Sabatier-Toulouse III, 115 rte de Narbonne, 31077 Toulouse Cedex 4.
[2]Université de Toulouse; INP-ENSAT, Av. Agrobiopôle, 31326 Castanet-Tolosan, France.
[3]South China Botanical Garden, Chinese Academy of Sciences, Xing Ke Road 723,Tian He District, Guang Zhou 510650, PR, China.
[4]UMR 5245 CNRS-INP-UPS; EcoLab; 31326 Castanet-Tolosan, France.

***Corresponding author:** camille.dumat@ensat.fr

Abstract

At the global scale, an increase of gardening activities is observed in urban areas. The questions of vegetable quality and more widely the elaboration of policy for sustainable management of the collective gardens need therefore to be investigated. An interdisciplinary and participative research study "JASSUR" based both on agronomy and risk assessement was therefore conducted in a French collective garden impacted by arsenic (As) pollution in wells for irrigation. Gardener surveys and public meetings permitted to study the gardeners' representations of risk and build solutions for a sustainable site management. The theoretical framework of Gilbert (2003) bringing a social construction of risk was applied to investigate our research question: in what way the presence of arsenic is or not a public problem and how each party takes ownership of this issue?

Without official As limit concentration for vegetables from gardens, a collective process of risk manufacture took place. Interviews of gardeners, meetings with stakeholders and quantitative sanitary risk assessment (QSRA) were performed to carry scientific arguments to the authorities in charge of these gardens and to inform the gardeners. Arsenic total and human bioaccessible concentrations were measured in both vegetables and soils and compared to reference data from national database. Moreover, vegetables quantities produced were obtained in the field from gardeners using harvest booklet. On the basis of the maximum calculated potential diary As quantity ingested and QSRA it was concluded that gardening activities could continue using safe water for irrigation. By favoring the exchanges between gardeners and with other actors: research, politics, the pollution induced a structuration of their community and favor a collective construction of risk management. Our interdisciplinary and participatory approach is therefore useful to improve further management of pollutions in collective or private urban gardens.

Keywords: Urban agriculture; Risks; Sustainable gardening; Pollution management; Regulation; Sciences and Society.

Codes from JEL: Environment and Development; Environment and Trade; Sustainability; Environmental Accounts and Accounting; Environmental Equity; Population Growth (Q560); Agricultural Policy (Q180); Food Policy; Nonrenewable Resources and Conservation: Government Policy (Q380).

1-Introduction

For many reasons such as economic crises or uncertainty about the quality and origin of purchased consumed plants, a growing development of gardening activities is observed across the planet (Chenot et al. 2013; Ghose and Pettygrove, 2014). In urban areas, numerous new collective gardens are therefore created in response to the social pressure. Producing quality plants is the main objective of gardeners (Gojard and Weber 1995; Pourias & Duchemin, 2013). According to Menozzi (2014), collective gardens are a real tool to think and develop the city. Besides real environmental issues and social cohesion, the association "Green Garden" in Britain, aims to offer a credible economic urban gardening alternative in connection with the food issue. Hale et al. (2011) consider that gardens are a potential urban resource for active and passive learning about ecological processes. Actually gardeners represent an important community awareness of means clustering of sustainable development. As demonstrated by recent research using geographic information and mathematical methods (Ghosh 2014), the development of gardening activities could contribute to preserve the environment. In an increasingly industrialized food system, children are disconnected from opportunities to grow their own food. Consequently, current and future generations of young people may lack the experience of gardening and a deeper understanding of our food system, ecological knowledge and a holistic appreciation of food and nutrition (Devine et al., 1998).

But, atmosphere or soil pollutions are often observed in these urban areas mainly due to roads proximity, agricultural and industrial activities which occurred during centuries (Douay et al., 2008; Mitchell et al., 2014). Actually, many chemicals can flow or accumulate in atmosphere, waters, garden soils (Schwartz, 2013), and finally vegetables (Uzu et al., 2014; Clinard et al., 2015). However, currently there are no French regulatory threshold values for total concentrations of pollutants in the garden soils (Foucault et al., 2012; Mombo et al., 2015). Indeed, only marketed plants are regulated in Europe and just on some targeted inorganic pollutants such as lead, cadmium and mercury (EC, n°466/2001). Arsenic (As) is a persistent highly (eco)toxic and very often observed metalloid in the environment (WHO, 2010) and accordingly to Jennings (2013), chronic oral As exposure can result in gastrointestinal distress, anemia, peripheral neuropathy, skin lesions, hyperpigmentation, and liver or kidney damage. For such no regulated inorganic pollutant, a specific quantitative assessment of health risks (QSRA) must then be carried out in order to scientifically access the human As exposure in the case of consumption of potentially polluted vegetables (Ademe, 2014). For example, QSRA was necessary in the case of As pollution determined in collective gardens in order to carry scientific arguments to the authorities in charge of these gardens and to inform the gardeners. The objective of the QSRA is to assess the pollutant quantity potentially ingested by gardeners in the case of consumption of contaminated plants and compare it with reference value (Boutaric, 2013; Dumat & Austruy, 2014). It’s therefore necessary to both fill the quantities of produced vegetables in the gardens and their use (consumption, donations...) thanks to a survey of gardeners and a measurement of the pollutant concentration in vegetables (Xiong et al., 2014).

However, gardeners certainly come in the collective gardens to mind off and produce good vegetables for their health. When informed of pollution in their gardens, legitimate concerns arise therefore (Austruy et al., 2013). The gardeners in collective gardens want to know if their gardening activities can expose them to pollutants. In case of potential pollution, they generally organize special meetings with the scientific experts and politics in charge of the site in order to obtain precisions on the sanitary risk and the ways of managements that can be performed. Collective performed assessment and management of the risk can sometimes conduct to a new norm or regulation as exposed by Boutaric (2013): he considers that sanitary risk assessment is one of the instruments developed by scientists and whose characteristic of decision support confers properties to the frontiers of science and politics.

This form of organization of scientific expertise and the decision process is traditionally presented as an aid to public decision-making in situations of uncertainty. Then, gardeners are awaiting clear and rapid answers to the question: will there be a risk for my health if I consume my garden's production? But, due to the complexity of the bio-physicochemical mechanisms involved in the transfer of substances in terrestrial ecosystems and the numerous occurring interactions, scientists can rarely spontaneously respond to this kind of question (Dumat et al., 2013). They need before to make surveys, preliminary observations and dedicate time and money to measurements. Moreover, they often have only a partial view of the ecosystem and it's therefore difficult to simply answer and with certainty to a simple question of a gardener on the impact of pollution. The answer of one scientific will be generally: "it depends" of soil characteristics (texture, pH, soil organic matter amount…), crop variety and practices (Dumat et al., 2013). Usually, scientific and technical uncertainty about the quality of food products is due to the product itself or its mode of production whose evil knows the possible negative externalities. Here, uncertainty is also related to soil characteristics and practices of gardeners, much more difficult to "fit", to "trace" and "control".

Promoting operational collaboration between researchers and gardeners, is therefore a crucial environmental health issue as millions of citizens cultivate and consume vegetables in the world. It's certainly the main goal of the national French scientific research project "JASSUR" (Associative Urban Gardens in France and sustainable cities: practices, functions and risks, http://www6.inra.fr/jassur) in which our present study falls. The JASSUR project proposes to clarify in an interdisciplinary way, functions, uses, way of operation, and benefits or potential hazards that induce associative gardens within sustainable cities emerging. The project aims to identify the necessary means of action to maintain or even restore, develop or evolve these associative gardens in urban areas faced with the challenges of sustainability. To do this, it relies on a consortium of 12 research partners (various institutions) and of associations in seven French cities (Lille, Lyon, Marseille, Nancy, Nantes, Paris and Toulouse). JASSUR is based on a central question: what services urban gardening associations provide in the sustainable development of cities? These ecosystem services rendered to the city, in the completeness of the meaning of this term proposed by the Millennium Ecosystem Assessment (provisioning, regulating, supporting and cultural services) are still very poorly understood. Faced with the knowledge to develop information for the JASSUR project is the assumption that the study of food services provided by these associative urban gardens, yet very little research objects is a link between: (i) bio-physical-chemical characterization of soil and products from these gardens: the question of the potential risk of pollution caused by urban environment (soil, atmosphere) is central here because that could thwart the food supply service; (ii) a socio-technical characterization of gardeners practices, both in crop choices, techniques, participation of their garden produces to food and good nutrition of their family; (iii) a socio-political characterization of the governance of these spaces in urban areas, particularly in terms of management of locations, modes of operation, the potential environmental and health risks. The food supply services (cultural practices, productions and products locations, measurements of quantities consumed and nutrient intake, gardeners representations regarding the interests and dangers gardens) are analyzed and possible pollution management methods by communities are also studied. We are in a case of "citizen science" as described by Callon et al. (2002): gardeners are directly implicated in the research program and participate to the risk construction and management.

In the context of the national JASSUR project, an interdisciplinary and participatory research study based both on soil fertility and arsenic risk assessment and management was conducted in a French collective garden impacted by arsenic pollution in wells used for vegetables irrigation. Vegetables quantities produced in their gardens and food practices were obtained in the field from gardeners using harvest booklet previously used by Pourias et al. (2015). Total and human bioaccessible arsenic concentrations were measured in vegetables and soils sampled in gardens and compared to the data from national database focused on metals in vegetables. All these obtained data permitted to calculate the maximum potential diary As quantity ingested and perform the QSRA: scientific assessment of sanitary risk. The exchanges with gardeners on agronomy highlighted their relatively poor understanding of mechanisms involved in nutrients and pollutant transfers towards plants. Consequently, the arsenic pollution permitted to improve the structuration of their community by the development of exchanges between one another. This case study also led to great exchanges (with politics and researchers among others) about the management of sanitary risks inducing a collective process of risk manufacture. Organization of information (as databases and free open access pedagogic resources on sustainable gardening practices) and development of communication tools were therefore aimed. Figure 1 presents the general design of the study.

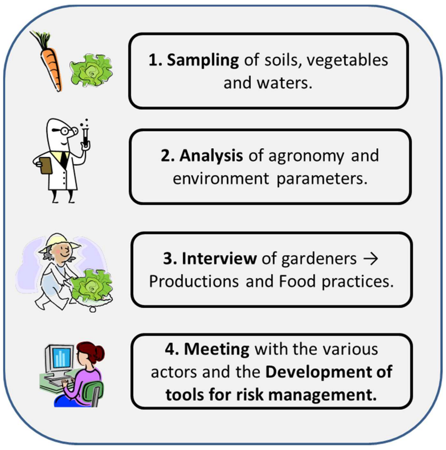

Figure-1. General design of the study.

Gardener surveys and public meetings have permitted to study the gardeners' representations of risk and build solutions for a sustainable management of gardening site. Gilbert (2003) in its publication “the manufacture of risks” exposes that the designation of risks as public problems as well as the selection and the grading of these risks are often explained in three great ways: (1) either like the result of arbitrations operated by the public authorities; (2) either like the result of confrontations between « civil society », and public authorities; (3) or still as the result of the way in which multiple actors define and build the problems. This theoretical framework was applied in this study to categorize gardeners in terms of their position with respect to the risk. Actually, the position of Gilbert (2003) brings an interesting perspective to this field: regardless of the scientific analysis, risk is a social construct. It will become a public problem if the various stakeholders will be appropriated for emergence as an issue to deal with. It's this process which is traced in this paper by observing interactions between gardeners, researchers and public authorities. The following question that guides the work: in what way will it proved the presence of arsenic or not being a public problem and how each party will take ownership of this issue? Our interdisciplinary and participative approach is therefore useful to improve further management of pollutions in collective or private urban gardens. After a chapter presenting the chronology of arsenic pollution “story” in the gardens and the interactions between the different actors involved, the collective construction of the sanitary risk of arsenic pollution in the gardens is described and finally it's explained how the problem of arsenic induced several changes both in the Environment-Health dynamics and interactions between the various actors involved in the polluted gardens.

2-Chronology of the arsenic pollution "story" in the gardens and interactions between the different actors involved

2-1. Description of the studied site

The associative gardens site is localized in Castanet-Tolosan near the "Canal du Midi" in Midi-Pyrénées Region. In 2005, a previously agricultural parcel was converted into 40 different individual parcels that are rented out by 50 amateur gardeners involved in the association and paying 50 euros per year. At the origin, soil characteristics were therefore approximately the same for all these 40 parcels. But, progressively in function on their agricultural practices each gardener significantly changed the soil characteristics of its parcel. Table 1 highlights these variations of exchangeable copper (Cu), phosphorus (P), potassium (K), organic matter concentrations, pH and CEC. Theses agronomic parameters were measured with standardized methods on dried and sieved under 2 mm soils.

Promoting sustainable gardening practices was targeted in our research study, especially based on a better knowledge by gardeners of both nutrients and pollutants transfers in the soil-plant-water systems in relation with their practices. Indeed, it's important for them to know the agronomic characteristics of their soil in order to reasonably choose the cultivated plants or the amendments. These soil parameters also influence soil-plant transfer of both nutrients and pollutants (Elouear et al., 2014). Moreover, the agronomic study provides a friendly handshake with the gardeners. The survey of gardeners highlights that Bordeaux mixture, the liquid manure (nettle and comfrey) and biological anti-slug are widely used. Medium Cu pollution was observed: Cu is low toxic for humans (except at strong dose), but it can reduce biological activity in soils. Exchangeable measured P and K nutrients (with normalized procedure) were compared with references values for fertilization (obtained from controlled field experiments). If the value for one studied soil is above the maximal accepted reference value of exchangeable element (Ti), then it's not necessary to add the nutrient (this is called "stalemate"). If the value is under the minimal accepted value of exchangeable element (Tr), then it's necessary to add a high quantity of the nutrient (this is called "building"). Using the reference values currently taken for agriculture, over-fertilization of garden soils was concluded in all plots. However, garden soils are different from agricultural soils: they present higher soil organic matter content and often have higher amount of coarse particles, it could be therefore pertinent to determine specific gardens reference values for fertilization.

Parcel number	pH-H_2O	pH-KCl	OM (%)	C/N	Clay (%)	Loam (%)	Sand (%)	Carbonates (%)	CEC (me.kg^{-1})
2	8	7.5	2.6	10	32	36	**32**	0.25	207
5	7.6	7.2	2	9	30	35	25	0.3	208
11	8.1	7.6	2.45	8.9	**35.8**	36.2	25.5	0.2	**265**
12b	8	7.6	3	11	35	37	28	0.3	211
13	**8.2**	7.4	2.85	9.7	31	**38.7**	27.8	**1**	209
15	7.6	6.8	2	10.6	35.3	37.1	25.7	0.1	237
21	7.8	7	2.8		24.4			0.7	146
26	**8.2**	7.4	**4.05**	**12.4**	33.5	37.2	25.4	**0.8**	242
35b	8.1	7.5	2.6	10.5	31	37	**32**	0.3	206

Parcel number	Exchangeable P_2O_5 JH (mg.kg^{-1})	Exchangeable K_2O (mg.kg^{-1})	Exchangeable Cu (mg.kg^{-1}) (Ti= 0,75)
2	**185** (50-125)	**575** (180-260)	1.8
5	**260** (170-240)	203 (180-260)	2.1
11	71 (50-125)	239 (200-285)	3.6
12b	53 (50-130)	260 (200-280)	2.8

13	80 (50-125)	225 (175-250)	2.3
15	79 (50-125)	**346** (200-280)	6.6
21	**383** (170-240)	**294** (200-280)	2.2
26	107 (50-125)	**280** (185-270)	5.5

Table-1: Agronomic parameters. Numbers in brackets and blue correspond to the reference values (Tr-Ti) which are obtained by field experiments.

2-2. Pollution context

Arsenic pollution of the well water used for watering vegetable productions of the associative gardens was discovered incidentally in 2010, by students as part of a pedagogic scientific work to characterize the agronomic and environmental quality of the site (Ladepeche, 2011). The figure 2 presents: (a) the localization of the site (1200m^2), (b) with the 40 parcels and the polluted wells.

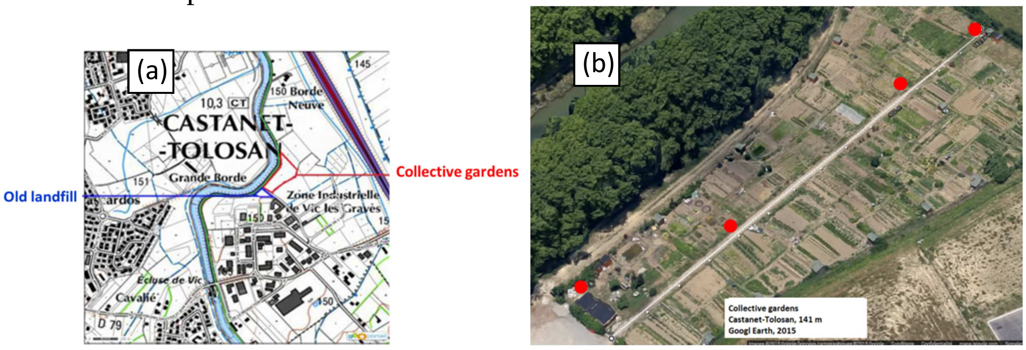

Figure-2. (a) Localization of collective gardens in Castanet-Tolosan (31) (b) description of the site with the 40 parcels and wells (red spots).

Following the detection of As pollution, the regional health agency (ARS) was contacted. Then, new water analyses were performed and finally a prefectural notification prohibited the use of water. Wells were then condemned in order to avoid acute health risk associated with the ingestion of contaminated water or its use for hand or vegetable washing. But as arsenic is highly toxic, gardeners remained expectantly on the quality of cultivated plants and the future of their gardens. That is why the participative research project on plant quantities and quality was organized. Thus, regular arsenic measurements were organized with gardeners and performed in water wells, soil and plant products on this site between 2010 and 2014 with regular exchanges with gardeners on the results. Moreover, discussions were held between the gardeners, the mayor and researchers to collectively manage the As pollution in a way taking into account gardeners' health and their numerous questions on environmental pollution.

2-3. Tools for risk assessment, communication and management

Initially, the Association of gardeners was mobilized by the researchers for educational project concerning agronomy. Then, when the As pollution of well water was discovered the concerns of different stakeholders have been facing the management of health risks. Once convicted wells, and therefore the known health risk controlled, gardeners wished to continue gardening and therefore expected quick answers from ARS, the mayor and researchers on the quality of cultivated plants. To respond to that social problem, the researchers first conducted spontaneous analyzes (without precise research program), then the JASSUR project (2013-2016) was funded by "sustainable cities" program from French Agency for Research (ANR). Previously, ADEME funded a first research program (without analyzes) dedicated to the state of knowledge instead of the gardens in France (SOJA project, 2009-2011). Following this project, analyzes of pollution in the gardens were aimed by ADEME. But, ultimately ADEME did not wish to engage in this gardens characterization project for economic and strategic reasons. However, thanks to the results of this project a book concerning the French gardens was written: “Jardins potagers: terres inconnues ?” (Chenot et al., 2013). Actually, the complexity of these ecosystems makes it difficult and expensive to characterize gardens and it generates numerous uncertainty. Facing the pollution and to manage the uncertainties, the various actors have aims and perceptions that differ: (i) gardeners want above all to continue their gardening activities; (ii) the mayor and the ARS want to manage health risks; (iii) researchers wish to achieve robust measures: production and quantification of measures of pollution in the gardens. Finally, these different actors interact throughout the project to co-build a common representation of the risk used then for its sustainable co-management.

The “Harvest Booklet” method described by Pourias et al. (2015) was used with gardeners from nine different selected parcels (numbers: 2, 5, 11, 12b, 13, 15, 21, 26 and 35b) in order to perform the quantification of productions. The booklet (see figure-3) includes tables with the following headings: (a) type of crop; (b) date of harvest; (c) quantity harvested (in grams or units); (d) use of the crop (eaten raw or cooked, preserved or immediate consumption); and (e) destination of the crop (gifts outside the close family). In addition the harvest booklets permitted to interview the gardeners to know their gardening practices (nature of the soil amendments and treatments) and their level of concern about As pollution. The harvest booklet may also be considered as a "listing": an instrument that transforms the material into writing, traces essential to the production of scientific facts. It’s through their configuration as the phenomena that are studied acquire visibility and true existence. The instruments of the "laboratory" produce a reality that Latour and Woolgar (1979) call "technical phenomena" which is the starting point for the production of fact. Without them, impossible to work on anything, actually, this reality is produced by the technical instruments in the form of traces; it’s as inscriptions that phenomena are apprehended by scientists. Further, meetings of the association and with city hall helped to complete the individual analysis of the organization of the association to deal with As. From 2010 to 2015, 15 meetings were organized between the researchers and the gardeners in order to communicate on the As pollution study and explain the data measured. In that way it was possible to motivate the gardeners to complete the “Harvest Booklet”.

Figure-3. Harvest Booklet: Front and Back Covers and Inside Pages. (Pourias et al., 2015)

2-4. Strategy of the study, sampling (waters and vegetables) and analysis

Water quality was studied in the wells used for gardens irrigation and outside the site in order to investigate the origin of pollution. Actually, numerous discussions were performed to define the As origin: natural geochemical background or anthropogenic activities?

Sampling of vegetables was performed according to the ADEME (2014) "Sampling Guide for Vegetables in the context of environmental diagnostics". Both lettuces (leafy vegetable) and carrots (root vegetable) were sampled. After peeling for carrots, vegetable samples were washed to remove potentially surface contamination (Uzu et al., 2010) and analyzed using the same procedure as Schreck et al. (2011). Human As bioaccessibility was performed according to Xiong et al. (2014) using the *in vitro* Unified Barge Method that simulates the processes occurring in the mouth, stomach and intestine compartments with synthetic digestive solutions. As bioaccessibility was finally expressed as the ratio between the extracted As concentration in the saliva-gastric phase and the total concentration before digestion. The data obtained were analyzed for differences between treatments using an analysis of variance (one-way ANOVA). Statistical analysis was carried out using the software Statistica, Edition'98 (StatSoft Inc., Tulsa, OK, USA). A Fisher's LSD test was used to determine the level of significance (p-value < 0.05) against the control.

3-Collective construction of the sanitary risk of As pollution in the gardens

3-1. Gardeners groups and level of implication in regards with As pollution

Once identified the risk of pollution, the ARS and the Mayor have positioned themselves: the main source of risk (wells) is confined. Gardeners have adopted various postures on the basis of refunds tangible scientific results on which to build. The interviews with the gardeners of the 9 plots studied in detail, and also the discussions at 4 general meetings with a total of 30 gardeners has allowed to identify three levels of interest in the problem of arsenic pollution: (group-I) the confidents, (group-II) the dynamics and (group-III) the opposites. Table 2 presents the profiles of these three groups. In addition to that categorization of gardeners in regards to the arsenic pollution, the dynamic of the actors and collective risk construction is analyzed further in the chapter 3-3.

Group of gardeners	Characteristics
(I) The confidents (20%)	Some gardeners feel little concerned with As pollution and do not care at all. Since the wells are convicted, they are heedless and listen distractedly to the information provided on the As analyzes. They make full confidence in the management of gardens, the mayor and scientists. They come to the gardens to cultivate vegetables and apply the guidelines of good practice, but don't ask questions or are dynamic agents of change. Better knowledge of factors influencing transfers of pollutants in soils or human exposure to pollutants is not a priority for them.
(II) Dynamic actors involved in environment-health aims (70%)	Another part of the gardeners (the majority) are very interested in information on arsenic pollution. They promptly want the results of measurement and ask many questions. They are dynamic actors to develop pro-health-environment practices. For example, providing quality compost or using green manure plants. They are also very active in the search for a lasting solution for watering gardens. Since the wells were closed and based on the arsenic analysis results they are not worried, because their opinion is based on scientific arguments. Moreover these gardeners are also strongly involved in the life of the association, very dynamic and motivated to take part in sustainable development projects such as the creation of a pond to encourage biodiversity in gardens (2013) or the creation of a plot garden accessible for handicapped gardeners (2015). They work in harmony with the Mayor and therefore are in a position of seeking solutions to sustainably manage the pollution and reduce As exposure while remaining in the gardens.
(III) Opposite gardeners (10%)	The last part of the gardeners is quite vehement during the meetings. They want to communicate their disagreement against the mayor who provided

	these gardens or against the scientists who can't convince them that the sanitary risk is controlled if human exposure is low. Moreover they don't understand why the As origin isn't determined with certainty. They would like that the mayor regularly write that As water pollution is totally controlled and has no impact on their health. Rather worried, they don't propose solution. Only one part of them is interested to known the results and have a better understanding of transfers. From another side, this gardener group is less involved in gardening activities and much more anxious with respect to pollution. They would like clear evidences that arsenic cannot contaminate them. A gardener in this group preferred to leave its garden, explaining that he was not reassured by the analysis of ARS, the posture of the mayor and researchers analysis.

Table 2: Three levels of gardeners' interest for arsenic pollution problem

3-2. Water pollution: what consequences and management?

The origin of the contamination is unclear…

The water pH ranged between 7 and 7.5. The table 3 presents arsenic concentrations measured in water of the various wells (P_1-P_4) between 2010 and 2014. In comparison with the regulated value for drinking water in France (10 µgAs.L^{-1}), we can conclude to strong polluted water. This is why water cannot be used anymore for hand washing and watering productions and even less ingested until further analysis are performed and demonstrate a reduction of As concentration. Meetings were organized with politic and technical services of the town in order to manage the situation. The regional agency for health was prevented by the researchers and supplementary measurements in waters were performed. Then a prefectural attestation has banned the use of the polluted water in 2011. Several hypotheses were proposed by the different actors to explain such As pollution of water wells:

1) A former landfill is located just near the main entrance to the gardens. As the gardens were moved in 2005, gardeners who support this hypothesis are highly critical because they think that the mayor has taken a bad decision with changing the location of these gardens.

2) Another hypothesis is the piling up of large quantities of pesticides enriched with arsenic in the soil after one pesticides factory closed in 1980. Few old gardeners who have been living since a long time in Castanet-Tolosan seem to remember these practices.

3) According to another gardener, during the explosion of the AZF factory in Toulouse, polluted excavated soils were used at regional scale; a third hypothesis is therefore that As pollution has been induced by the addition of these polluted lands. However, as the main chemical substance used on the AZF site was ammonium nitrate and moreover according to The ARIA database (Analysis, Research, and Information on Accidents) most of the polluted lands were cleared on the site (http://www.aria.developpement-durable.gouv.fr/wp-content/files_mf/FD_21329_Toulouse_2001_fr.pdf), this hypothesis seems therefore implausible.

4) A final hypothesis is the natural origin of arsenic in the mother rock from which the soil has developed; well water could therefore enrich especially as these wells are often used and dug deep. Actually, high As values in waters due to the natural alteration of rock enriched with arsenic was effectively observed in the Midi-Pyrénées Region.

In addition of the wells in the collective gardens, supplementary analyses were performed in different wells from surrounding areas upstream and downstream of the collective gardens, and no pollution of water was observed. In consequence, the hypothesis of As transfer from an anthropogenic storage (landfill for instance) was ruled, and the local geology origin of arsenic was concluded. But it was complex to explain to certain gardeners why the origin of the pollution is difficult to certainly determine. Actually, the precise geology of the site was not known, it was therefore difficult to know where to dig a new well in order to avoid the geologic rock enriched in arsenic. Relatively random sampling was used and unfortunately the new P_4 (created in 2013) was finally also enriched with arsenic.

Well number and date for sampling.	**P_1** 02-2011	P_1 05-2014	**P_2** 02-2011	P_2 05-2014	**P_3** 11-2010	P_3 01-2011	P_3 02-2012	**P_4** 05-2014
As ($\mu g.L^{-1}$)	5	28	9.9	28	120	372	220	90

Table-3. Values of arsenic concentrations in wells water since 2010. 2

…But safe watering solution exist

These strong concerns from gardeners were recounted in the local press (Ladepeche, 2011): Castanet-tolosan (France, 31), Arsenic pollution home gardening, interview with the responsible of the site. “We discover with surprise, bitterness and concern the serious pollution of our wells condemning the continuation of our gardening activities and that without understanding the origin". Raymond Joly, president of the association of the collective gardens in Castanet (near one of the polluted wells in the picture bellow: figure 4), is worried, as he wrote to the mayor.

Figure-4: The head of collective gardens (R. Joly) near one of closed polluted wells (Ladepeche, 2011)

Many gardeners who have plots on municipal land, were shocked to learn that the well water was polluted with arsenic. Since a municipal ordinance prohibiting watering was decided, discussions started between the gardeners both about the solutions for irrigation of cultures without the wells and about the potential soil and vegetables As pollution. Gardeners are party-actors in the development of these solutions, not mere recipients to apply the solution adopted for their practices. Overwhelmingly they want to keep their garden and are very motivated to find solutions for watering crops by different means than the use of wells. Moreover once the danger associated with wells of the water is removed, a shift in the health risk assessment is logically to soil quality and especially plants. However, gardeners' exposure to arsenic will be influenced both on arsenic concentrations in plants and also garden uses. The risk is multi-criteria and is built on the land. Different approaches have been explored: (i) Use water from the near channel? (ii) Use drinking water? (iii) Establish a water decontamination system. Finally, the mayor organized the access to safe drinking water for the gardeners? Actually, the Mayor has an administrative obligation to protect gardeners' health in collective gardens. That is why he needs to take care with sanitary risk management. In the case of water pollution, it's quite easy to take decision as maximum limit value is available for water quality. But, in the case of vegetables quality it's more difficult to take a decision as metal(loid)s phytoavailability depends on numerous parameters (Shahid et al., 2014). Then, questions were quickly raised about the quality of plants: what risks? Should the gardens be condemned or is it possible to continue gardening and under which conditions?

3-3. Dynamic of the actors and collective risk construction…

The collective risk construction

This chapter aims to describe the collective production of risk process. It emphasized how the risk of contamination has been built; what the actors (gardeners, researchers) wore and enlisted to highlight the risk. This study involves three main categories of stakeholders: gardeners, public managers and researchers. However, when hollow inside of these categories, as shown in Table 2 for gardener profiles, we see that concerning the management of pollution membership of a large category is not a key criterion of the posture adopted by each person. Actually, some gardeners are very involved in the acquisition of useful data for researchers, "we really appreciate the work done by researchers to accompany us in the management of pollution and in addition it costs nothing!" (verbatims collected in 2012 at a public meeting concerning the collective gardens). Other gardeners do not believe that the mayor takes the measure of the situation and doubt the seriousness of the risk management by the ARS, the Mayor and experts: "would have the mayor agrees in writing that the gardens are safe for our health "(verbatim collected in 2014, while both the ARS and the mayor gave the green light to continue gardening activities after the closing of wells). In order to explain to that category of gardeners why only certain analysis are performed in the gardens and no all the available scientific analysis, a parallel between “human health” and “environmental health” can be used: a doctor first performs simple, quick, cheap and standard tests and an interview of its patient before making a diagnosis and then he may eventually send him to consult a specialist for further analysis. An expert in soil science will proceed in the same by steps way and taking into account the economic aspects of the soil quality study.

Researchers involved in the project are also implicated at different levels: research program JASSUR, teachings and involvement as a citizen. The scientific risk assessment is carried out by experts in collaboration with the gardeners in the JASSUR project. Construction of the risk and its management is conducted by the group of gardeners who works with the mayor, its services and asks researchers. Researchers who are involved in the management of pollution and are working at the interface between the gardeners and the authorities organize research and participate as experts (scientific assessment) and also as observers (in risk management by gardeners and mayor). We are therefore in a case of risk manufacture of type 3 according to the theory developed by Gilbert (2003) in its publication “the manufacture of risks”. The author uses the concept of risk manufacture to underline here the constructed nature and not given risks. The objectification of labor risks performed through the use of technical and scientific expertise does not overlap - even opposing - the perception that the public (population, public opinion ...) can have these risks. Therefore, public authorities (government, state ...) responsible for collective security, are forced to make adjustments and even trade-offs to integrate this dimension in risk management. Therefore shifts can occur constantly between these different modes of explanation. One of the challenges for human and social scientists is probably to better understand the multiple uses of these different modes of explanation of "manufactured risks". This approach relies on the ability to carry through an effort of knowledge, an objectification of a large part of the dangers weighing on communities. Considered as existing in it, these dangers have causes that can be identified, probability of occurrence that can be calculated and any damage can be assessed. With this "risk setting", the uncertainties associated with hazards are reduced, facilitating their objectification. Overall, therefore, the idea of a possible risk control is required thanks to the link between expertise and decision. The development of new principles such as the precautionary principle, which is accompanied by new forms of knowledge and action, however, makes possible the treatment of problems located at the limits of knowledge and management capacities - even if questions are emerging on the reality of the threats in question and the given scope to the principle of precaution. The main obstacles lie elsewhere, in the way the public perceives the risks and threats.

Several uncertainties and several postures of the actors…

Regarding the management of uncertainties related to the complexity of pollution in the gardens, the different actors involved have different postures due to varying levels of expertise and moreover various issues. Chevassus-au-Louis (2000) describes in detail the thinking on uncertainties in areas that affect food. However, in the case of collective gardens, except if the sanitary risk is very high, the gardeners generally want to stay in their gardens and continue their activities: they research therefore solutions to manage the pollution and are very interested to collaborate with the other actors (mayor, scientific experts). It's why only a minority of gardeners adopts the posture described by Chevassus-au-Louis (2000). The author highlights that although the decrease in the overall dietary risk seems proven in France, citizens, warned by some recent crises, are increasingly perplexed about health control reality. A secular logic, qualitative, partly due to the symbolic value of food, opposes the quantitative and probabilistic approach of experts. To conduct comparative evaluations of different risks, experts have developed a metric derived from game theory, that risk is defined as the product of the danger by its probability of occurrence (Chevassus-au-Louis, 2000). This metric, based on the law of large numbers, is facing that of the citizen. For the acts of his life - and food is one - the citizen prefers to have binary indicators: what is or what is not dangerous. Moreover, the notion of "quality" of the hazard, defined by a set of characteristics which, similar risks will lead citizens to consider some acceptable and others not. Several "attributes" of a risk are capable of modulating its acceptance, including: (i) the voluntary nature (I decided to expose myself to the risk) or sustained (someone else exposes me) risk; (ii) his known character (I know when I expose myself) or unknown; (iii) the immediate consequences (I quickly perceive the possible effects) or delayed hazard, if the consequences to future generations is an extreme case of delayed effects; (iv) the just character (those who create risk are those exposed to it) or unfair risk; (v) the catastrophic potential, that is to say the number of people affected by the problem; (vi) confidence or not in the risk assessment made by scientists. This paradigm, whose relevance is supported by empirical studies, leads to the conclusion that the qualitative characteristics of a risk are, for the citizen, at least as important as its quantitative characteristics lead to its acceptance or refusal. If this approach of "qualities" of the risk is relevant, it can provide the key for a "reconciliation" of the citizen and his diet.

4-The problem of arsenic induced several changes both in the Environment-Health dynamics and interactions between the various actors involved in the polluted gardens

4-1. Scientific approach of the environment and Health risk: "QSRA"

Gathering knowledge dealing with pollutants transfer in the environment is crucial

As shown by the figure 5: **(A)** the collective gardens of Castanet-Tolosan are productive, between 80 and 100% of the available surface area is used to grow vegetables. However, gardeners pay special attention to the aesthetics of gardens: flowers and decorations are present in all the plots. **(B)** Bordeaux mixture ($CuSO_4$) is currently used in the gardens. However, copper is persistent in the environment so it'd be wise to reduce inputs. **(C)** To obtain good yields of vegetables, gardeners realize the contributions of nutrients mainly using composts and frequently irrigate their plots. The issue of water quality is therefore crucial for them, and **(D)** since As discovery in well water, meetings between the different actors have been regularly organized (2011-2015).

Figure-5: **(A)** productive collective gardens of Castanet-Tolosan. **(B)** Bordeaux mixture ($CuSO_4$) is currently used in the gardens (blue spots on leaves). **(C)** The issue of water quality is crucial for gardeners and **(D)** meetings between the different actors have been regularly organized to discuss that subject (2011-2015).

Improving the scientific knowledge on: (i) As soil-plant transfer and (ii) QSRA, of the different actors involved on potential arsenic exposure (induced by ingestion of vegetables cultivated in the collective gardens of Castanet-Tolosan) is an important challenge to manage the pollution on scientific bases. Moreover, it's important to describe clearly this experience of As pollution to further diffuse it to the French community of gardeners. If citizens are interested in sustainable environmental management, they especially feel concerned about their health as concluded from our study.

The sanitary risk occurring with arsenic found in water and potentially in vegetables they cultivate with care is a driving force for gardeners to understand the transfer of chemicals in the environment. They understand that the characteristics of the soil or the crop species can influence As amount found in the crops. In this favorable environment to trade, it's also an opportunity for researchers to educate gardeners in sustainable gardening practices, for example, to determine their soil texture, to be vigilant about Bordeaux mixture doses made or compost quality.

Using Daily Intake measurement could help to assess health risks efficiently

In the studied collective gardens, water is significantly polluted with As in regards to the French regulation so restriction was posed by authorities to forbid its use. But assessing the potential sanitary risk due to soil and plant pollutions is complex and needs several field measures. Indeed, previously to root uptake, a transfer step from soil to soil solution occurs and represents the fraction of pollutant which is eventually considered as phytoavailable (Austruy et al., 2014). Now, this phytoavailable fraction is strongly influenced by soil parameters such as pH, soil texture, organic matter content and the type of plant (Leveque et al, 2014). Measuring the pollutant concentration in the edible parts of plants permits to obtain that phytoavaible fraction. In order to assess human As exposure following ingestion of cultivated vegetables potentially polluted, daily intake (DI, $\mu g.d^{-1}$) can be estimated from the vegetable measured As concentrations ($\mu gAs.kg^{-1}$) and daily vegetable consumption rates (kg.d^{-1}). Daily vegetable consumption is generally obtained from field studies such as those carried out by Sharma et al. (2009). They observed pollution of vegetables in and around an Indian city and studied the associated risk of exposure to the metals. Formal interviews conducted in the urban areas of Varanasi showed that the average daily consumption of fresh vegetables per person (body weight of an average adult: 60 kg) was 77 g of fresh weight (FW) or 13 g DW. Interviews of gardeners from Castanet indicate a consumption of FW vegetables between 30g and 300g.d^{-1}.

Crop yield and diversity in the gardens

The following figure-6 regroups the quantities of vegetables produced in the gardens in 2013 (a) and 2014 (b) obtained by interviews of the gardeners through the harvest booklet. Accordingly to Clinard et al. (2015), if high plants biodiversity was observed in collective gardens, approximately ten species are widely cultivated in the parcels. Potatoes, tomatoes, green beans, salads, zucchinis, leeks, pumpkin, cabbages, cucumbers, broad beans, eggplants and carrots were the most common fruits and vegetables cultivated and eaten in large quantities. For studied cropped plots with average surfaces around 110m^2 there are significant changes in total quantities of produced vegetable: a factor of 5 for 2013, between 56 kg.year^{-1} 226 kg.year^{-1} and the same trend for 2014 between 48 and 238 kg.year^{-1}. From one year to the other (2013 and 2014), quantities of produced vegetables were stable, however the cultivated species varied: for example due to heavy rains in 2013, tomato production was relatively low, the gardeners have adapted their practices to climate and favored potatoes cultivation.

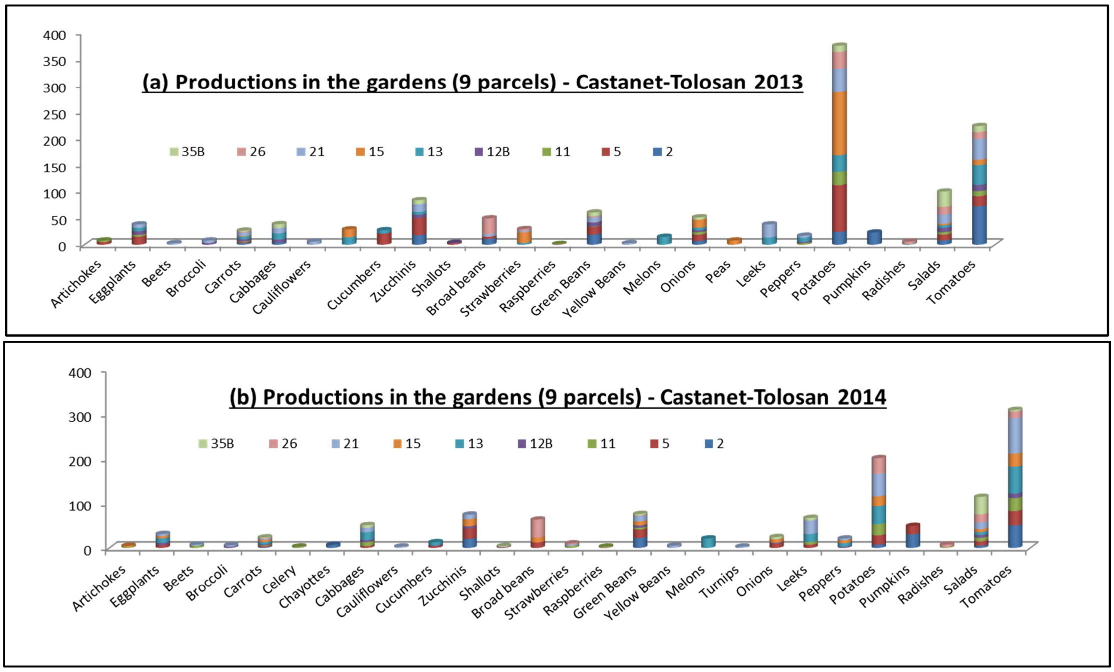

Figure-6: The quantities of vegetables (kg fresh matter) produced in the gardens in 2013 (a) and 2014 (b) obtained by interviews of the gardeners using the harvest booklet.

Arsenic content in edible vegetables: the interest of open-access databases:

In 2010, 2013 and 2014, arsenic was analyzed in vegetables and the corresponding soils in order to follow the potential evolution of the pollution and inform the gardeners. In 2010 analysis were performed on various species (carrots, lettuces, green beans and leeks) and [As] results were all under 0.05 mgAs.kg^{-1} dry weight (DW): it means low As concentration such as value measured for vegetables cultivated on unpolluted soils (see BAPPET database, Ademe 2014). Then As measures were regularly performed in 2013 and 2014, both on lettuce (leave plant) and carrot (root plant). Table-4 gives theses total and bioaccessible measured As concentrations. Nowadays, As concentration is not regulated in consumed plants. To interpret the measured As values in the gardens, it's therefore necessary to compare with values of plants grown under different As conditions (different uncontaminated and contaminated soils) available in the free open access BAPPET database. That database is widely used by professional and researchers interested by plant quality in relation with metal pollutions.

Parcel number	Surface (m^2)	$[As]_{Lettuce}$ ($mg.kg^{-1}$)	Bioaccessibility (%)	$[As]_{Carrots}$ ($mg.kg^{-1}$)	Bioaccessibility (%)
2	105	0.04±0.003 / *0.035*	66	0.01±0.001 / *0.015*	71
5	142	0.03±0.0015 / *0.024*	45	0.01±0.001 / *0.01*	53
11	142	0.03±0.001 / *0.03*	44	0.01±0.001 / *0.009*	53
12b	71	0.03±0.005 / *0.025*	50	0.01±0.001 / *0.01*	57
13	163	0.065±0.01 / *0.07*	30	0.02±0.0015 / *0.015*	39
15	150	0.03±0.001 / *0.035*	42	0.01±0.001 / *0.01*	51
21	124	0.065±0.01 / *0.065*	71	0.02±0.0015 / *0.02*	75
26	124	0.055±0.005 / *0.05*	21	0.015±0.001 / *0.01*	29
35b	50	0.035±0.001 / *0.03*	55	0.01±0.001 / *0.015*	65

Table-4: As Total concentration and bioaccessible fraction measured inlettuces and carrots, both in 2013 and 2014.

The following table-5 presents the results (minimum and maximum values) of extraction data from BAPPET. Mench & Baize (2004) also reported values of 0.1 $mg.kg^{-1}$ DW for spinach and 0.3 for carrots organically grown. The As concentration measured in soils for various parcels was maximum 14 $mg.kg^{-1}$, with 2% of $CaCl_2$ phytoavailable fraction. According to Austruy and Dumat (2014) ordinary As values in French unpolluted soils are between 1 and 25 $mg.kg^{-1}$ DW. But, locally natural high concentrations (100 $mgAs.kg^{-1}$) were observed in calcareous or phosphorus deposits. According to these different results, we can conclude that cultivated vegetables and the gardens soils aren't significantly polluted with As.

Plant	$mgAs.kg^{-1}$ DW plant	$mgAs.kg^{-1}$ DW soil
Lettuce	**1.6** - 11	17 - 115
Carrot	**0.11**-1.2	17 - 115
Leek	0.001-0.025	100 -140
Green bean	0.1 - 0.75	17 - 115
Pea	0.04	322
Radish	0.6-3.9	23 - 196

Table 5: Results (min - max) from BAPPET in plant and soil.

The following Eq. (1) is generally used to calculate the daily human intake of pollutant (Swartjes 2011; Okorie et al. 2012):

$$DI = [pollut]_{veg} \times DC_{veg}$$

With DI the daily intake in $\mu g.d^{-1}$; $[pollut]_{veg}$ the vegetable pollutant concentration, in $\mu g.kgFW^{-1}$ and DC_{veg} the Daily vegetable consumption in $kgFW.d^{-1}$

The determined DI values are then compared to tolerable daily intake (TDI, $\mu g.kg^{-1}.d^{-1}$), expressed as the quantity of pollutant ingested each day (µg) as a function of kg body weight (BW). In regards to the health risks associated with the presence of As, TDI-As is equal to 0.003 $mg_{As}.kgBW^{-1-1}.d^{-1}$ (Okorie et al. 2012), which corresponds to 180 $\mu g_{As}.day^{-1}$ for a 60kg human. In our study, the maximum measured As concentration in vegetables was 0.065 $mg_{As}.kg^{-1}$ DW. The assessed daily ingested As quantities (in the case of cultivated vegetables consumption) are therefore between 0.325 μg_{As} and maximum 3.25 $\mu g_{As}.d^{-1}$day for the

gardeners in Castanet. These values can be compared with the TDI value of 180 $\mu g_{As}.d^{-1}$ (55 times higher than 3.25).
The maximum daily quantities of vegetables consumed to reach the TDI can be calculated with Eq. (2):

$$DC_{MAX} = \frac{TDI}{[pollut]_{veg}}$$

With DC_{MAX} the Maximum daily vegetable consumption ($kg_{veg}.kgBW^{-1}.d^{-1}$)

Using the concentration values measured in lettuce and 60 kg BW as an average adult weight, the maximum daily quantity of vegetables cultivated in the gardens that can be consumed without exceeding the TDI was therefore calculated: 2.8 kg DW or 16.8 $kgFW.d^{-1}$. Moreover the bioaccessibility measures indicate that only one part of the ingested As is bioavailable. We can therefore conclude with the actual scientific knowledge and regulation that the cultivated vegetables in the collective gardens from Castanet can be consumed, without sanitary risk induced by As observed in the closed wells.

Here, there is therefore the result of the risk assessment by the "experts". In relation to the types of gardeners presented in Table-2, some gardeners and the Mayor are reassured, other gardeners are heedless because this risk was not seen, and yet others cast suspicion on these results as they would like/expect a large-scale program of measures to be funded by the city and moreover uncertain origin of pollution still permits multiple hypotheses. Thus, environmental quality measurement (soil, water, air) upstream of the development of new gardens as well as the establishment of channels for amendments qualities (straw, compost ...) appear as certainly essential for credible public action and effectively promote the development of this form of agriculture.

Using and completing existing databases on soil quality has to be promoted

Finally, the question of the pollution origin remains unanswered as the priority of the ARS and of Mayor of Castanet-Tolosan is certainly to protect populations (and not to perform scientific investigations). This objective is achieved with shut-in wells and controlling the quality of cultivated plants. Anyway, looking beyond the pollution source is an approach that is advocated through sustainable management of soil resources. Actually, in the cases where the source of pollution is located and can be removed from the environment, risks of transfers are then permanently excluded. That's why the potentially most polluting anthropogenic activities in France: ICPE (http://www.installationsclassees.developpement-durable.gouv.fr/Definition.html) are classified for the protection of the environment. The ICPE regulation particularly imposes the participation to BASIAS[a] and BASOL[b] databases that inform on the kind of activities performed by classified plants and soil remediation actions. This approach is pragmatic and allows a rational pollution management based on knowledge of chemical substances with first focus at the sites scale. However, two elements complicate this kind of approach: (i) all the information is not listed in these databases and (ii) pollution sources can sometimes be diffuse or natural (positive geochemical anomaly such as in the urban garden ‘Jardin des Eglantiers’-Nantes where citizens are facing an important metal anomaly (Lead)) and (iii) to identify the source of pollution can sometimes be a very random, long and expensive project. It appears therefore appropriate to strengthen regulation to systematize the analyses upstream of new community gardens installation.

a-BASIAS: historical inventory of industrial sites and service activities; http://www.developpement-durable.gouv.fr/BASIAS-Inventaire-historique-de.html
b-BASOL: database on contaminated/potentially contaminated land calling for government action, preventive or curative; http://basol.developpement-durable.gouv.fr/

4-2.The problem of arsenic pollution has breathed new dynamic on health and environment issues

For most of the gardeners, the numerous interactions between researchers ultimately strengthened their skills in the health and environment fields. They were very active to research for new irrigation solutions which they then put in discussions with researchers and the mayor. They also diversified their actions: creating a pond to encourage biodiversity in gardens (2013) and a garden space open to people with disabilities (2015). It also can be noticed that only one parcel was dropped by a couple of gardeners because of the risk of arsenic pollution: the collective construction, ownership of risk management have therefore worked on this site. Researchers for their part have also evolved during the project from a highly scientific attitude towards citizens' benefit posture: both keeping scientific expertise with an open mind societal concerns permit to effectively develop Science and Society projects. The researchers particularly strengthened the network of actors by offering meetings where managers and gardeners from several community gardens were invited. The mayor now wants to develop an eco-district for which he has requested meetings with the researchers prior to the project.

So, in order to develop a complete risk management in the gardens, it’s particularly interesting to rely on gardeners from Group-II (table-2) to organize the research and disseminate information because they are particularly receptive and dynamic. However it’s also very important to discuss with the gardeners from the Group-III because they have another rationality that the only rational scientist to assess the risks. Exchange with the gardeners of this group has allowed a better understanding by researchers of the knowledge of these gardeners on the link between environment and health. Responding to numerous questions of those gardeners on vegetable quality (in terms of concentration As) and also on soil quality has allowed to reassure the robustness of the analysis. Actually, Farges (2014) examined the conditions in which allotment gardeners integrate practices and norms on sustainability (through a one-year ethnographic research project) and demonstrated that while they adopt new cultivation techniques for their plots, the meanings of their gardening practices differ, as do their relationships with the environment. Three “ideal types of gardeners” were identified and Farges (2014) showed that the diffusion of pro-environmental practices is not systematically related to share concerns and that the meaning of practices can be interpreted differently by policymakers and lay individuals.

However, one gardener in conflict with management team has chosen to leave its garden because he had the feeling that "the mayor has already made a strong mistake by proposing that polluted site for installation of the gardens." Moreover, we observed the problem of temporality between from one side the gardeners who want instant answers and from another side the municipality and researchers that need time for measurements, surveys, analyzes and that take into account economic criteria to choose one kind of solution, while gardeners directly concerned by the site have sometimes other expectations.

5-Conclusions and Perspectives

Arsenic is a non-regulated pollutant for vegetables cultivated in gardens, and more widely for commercialized vegetables in Europe. By favoring the exchanges between gardeners, the arsenic pollution induced a certain structuration of their community and permitted numerous exchanges with other actors: research, politics and progressively a collective construction of risk management. Indeed, as part of the research project "JASSUR" scientific data acquisition was performed with the involvement of different actors working together. A collective manufacture, evaluation and risk-management were developed in the gardens. It integrates the different points of view (more or less scientist; more or less rational) of the actors on the risks to find alternative ways of risk management that meet the needs of this group of stakeholders.

Assessing the potential sanitary risk induced by arsenic pollution needs to both quantify the productions in gardens and measure the As concentrations in consumed vegetables in order to precise the human exposure and finally to compare it with reference values (such as TDI). That multi-steps procedure can potentially induce uncertainties. To improve the precision on potential human exposure to pollutants in the gardens, we need to know the part of produced plants truly consumed by gardeners: as for instance, one part of the productions can be given to friends or the number of persons in the family can change. Further investigations are therefore needed to think about As regulation for consumed vegetables as that pollutant is widely observed at the global scale.

In urban areas with high population density, numerous cases of significant pollution media exist (soils, waters, atmosphere), but citizens generally have only low knowledge about mechanisms involved in pollutant fate in the environment leading to wrong conclusions on the environmental or sanitary risks. For instance, even very small amounts of As in water can induce toxicity if ingested, when higher As quantity in soil won't induce sanitary risk due to adsorption on soil components. This explains why drinking water was prohibited in the studied gardens, when vegetables consumption can continue. Discussing about metal concentration in vegetable requires some precautions, for instance: (i) to precise the unit and if the result is expressed in fresh or dry plant matter; (ii) to define the sampling and analytical procedures used. Misinterpretations must be absolutely avoided because of decisions such as the prohibition of cultivating edible plants can then be taken. Regarding the search for alternative solutions for watering gardens, water from the nearby Canal du Midi will be used in 2016 with the agreement of the administration.

More broadly, our results illustrate the complexity of the interactions involved in the fate of pollutants in the ecosystems such as gardens with a high heterogeneity. How to reconcile scientific research thrust of the mechanisms involved and practical solutions to improve ecosystem services? This is an important challenge to increase initiatives to bring science and society in this direction. It's the case of the participatory research-formation network ''Reseau-Agriville'' (http://reseau-agriville.com/) which is an innovative project with shared and free resources concerning urban agriculture. They help to shape a favorable interface between knowledge and practice in the context of ecological transition at the global scale. Gardeners are very independent and therefore *a priori* reluctant to meet the imposed rules. However, when the central issue is health (and a second time environment knowledge) they are mostly ready to mobilize to act in cooperation with other actors in a climate of mutual respect. This is why making different levels of networking (at regional, national and international scales) appears as an effective approach. It can also be pointed out that health is a good lever to mobilize citizens on the quality of the environment. Actually, the authorities in charge of public gardens now have a responsibility for the health of gardeners who exploit these plots, but no regulatory obligation on the quality of soil or plant products. To conclude, in the case of pollutions in the ecosystems gardens, the construction of risk faces the complexity of both scientific and social factors, that's what makes the richness of this lands whose stakes in terms of sustainable development are such we can only raise!

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