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Risk perception and access to environmental information in four areas in Italy affected by natural or anthropogenic pollution

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ABSTRACT

A human biomonitoring (HBM) survey in four areas affected by natural or anthropogenic arsenic pollution was conducted in Italy within the framework of the SEpiAs project. A questionnaire, including the exploration of risk perception (RP) regarding environmental hazards and access to and trust in information, was administered to 282 subjects stratified by area, gender and age.

The survey was designed to investigate how populations living in polluted areas could adopt prevention-oriented habits, fostered by the awareness of existing risks and, in addition, how increased knowledge of RP and information flows could support researchers in identifying recommendations, and presenting and disseminating HBM results.

This study characterizes the four areas in terms of RP and access to and trust in environmental information, and provides insights into the influence of RP and environmental information on food consumption.

For the data analysis, a combined random forest (RF) and logistic regression approach was carried out. RF was applied to the variables derived from the questionnaire in order to identify the most important in terms of the aims defined. Associations were then tested using Fisher's exact test and assessed with logistic regression in order to adjust for confounders.

Results showed that the perception of and personal exposure to atmospheric and water pollution, hazardous industries and waste, hazardous material transportation and waste was higher in geographical areas characterized by anthropogenic pollution. Citizens living in industrial areas appeared to be aware of environmental risks and had more confidence in environmental non-governmental organizations (NGOs) than in public authorities. In addition, they reported an insufficient circulation of information.

Concerning the influence of RP and environmental information on food consumption, a high perception of personal exposure to atmospheric pollution and hazardous industries was associated with a lower consumption of local fish.

In conclusion, different RPs and information flow patterns were observed in areas with arsenic of natural origin or in industrial contexts. These findings may be useful for targeted risk communication plans in support of risk-management strategies.

1. Introduction

The health risks caused by environmental pressures have attracted increasing public attention. They are of concern at both global and local levels, and are often fostered by the media. Research in the environmental health domain is often required to understand exposure pathways and to suggest preventive measures in high-risk areas (Comba et al., 2007). Over the past few decades the European Union has promoted the growth of "scientific citizenship" (Kok, 2004), as a means to engage communities in local governance, including risk management (Friedman et al., 2015).

The scientific community is aware of the complexity of environmental health issues. Especially in areas where there are environmental hazards, public alarm has been raised, a clear understanding of the risks is lacking, and urgent decisions are needed (Funtowicz and Ravetz, 1992). In these cases, a combination of qualitative and quantitative studies is required to facilitate risk communication and the involvement of the general public. Multidisciplinary groups are convened to carry out

Abbreviations: HBM, human biomonitoring; RP, risk perception; RF, random forest; NGOs, non-governmental organizations.

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complex studies on environmental health determinants (Cirillo, 2014), including expertise in anthropology, sociology and risk communication, and to facilitate the knowledge translation and exchange (Cori, 2016).

The efficacy of strategies aimed at reducing risk in areas characterized by environmental pressure is significantly determined by human behavior, which is strictly connected to risk perception (RP). RP is influenced by a number of personal variables such as education, gender, number of children (Flynn et al., 1994; Kone and Mullet, 1994; Dosman et al., 2001), by the quality of information regarding health and the environment (Wallquist et al., 2010), by the trust in institutions responsible for risk governance. Moreover, the characteristics of the risk and the multiple variables that shape the culture are relevant; cultural prototypes can be considered, and several studies pointed out that in a process of globalization professional values and worldviews are more relevant that national identities in explaining attitudes towards risk (Renn and Rohrmann, 2000).

There are multiple interconnections among perception, behavior, and socioeconomic characteristics, and they become even more complex in the case of human biomonitoring (HBM). The US National Research Council recognized the importance of communication in all the phases of HBM research, where it is recommended that groups of donors be included (Committee on Human Biomonitoring for Environmental Toxicants, 2006). Keune and colleagues reported the experience developed in Flanders (Belgium), where traditional and innovative tools have been used to support communication, supplemented by a multidisciplinary research group (Keune et al., 2008). In Italy, several HMB surveys have included communication activities, using both traditional and innovative instruments (Bianchi et al., 2014a; De Felip et al., 2014; Cori, 2006; Cori et al., 2009a, 2009b). One of these instruments is the SEpiAs study (Epidemiologic Surveillance in areas with natural or anthropogenic Arsenic pollution) based on HBM and preclinical risk surveys.

SEpiAs was designed to build new knowledge regarding the early effects and intake of arsenic, to understand the exposure pathways and to provide recommendations for prevention. The knowledge of information sources and the comprehension of risk perception in relation to different environmental pressures is critical. The information acquired in this domain can play a key role in defining suitable communication strategies and in supporting effective prevention policies (Rosa et al., 2014). An important aim in this field is to clarify the relationship between exposure and risk perception, knowing that it is specific for each type of environmental exposure. Thus, RP could be considered as one of the key elements in making recommendations for public health protection based on environmental epidemiology research results. The use of knowledge gained by questionnaires and by the qualitative insights included in the background information is illustrated in the SEpiAs case, along with considerations regarding further developments. The change in RP and exposure and in their relationship will in fact be analyzed after the completion of the SEpiAs follow up phase, which is ongoing. In this view, consideration of RP in surveillance programs represents advancement in the evaluation of the effectiveness of primary prevention interventions.

The present study analyzes the section of the HBM questionnaire used by SEpiAs dedicated to risk perception, information and trust.

The aim of this study, which was developed within SEpiAs, is to characterize the four areas in terms of RP and access to information on the environment and health, and on trust in different sources of information. Insights into the influence of RP and environmental information on food consumption are also provided.

The SEpiAs study was carried out in Amiata and Viterbese, two mountainous/hilly areas located in central Italy, characterized by arsenic of natural origin, and in two cities in southern Italy, Taranto and Gela, where arsenic originates from anthropogenic sources (Bustaffa et al., 2014).

The four areas included in the SEpiAs study were: Viterbese: the Municipalities of Civita Castellana and Ronciglione, (Latium, central Italy); Amiata: the Municipality of Abbadia San Salvatore (Tuscany Central Italy); the Municipality of Gela (Sicily, southern Italy); the Municipality of Taranto (Apulia, Southern Italy). In Viterbese, arsenic is recognized as the main pollutant in water. It has been constantly monitored by public health authorities, which asked from 2004 to the end of 2012 three derogations to the EU Directive establishing the limit of 10 μg/l (instead of 50 μg/l) (Directive 98/83/CE). Since the beginning of 2013, in most of the 60 Municipalities in the Viterbo Province the water distributed by the public aqueduct is non-drinkable (D'Ippoliti et al., 2015; Cubadda et al., 2015).

In Amiata, the mining of cinnabar for mercury extraction was intense from 1846 until 1976, thus spreading pollution in the area. Since long time, the area has been exploited for geothermal energy (Gray et al., 2014; Tamasi and Cini, 2004).

The environmental characterization of Taranto and Gela is profoundly different. These areas are highly polluted and have been included in the list of reclamation sites of national interest since 2000. They are characterized by large industrial sites, which were built during the 1960s, with various sources of arsenic emissions, located very close to both cities (Pirastu et al., 2013).

The exposure of the general public to information to environmental pollution and health risks was explored via in-depth interviews and meetings with stakeholders in the initial phase of the SEpiAs study. In the Viterbese area, the local communities are concerned and the local media tend raise the alarm whenever health-related news emerges or epidemiological data and environmental monitoring data are disseminated. During the SEpiAs implementation, specific articles and TV broadcasts on the presence of arsenic in the tap water were constant.

In Amiata, the local community is aware of the presence of mercury and arsenic in the environment and has raised concerns regarding geothermal energy. Residents usually mention mercury, and are worried about metals in general. There was no single information flow while SEpiAs was operative in the area.

In Taranto, the information flow regarding environmental pollution and health consequences has been intense and dramatic, especially when the investigations of the prosecutor's office were made public, or environmental studies were released. The community is polarized between those with negationist attitudes and those showing great concern, represented by different components of society including non-governmental organizations (NGOs), and the debate is open regarding the fate of the local steel factory. Local authorities, and in particular the Regional Environmental Agency have been publicizing information and scientific data.

Also in Gela the information flow regarding the environment and health issues has been intense, especially linked to epidemiological studies, both on the presence of congenital anomalies (Bianchi et al., 2006; Bianchi et al., 2014b) and arsenic as revealed by a previous HBM survey (Bianchi et al., 2014a). Here the polarization is mainly between workers supported by unions, with a conservative approach to defending jobs, and NGOs committed to the environment and health protection, with local authorities in the middle but not playing much of an active role in the public arena.

In Taranto and Gela areas the main attention by the media was devoted to the pollutants usually emitted by the steel industry and the petrochemical factories, while the arsenic issues have been always left in the shadow. Otherwise, in the Viterbese and Amiata areas, the arsenic pollution has been constantly on top of the environmental health priorities.

2. Material and methods

2.1. The community "exposure" to information

Taranto has a higher frequency of NGOs than in the other industrial area of Gela; Viterbese and Gela area are characterized by a diffuse presence of radio and television broadcasters.

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In order to characterize the presence and the role of media in the investigated areas, the number of NGOs active on environment and health issues, local radio and television stations, printed and online newspapers were included in Fig. 1. The size of the population living in the areas under investigation is also considered.

2.2. SEpiAs communication tools

There are four traditional communication tools used in SEpiAs. Firstly, the research protocol, approved by the ethical committee of each local health authority. Secondly, leaflets and posters for public information, distributed during the enrollment phase. Thirdly, a legally required informed consent paper, where the respondents indicated their intention to receive individual results, alone or together with general practitioners. And finally, the form for individuals' consent for personal data processing, which complements a detailed HBM questionnaire, administered to each participant. The questionnaire collects information on lifestyle, diet, health conditions and exposure to chemicals during the working life, leisure activities, gardening, etc. These questions are commonly used and are necessary to interpret the results of the HBM studies. The section of the questionnaire exploring risk perception, access to information on environment and health, and trust in different sources of information, is used together with the qualitative background information, and they are the innovative instruments used in SEpiAs (Keune et al., 2008; Bustaffa et al., 2014).

2.3. The questionnaire

The SEpiAs HBM questionnaire was administered by trained personnel to 282 subjects, stratified by area, gender and age (characterized into age classes: 20–29, 30–39, 40–44). In the four areas, of the 341 individuals contacted, 290 were enrolled (85%), with a recruitment percentage ranging from 92.4% in Amiata to 80.2% in Gela; 282 people, eleven more than the 271 accepting the HBM, were interviewed by questionnaire (97.2%), with a response percentage ranging from 91.8% in Amiata to 100% in Viterbese and Taranto (Bustaffa et al., 2014). Although the sample size was small due to the high cost of the HBM survey, we believe this is to some extent compensated for by the stratification of the sample, the high acceptance rate, and adjustments for several co-factors as described in Section 2.4.

The questionnaire included an extract from the Spatial Perception of Risk, Health, Environment, and its Communication (PRITASC) survey, developed under the scrutiny of an international committee (Signorino and Beck, 2014). It consists of an informative block of 12 questions (section K of SEpiAs questionnaire), which were exploited in this study (Table 1).

The 12 questions related to RP and access to and trust in environmental information were transformed into 130 variables. For analytical purposes, the database containing the survey answers was edited. Multiple-choice questions were split into multiple questions and labels 1/0 (yes/no) were assigned whether the answer was selected or not.

In terms of RP, respondents were asked to express their degree of concern on a Likert-type scale ("extremely worried", "very worried", "moderately worried", "not worried"), which assumes that the intensity of feeling about a topic is linear. Variables were codified according to a modified Likert-type scale: subjects responding "don't know" and "not worried" were aggregated (Signorino and Beck, 2014); subjects responding "extremely worried" and "very worried" were aggregated since there were few "extremely worried" respondents.

Questions related to general characteristics of individuals, education and working conditions, (Table 2) were also taken into consideration since they are proved to be factors affecting the RP patterns (Signorino and Beck, 2014). Questions related to consumption of food found to be associated with high urinary inorganic arsenic concentrations, such as tap water, vegetables and fish of local/own origin (Table 2), were selected for the second set of analyses.

2.4. Statistical methods

The study was performed using a combination of random forest (RF) and logistic regression. RF (Breiman, 2001) was used on variables derived from the survey in order to identify the most informative variables, namely those able to:

- best distinguish the four study areas (defined into four categories: Amiata, Viterbese, Taranto, and Gela) in terms of: i) risk perception; ii) access to environmental information; iii) trust in environmental information
- give insights into the influence of RP on the consumption of food known to be associated with high urinary inorganic arsenic concentrations.

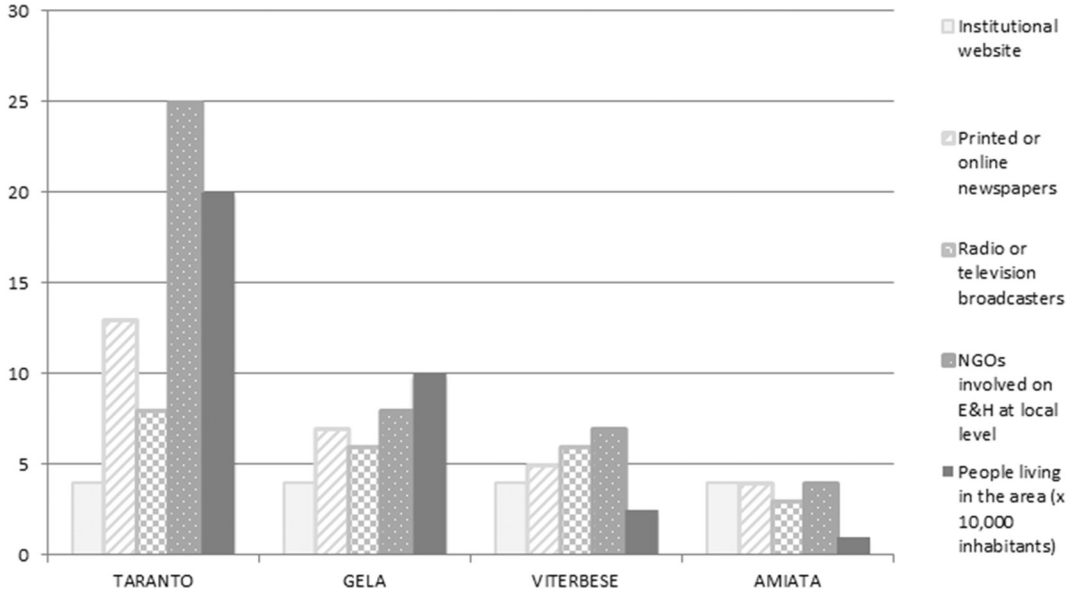

Fig. 1. Presence of media and non-governmental organizations (NGOs) in the four areas.

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Table 1
Block of questions exploited for risk perception (RP), access to information on environment, and trust in different sources of information (Section K).

Question	Type
1. To what extent do you feel directly exposed to each of the following environmental hazards?	Categorical (5 levels)
2. Can you order them according to your perception of personal exposure?	Ranking
3. In your opinion, which of the following environmental hazards are present in your residential area?	Multi-choice
4. What do you consider to be the environmental situation in your residential area?	Categorical (5 levels)
5. Do you feel informed about the environmental hazards characterizing your residential area?	Dichotomous
6. Do you feel informed about the environmental hazards you feel exposed to?	Dichotomous
7. Which of the following media do you prefer?	Multi-choice
8. Which of the following sources do you use to get informed about the environmental hazards you feel exposed to?	Multi-choice
9. Have you ever heard about environmental problems in your particular residential area?	Dichotomous
10. Have you ever heard about health problems in your particular residential area?	Dichotomous
11. In your opinion, who is responsible for healthcare?	Open question
12. In your opinion, how probable are each of the following diseases in a polluted area?	Categorical (5 levels)

In the first set of analyses, aimed at characterizing the four areas in terms of RP and access to and trust in environmental information, the area was chosen as the dependent variable.

In the second group of analyses, aimed at evaluating the influence of RP and information on food consumption, three exposure factors associated with high levels of urinary inorganic arsenic, as reported in the literature and emerging from the SEpiAs study (Bustaffa et al., 2014), were chosen as the dependent variables in three different analyses (Table 2).

Subsequently, for both sets of analyses, in order to assess statistically significant associations between the variables selected by RF and the dependent variable, Fisher's exact test was performed.

Table 2
Characterization of collected sample (N = 282).

General characteristic	Classification	n	%
Gender	Men	140	49.6
	Women	142	50.4
Age	20–29	115	40.8
	30–39	105	37.2
	40–44	62	22.0
Area	Amiata	67	23.8
	Viterbese	72	25.5
	Taranto	52	18.4
	Gela	91	32.3
Educational level	Low (primary/secondary school)	50	17.7
	Medium-high (high school or higher)	232	82.3
Working conditions	Not exposed to dust, chemicals, gas, radiation	165	58.5
	Exposed to dust, chemicals, gas, radiation	117	41.5
Food consumption	**Classification**	**n**	**%**
Exposure to "tap water"	Not consumers	211	74.8
	Consumers	71	25.2
Exposure to vegetables of own/local production	Not consumers	208	73.8
	Consumers	74	26.2
Exposure to fish of own/local production	Not consumers	224	79.4
	Consumers	58	20.6

Tap water, vegetables and fish of local/own origin were found to be associated with high urinary inorganic arsenic concentrations (Bustaffa et al., 2014).

Logistic regression was then carried out by adjusting for educational level and working conditions (first set of analyses) and by area (second set).

In order to increase the interpretability of results and the power of analysis, questions expressed on a Likert-type scale were finally presented as dichotomous variables. A multiple logistic regression was also performed for categorical variables related to risk perception and expressed in the modified Likert-type scale. Since ORs appear similar between "moderately worried" vs baseline ("extremely worried"/"very worried") and "not worried"/"don't know" vs baseline, subjects responding "moderately worried" were aggregated with those responding "not worried"/"don't know".

Associations with a p value < 0.05 were considered statistically significant. Since in the first set of analyses, many statistical tests were conducted, the Bonferroni correction was used to determine the p-value < 0.001, which was considered adequate to interpret results of multiple-comparison tests. Statistical analyses were performed using the R package (R Development Core Team, 2010) and STATA13 (StataCorp, 2013).

3. Results and discussion

The results of the PRITASC survey were considered in the interpretation, as a set of questions from this study were selected for the SEPIAS questionnaires (Signorino and Beck, 2014). The extensive body of research referred to risk perception, developed by social science, psychology and cultural studies was reviewed, together with the behavioral change theories, to advance further hypotheses (Davis et al., 2015; Rosa et al., 2014; Renn and Rohrmann, 2000). Several studies are referred either to natural hazards or to technology-induced hazards, whereas studies comparing RP related to the two sources of risk are limited (Salvati et al., 2014; Hwang, 2011).

3.1. Characterization of the four areas in terms of risk perception of environmental hazards

The RF method identified a set of 18 informative variables out of the 130 constituting the starting set (Table 3). Fisher's exact test confirmed the presence of a statistically significant association between each variable identified by RF and the area. Logistic regression was then carried out adjusting for educational level and working conditions (Table 3), since these proved to be the factors affecting the RP patterns (Signorino and Beck, 2014) and were heterogeneously distributed in the areas.

The whole Taranto sample and most of the Gela sample considered the environmental situation of the area as "severe", with statistically significant differences with respect to Amiata and Viterbese. A significant difference was also observed between the Viterbese and Amiata (OR = 4.16) samples, where 80.6% of the sample considered the environmental situation of the area as "acceptable".

The Taranto and Gela samples showed a high perception regarding the presence of hazardous material transportation, waste, hazardous waste, atmospheric pollution, hazardous industries and water pollution, with statistically significant differences compared to the Amiata and Viterbese samples. Concerning the perception of water pollution, a significant difference was also observed between the Viterbese and Amiata samples (OR = 2.45).

The Gela and Taranto samples showed a high perception of personal exposure to hazardous industries, water pollution, and hazardous waste, with statistically significant differences compared to Amiata and Viterbese.

The Gela sample showed the highest perception of personal exposure to hazardous material transportation and to hazardous waste. The Taranto sample showed the highest perception of personal exposure to atmospheric pollution, with statistically significant differences with respect to Amiata and Viterbese. These observations are consistent

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Table 3
Characterization of the four areas in terms of risk perception (RP) of environmental hazards, according to the variables identified by the random forest (RF) method.

Risk perception	Amiata	Viterbese	Taranto	Gela	
Perception of the personal exposure to hazardous material transportation	9 (13.4)	11 (15.3)	12 (23.1)	41 (45.1)	*Freq (%)*
	1.00	1.17	2.14	6.86***	*OR*
Perception of the personal exposure to waste	15 (22.4)	16 (22.2)	26 (50.0)	38 (41.8)	*Freq (%)*
	1.00	0.98	3.42**	2.50*	*OR*
Perception of the personal exposure to hazardous waste	21 (31.3)	17 (23.6)	26 (50.0)	70 (76.9)	*Freq (%)*
	1.00	0.67	2.20*	7.78***	*OR*
Perception of the personal exposure to atmospheric pollution	36 (53.7)	47 (65.3)	48 (92.3)	65 (71.4)	*Freq (%)*
	1.00	1.64	11.65***	2.58**	*OR*
Perception of the personal exposure to water pollution	27 (40.3)	50 (69.4)	46 (88.5)	68 (74.7)	*Freq (%)*
	1.00	3.34*	11.17***	4.50***	*OR*
Perception of the personal exposure to hazardous industries	21 (31.3)	26 (36.1)	48 (92.3)	75 (82.4)	*Freq (%)*
	1.00	1.22	25.89***	10.96***	*OR*
Perception of the presence of hazardous material transportation	1 (1.5)	2 (2.8)	34 (65.4)	64 (70.3)	*Freq (%)*
	1.00	1.88	121.26***	141.65***	*OR*
Perception of the presence of waste	9 (13.4)	12 (16.7)	45 (86.5)	67 (73.6)	*Freq (%)*
	1.00	1.30	41.92***	17.89***	*OR*
Perception of the presence of hazardous waste	10 (14.9)	11 (15.3)	45 (86.5)	73 (80.2)	*Freq (%)*
	1.00	0.98	34.07***	23.29***	*OR*
Perception of the presence of atmospheric pollution	28 (41.8)	37 (51.4)	50 (96.2)	85 (93.4)	*Freq (%)*
	1.00	1.47	33.40***	18.01***	*OR*
Perception of the presence of water pollution	28 (41.8)	46 (63.9)	51 (98.1)	88 (96.7)	*Freq (%)*
	1.00	2.45*	70.08***	41.02***	*OR*
Perception of the presence of hazardous industries	6 (9.0)	12 (16.7)	51 (98.1)	83 (91.2)	*Freq (%)*
	1.00	2.08	550.06***	106.88***	*OR*
Environmental situation in the area: severe	13 (19.4)	34 (50.0)	52 (100)	81 (93.1)	*Freq (%)*
	1.00	4.16***	–	59.58***	*OR*

Risk-related health status perception	Amiata	Viterbese	Taranto	Gela	
Perception of the probability of chronic respiratory diseases in a polluted area	49 (80.3)	43 (66.2)	51 (98.1)	76 (87.4)	*Freq (%)*
	1.00	0.45	12.08**	1.86	*OR*
Perception of the probability of hepatic diseases in a polluted area	34 (63.0)	17 (34.7)	26 (70.3)	51 (67.1)	*Freq (%)*
	1.00	0.32**	1.52	1.30	*OR*
Perception of the probability of cancer in a polluted area	60 (90.9)	44 (65.7)	50 (96.2)	88 (97.8)	*Freq (%)*
	1.00	0.19**	2.40	4.35	*OR*
Perception of the probability of leukemia in a polluted area	43 (79.6)	28 (50.0)	47 (92.2)	70 (82.4)	*Freq (%)*
	1.00	0.22**	2.58	1.13	*OR*
Perception of the probability of congenital anomalies in a polluted area	35 (70.0)	26 (43.3)	42 (84.0)	84 (92.3)	*Freq (%)*
	1.00	0.31**	2.27	5.77**	*OR*

Bonferroni correction was used to determine the p-value of 0.001 ($\alpha_c = \alpha/c = 0.05 / (3 * 18)$), where c is the number of comparisons.
Abbreviations: A = Amiata; V = Viterbese; T = Taranto; G = Gela.
Only frequencies and percentages referring to the answer "Yes" are reported.
OR = odds ratio adjusted for educational level and working conditions. Logistic regression was carried out using Amiata as a reference level.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

with the perception of the presence of hazardous material transportation and atmospheric and water pollution, as previously mentioned.

Concerning the perception of personal exposure to water pollution, a higher RP was also observed in the Viterbese sample compared with Amiata (OR = 3.34), although not statistically significant taking into account the Bonferroni correction.

The environmental health RP was high in all areas. An extremely high perception of the probability of chronic respiratory diseases in Taranto (OR = 12.8, $p < 0.01$) and of the probability of congenital anomalies in Gela (OR = 5.77, $p < 0.01$) were reported. In Viterbese the risk-related health status perception was the lowest with statistically significant differences from the other areas. In all cases, the differences were not statistically significant taking into account the Bonferroni correction.

Logistic regression also indicated that people professionally exposed to dust, chemicals, gas, and radiation had a lower perception of personal exposure to hazardous material transportation (OR = 0.45, $p = 0.014$) and to atmospheric pollution (OR = 0.55, $p = 0.041$) than subjects not professionally exposed. In addition, people with a medium-high educational level (high school graduation or higher) had a higher perception of the presence of hazardous waste in the area (OR = 3.04, $p = 0.013$) than subjects with a low educational level. This medium-high educational level group was also more likely to believe that leukemia and chronic respiratory diseases could occur in polluted areas (OR = 2.55, $p = 0.022$ and OR = 2.16, $p = 0.060$, respectively).

PRITASC survey analyzed a complete set of questions to understand the "mental map" of people living in two industrial areas, to obtain insights for security planning (Signorino and Beck, 2014). The results revealed that the two communities had different perceptions of diverse risks, except for the risk directly associated with the presence of industrial plants: environmental degradation, serious illnesses and industrial disasters.

This is confirmed by the results of the present study, where the respondents living in Taranto and Gela, two industrial areas, showed a higher RP compared to the Viterbese and Amiata areas, where natural hazard is present. In general, the perception of the presence of environmental hazards was higher than the perception of the personal exposure to environmental hazards.

The study of Salvati et al., conducted in Italy, provides insights for a comparison between natural and technology-induced RP. The preliminary results showed that in 2013, people in Italy felt more exposed to technological than natural risks, and specifically to environmental

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pollution, followed by road accidents. The ranking was the same in 2012 (Salvati et al., 2014). The difference in the perception of natural versus technological risks is taken into consideration. Human-made risks seem to be more acceptable than natural risks, but they are much more influenced by public acceptance, that is strictly linked to risk management, trust and local experience (Renn and Rohrmann, 2000).

3.2. Characterization of the four areas in terms of environmental information

RF identified a set of 17 informative variables out of the 130 constituting the starting set (Table 4). Fisher's exact test confirmed a statistical significant association between 16 out of the 17 variables identified by RF and the area. Logistic regression was carried out adjusting for educational level and working conditions.

Concerning access to information, all areas preferred the Internet, with percentages ranging from 65% to 80%. Local TV channels were reported to be commonly watched in Gela and most of the samples of Amiata and Gela (>70%) reported that they watched national TV channels.

The Gela sample declared the lowest perception of information regarding the exposure to environmental risks (30.8%) with statistical significant differences with respect to Amiata.

The proportion of the Gela sample declaring that they were insufficiently informed about the exposure to environmental risks had the highest expectation to be informed by Public Authorities (31%).

The majority of Taranto sampled subjects (51.9%) considered environmental NGOs as the main source of information on exposure risks. This tendency was also observed in the Gela sample and, although declared by less than half of the sample (37.4%), it was statistically higher than the Amiata and Viterbese samples.

Concerning the information received on environmental problems in the area, most of the Taranto sample reported that they were informed by the media (61.5%) and environmental NGOs (50%) and this is in agreement with the characterization of the four areas in terms of presence of media (Section 2.1). In the Gela sample, most of the information on environmental problems appeared to be provided by ordinary people (51.6%). Institutions seemed to be more important as a source of information on environmental problems in the Viterbese sample than in the other areas, showing a statistically significant difference.

The whole sample appeared to be less informed about health than environmental problems. Most respondents in Gela and Taranto reported that they were informed by other members of the public.

Media and NGOs appeared to be more involved in the information on environmental problems than on health problems (Media in Taranto: 61.5 vs 48.1%; NGOs in Taranto: 50 vs 32.7%).

Table 4
Characterization of the four areas in terms of available and accessible environmental information, according to the variables identified by the random forest (RF) method.

Characteristic	Amiata	Viterbese	Taranto	Gela	
National TV channels are the reference media	48 (71.6)	37 (51.4)	22 (42.3)	65 (71.4)	*Freq (%)*
	1.00	0.42**	0.29**	0.98	*OR*
Local TV channels are the reference media	10 (14.9)	18 (25.0)	17 (32.7)	55 (60.4)	*Freq (%)*
	1.00	1.99	3.15**	9.46***	*OR*
Radio is the reference media	12 (17.9)	6 (8.3)	11 (21.2)	26 (28.6)	*Freq (%)*
	1.00	0.42	1.30	1.84	*OR*
Information about environmental hazards characterizing the residential area¥	21 (31.3)	30 (41.6)	18 (34.6)	28 (30.8)	*Freq (%)*
	1.00	0.13**	0.10**	0.05***	*OR*
Expect to be informed by public authorities regarding the risk exposure	7 (15.2)	13 (31.0)	10 (29.4)	33 (52.4)	*Freq (%)*
	1.00	1.87	1.99	4.88***	*OR*
Environmental NGOs are the reference to obtain information about risks of exposure	4 (6.0)	7 (9.7)	27 (51.9)	34 (37.4)	*Freq (%)*
	1.00	1.63	15.81***	9.66***	*OR*
Information received from media on environmental problems in the area	4 (6.0)	29 (40.3)	32 (61.5)	39 (42.8)	*Freq (%)*
	1.00	10.55***	22.95***	10.75***	*OR*
Information received from institutions on environmental problems in the area	4 (6.0)	26 (36.1)	4 (7.7)	9 (9.9)	*Freq (%)*
	1.00	8.92***	1.26	1.83	*OR*
Information received from environmental NGOs on environmental problems in the area	9 (13.4)	9 (12.5)	26 (50.0)	25 (27.5)	*Freq (%)*
	1.00	0.91	6.43***	2.56*	*OR*
Information received from other people on environmental problems in the area	12 (17.9)	18 (25.0)	23 (44.2)	47 (51.6)	*Freq (%)*
	1.00	1.51	3.46**	4.77***	*OR*
Information received on health problems in the area	47 (70.2)	37 (51.4)	52 (100)	89 (97.8)	*Freq (%)*
	1.00	0.41*	–	19.42***	*OR*
Information received from media on health problems in the area	3 (4.5)	7 (9.7)	25 (48.1)	33 (36.3)	*Freq (%)*
	1.00	2.23	19.09***	13.45***	*OR*
Information received from NGOs on health problems in the area	1 (1.5)	4 (5.6)	17 (32.7)	16 (17.6)	*Freq (%)*
	1.00	3.83	30.57**	13.54*	*OR*
Information received from "people" on health problems in the area	15 (22.4)	16 (22.2)	33 (63.5)	64 (70.3)	*Freq (%)*
	1.00	0.98	5.74***	7.66***	*OR*
Institutions are responsible for healthcare	18 (26.9)	38 (52.8)	38 (73.1)	33 (36.3)	*Freq (%)*
	1.00	3.05**	7.46***	1.70	*OR*
Local Health Authorities are responsible for healthcare	19 (28.4)	11 (15.3)	8 (15.4)	10 (11.0)	*Freq (%)*
	1.00	0.44	0.39	0.25**	*OR*
Citizens are responsible for healthcare	13 (19.4)	23 (31.9)	2 (3.8)	23 (25.3)	*Freq (%)*
	1.00	1.94	0.16*	1.40	*OR*

Bonferroni correction was used to determine the p-value of 0.001 ($\alpha_c = \alpha/c = 0.05 / (3 * 17)$), where c is the number of comparisons.
Abbreviations: A = Amiata; V = Viterbese; T = Taranto; G = Gela.
Only frequencies and percentages referring to the answer "Yes" are reported.
OR = odds ratio adjusted for educational level and working conditions. Logistic regression was carried out using Amiata as reference level.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.
¥ Categorical variable ("Yes"/"no"/"don't know"). ORs were obtained by multinomial logistic regression and refer to respondents answering "don't know".

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Results from logistic regression also indicated that people with a medium-high educational level (high school graduation or higher) had a lower tendency to consider local TV channels as the reference media (OR = 0.47, $p = 0.035$).

In contrast, people with a medium-high educational level more frequently: i) considered environmental NGOs as the reference for information on exposure risks (OR = 3.89, $p = 0.010$); ii) declared that they had received information on health problems in the area (OR = 2.99, $p = 0.015$), specifically from the media (OR = 4.49, $p = 0.008$); and iii) considered public institutions as responsible for healthcare (OR = 2.03, $p = 0.050$).

Logistic regression also indicated that people professionally exposed to dust, chemicals, gas, and radiation had a higher tendency to consider Local Health Authorities as responsible for healthcare (OR = 2.01, $p = 0.043$).

The process and use of information is particularly interesting to understand the direction of choices and the possibility to influence them, both for researchers and policy makers. To explain the process information-perception-action, the research proposed the psychometric approach, detailing the influences of several risk characteristics on RP. The "semantic images" proposed by Renn are presented to describe "cultural prototypes" that help to explain the attitudes towards risk. Risk as a pending danger (Damocles sword); slow killers (Pandora's box); cost-benefit ratio (Athena's scale); avocational thrill (Hercules image): all four descriptions are linked to different interpretation of the information received (Renn and Rohrmann, 2000).

3.3. Influence of risk perception and environmental information on food consumption

In areas affected by arsenic pollution and characterized by an effective and reliable network of environmental information, also taking into account the differences described above, a reduced consumption of food known to be associated with arsenic pollution might be expected. Similarly, subjects characterized by a high RP of environmental hazards might be expected to be more careful in food consumption than subjects showing a low RP.

The combined approach of RF and logistic regression was also applied to investigate these hypotheses. Geographical area was considered as a confounder since it was associated both with RP and access to/trust in environmental information and with food consumption. The effect of RP and environmental information on consumption of local fish was only investigated in Gela and Taranto, since Amiata and Viterbese are located in hilly-mountainous areas.

Three different sets of analyses were performed and considered the consumption of tap water, vegetables of local/own origin and local fish as dependent variables. The results revealed that a high perception of personal exposure to atmospheric pollution and to hazardous industries was associated with a lower consumption of local fish (OR = 0.12, $p = 0.013$ and OR = 0.12, $p = 0.007$, respectively; 50 consumers, 20.6%, out of 282 respondents).

In contrast, an influence of RP and/or environmental information on the consumption of tap water and vegetables of local/own production was not revealed.

4. Conclusions

The combined approach of RF and logistic regression was found to be a reliable method for the characterization of areas in terms of RP and environmental information.

RF was effective in identifying variables that best distinguished groups of exposure (people drinking/eating food associated with high levels of urinary inorganic arsenic concentration vs. people that do not). However, in this case, the combination with logistic regression was important in considering the confounding effect of the geographical area.

The perception of the presence and of the personal exposure to atmospheric and water pollution, hazardous industries and waste, hazardous material transportation and waste was higher in Taranto and Gela (both in industrial areas) than in Amiata and Viterbese (both hilly/rural).

The health-related RP was high in all areas. This is likely due to the fact that the main focus of the questionnaire was aimed at investigating the perception of the environmental situation of the areas of residence. These results appear to be in line with other studies in which citizens took into account the evidence produced by researchers (Cori et al., 2010). However, the percentages of subjects reporting that they were "sure" or "very likely" to have chronic respiratory and hepatic disease, cancer, leukemia and congenital malformations in polluted areas were high, and suggest the need to produce reliable information on health issues related to pollution.

The percentage of subjects reporting to have had information on environmental problems was always higher than the percentage of subjects that claimed that they had had information on health problems. This discrepancy could be tackled by developing appropriate actions aimed at informing citizens of the health risks caused by exposure to specific pollutants in residential areas.

The Viterbese sample seemed to correctly correlate water pollution to arsenic pollution. In general this sample appeared to be the best informed regarding the environmental situation of the residential area. In fact, citizens had the highest perception of knowledge regarding the personal exposure to environmental risks to health. In addition the answers to the survey questions appeared to be the most balanced, both in terms of RP and risk-related health status perception, compared to the other areas which, in contrast, were characterized by an extremely high (Taranto and Gela) or low (Amiata) RP. In the Viterbese sample, a higher trust was reported in institutions that are considered as a source of information on environmental problems more than in the other areas. The more balanced RP characterizing the Viterbese sample could be interpreted as the result of accurate environmental information also provided by NGOs.

In the Taranto and Gela samples, NGOs played a significant role in providing environmental information, often compensating for the lack of information from public authorities.

Concerning the influence of RP and environmental information on food consumption, a high RP was found to be correlated to a decreasing consumption of local fish. However, an influence of RP and/or environmental information was not found on the consumption of tap water and vegetables of local/own production.

These results highlight the importance of highly specific environmental information in order to induce rational and reasonable, but not alarmist, caution in the consumption of food grown in polluted areas and not subjected to adequate quality and safety controls. This confirms the importance of evaluating the RP related to food which, as already observed, influences consumption (Dosman et al., 2001; Lobb et al., 2007).

These results also highlight the importance of an efficient knowledge transfer from scientific studies to: i) policy makers, to ensure an evidence-based risk governance; ii) citizens, by making the scientific language understandable in order to facilitate the participation of the general public in personal and collective decisions in the environmental and health domain.

In conclusion, the assessment of RP should be considered as a key tool for creating risk communication plans in support of risk-management strategies. In particular, risk communication should take into account how personal experiences affect the perceptions of and beliefs about environmental hazards.

To extend the use of RP in environmental epidemiology investigations, further studies are needed, for example to investigate the association of RP with environmental exposures.

The authors believe that the consideration of RP in epidemiological surveillance programs, on its own or in parallel with a HBM program,

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may represent a relevant advancement in the evaluation of the effectiveness of primary prevention interventions.

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