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SHORT RESEARCH AND DISCUSSION ARTICLE

Stakeholder consultations and opportunities for integrating socio-behavioural factors into the pesticide risk analysis process

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Abstract The pesticide risk analysis process is well regulated in the EU, especially in relation to placing on the market authorisation procedures, but in order to avoid risks for human health and environment in the use phase, information on how these substances are employed and on socio-behavioural factors that can influence the exposure have to be taken into account. To better explore reasons about the gap between risk assessment and risk management, within the EU FP7 Health and Environmental Risks: Organisation, Integration and Cross-fertilisation of Scientific Knowledge (HEROIC) project, a stepwise stakeholder's consultation process was developed using a mixed approach in two different phases (survey and roundtable). We elicited stakeholder views regarding factors that could limit the pesticide risk assessment phase linked on how the knowledge is produced and the way the data are used in risk management and in risk communication, also taking into account qualitative factors such as responsibility, trust and behaviours, which could have impact on risk assessment policies. Activities deployed indicate that some changes and interaction are needed to better define the problems at the formulation stage, and the type of information risk assessor has to provide, to better inform risk manager in addressing different societal needs, to strengthen the credibility of the process of risk assessment and improve the effectiveness of policies. Integrations between disciplines may initially increase the complexity but in turn will provide a better and more useful estimation of the risk, reinforce transparency and drive a more efficient use of risk management resources.

Keywords Pesticides · Risk assessment · Risk management · Stakeholder consultation · Knowledge · Survey · Roundtable

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Introduction

In 2013, an Eurobarometer survey to evaluate European citizens' attitudes towards science and innovation (Special Eurobarometer 419) shows that '*Europeans support the role of science and technology in society but, at the same time, expect scientists and politicians to ensure that their values and concerns are taken into account*' (Research, Innovation and Science Commissioner Máire Geoghegan-Quinn).

In 2004, the European Commission (EC) launched the first European Environment and Health Action Plan (EHAP) to improve the information chain, fill the knowledge gaps, review policies and improve communication. One of the main EHAP conclusions was to consider that new changes and challenges deserve considerations within a broader spatial, socioeconomic and cultural context.

The current EU policy development process is now driven by 'Europe 2020—a strategy for smart, sustainable and inclusive growth' which is particularly focussed on considering integration of information, research, environment, health concerns and stakeholder consultation as a basis for an integrated decision making.

To support policy, different forms of analysis of the risk which take into account the complexities, interdependencies and uncertainties of the real world are needed. These analysis should not cover only aspects that have traditionally been the

focus of risk assessment (RA) but also aspects that are mediated via human behaviours and perceptions which are a function of where people live and spend their time; the personal and societal characteristics of the populations (age, gender, socioeconomic status, culture, belief systems, etc.); and the associated susceptibilities, attitudes and values (Briggs 2008). 'Behaviour' is a term that covers a lot of ground. It refers to what people do, as well as what drives them to do things, and it involves psychological processes like emotion. 'Social', on the other hand, reflects how individuals interact with each other, in small groups, families and communities, as well as within populations and in society (from US National Institute of Health (NIH)).

In this framework, the Health and Environmental Risks: Organisation, Integration and Cross-fertilisation of Scientific Knowledge (HEROIC) research project (www.heroic-fp7.eu) was developed to help identify and answer the needs for integrated RA approach in chemicals. Overall vision of the project is described in the project white paper (Wilks et al. 2015) already published.

The project, supported by the European Commission under the Seventh European Framework Programme, produced also a position paper (Pery et al. 2013), where it was recognised that there is growing complexity due to multi-disciplinarily of RA sciences, risk managers decisions are not purely science-driven and the role of social-behavioural factors in the developments of the chemicals risk evaluation has been rather limited.

Plant protection products (hereafter pesticide) represent an interesting case as risk analysis' community is highly diverse including various interested and affected parties such as regulatory risk assessors, risk managers and risk communicators as well as applicants for product authorisation, the wider scientific community and the general public. In addition, compared to other chemical classes, pesticide risk analysis process started long time ago; is well regulated in the EU, especially in relation to placing on the market authorisation procedures (Directive 91/414/EEC now replaced by Regulation No. 1107/2009); and there is wide evidence that, in order to avoid risks for human health and environment, information on how these substances are employed and on how socio-behavioural factors can influence the exposure for humans and the environment have to be taken into account (Remoundou et al. 2014; Sacchettini et al. 2015).

In 2009, the Council of the European Union adopted the Directive 128 establishing a framework for community action to achieve the sustainable use of pesticides (SUD). As a consequence, member states (MSs) are required to develop specific measures to minimise environmental and occupational exposure to pesticides, as well as communication programs aimed at raising awareness amongst residents and bystanders about the risks of pesticide exposure. From the EU legal perspective, the SUD aims to bridge the gap between RA and risk management (RM) generated by the difference in the parameters considered. Indeed, pesticide RA, as currently performed, is a deterministic and quantitative process. Mitigation measures are considered to reduce risk, and the authorisation is bounded to the good agricultural practices. Socio-behavioural aspects are not addressed except for very few cases, and commonly, it is argued that engagement in unsafe pesticide use and disposal practices is the result of a lack of knowledge and misperceptions of the risks associated with pesticides amongst operators and workers.

The objective of this paper is to better explore the underlying reasons of this gap in the pesticide case identifying key driving factors. Such factors once identified could be useful in determining adjustments and eventual revisions of RA processes to ensure that socio-behavioural factors are comprised in the evaluations of the risk.

Materials and method

The overall purpose of this activity was to identify those factors that make RA less effective and to take them into account in future developments and modulations of how the RA processes are organised. The effectiveness of RA can be jeopardised by socio-behavioural factors that deviate the population exposed to a risk from the characteristics of the generally accepted target group for the RA. Various characteristics and dynamics of the population as well as differences in behaviour, due to cultural aspects, level of education, economic aspects, attitude towards risk, etc., can produce such deviations. We also need to take into account social-behavioural factors that could influence risk perception, since the acceptability of a risk is the result of intuitive biases and economic interests that often reflect cultural values (Rohrmann 2008).

A literature review was performed, and an analysis of the state of the art on socioeconomic analysis frameworks was conducted to try to identify if factors linked to psychological and sociological realities, such as responsibility, trust, reliance and beliefs, can have an influence and limit the decision quality and the choice of the approach to be taken. Furthermore, a stakeholder consultation was developed to identify views and priorities regarding factors limiting the pesticide RA phase linked on how the knowledge is produced and the way the data from RA are used in RM and in risk communication (RC).

Stakeholders participation is defined as an '*active involvement where actors bring inputs* […] *at one or several stages of the research project, e.g. research proposal/design*, *coordination*, *execution*, *dissemination and/or follow-up*' (Jolibert and Wesselink 2012). Stakeholder's involvement and social learning processes play a key role in the new public participation process (Pahl-Wostl et al. 2008) and

represent a valuable opportunity to improve the system and information source.

Of course, there are various ways to consult stakeholders and Rowe and Frewer listed over 100 engagement mechanisms, and this list is far from exhaustive (Rowe and Frewer 2005). However, in order to be as efficient as possible and taking into account the kind of information that we want to obtain, it was decided to adopt a mixed approach including the following two different kinds of consultation mechanism: *questionnaire-based quantitative tool* together with *face-to-face meeting*.

In the *questionnaire-based quantitative tool*, stakeholders are requested to individually answer questions by choosing from a limited number of provided answers. Because there are only multiple-choice questions, it represents an efficient way to obtain sufficient data in a short time. However, as a passive consultation method, it 'does not permit deeper discussion and might be dominated by more organised interests' (Scott 2010). Since there is no clear methodology on how to conduct this tool, we have adhered to the following generally accepted EU principles for stakeholder consultations: transparency, proportionality, inclusiveness, accountability and coherence.

In the *face-to-face meeting*, stakeholders are invited to share data and judgements. Group interactions can identify the consensus opinion given the current state of knowledge and can generate interpretations that are different from those obtained by individual experts (Cooke 1991). In this iterative approach, experts are allowed to discuss their original opinions and to arrive together at a collective opinion. This 'dialogue-based method' is more flexible than the quantitative ones and allows greater spontaneity and adaptation of the interaction between the researcher and the study participant. Participants have the opportunity to respond more elaborately and in greater detail than is typically the case with quantitative methods. In turn, researchers have the opportunity to respond immediately to what participants say by tailoring subsequent questions to information the participant has provided (Mack et al. 2005).

Thus, in order to have the advantages of both instruments and to compensate for their relative disadvantages, it was decided to develop a stepwise stakeholder consultation process in two different phases.

Phase 1—exploratory stakeholder survey

The survey was conducted in the period of May–September 2013 using a web-based tool (SoGoSurvey—http://www.sogosurvey.com). The questionnaire was composed by 14 multiple-choice questions and was divided in the following four different parts: factors limiting the RA phase, factors limiting RM monitoring and mitigation measure, policy and administrative influence and economic issues and communication.

A database of 511 selected stakeholders was specifically established for this activity including an equilibrated number of relevant experts divided per the following criteria: kind of expertise (RA, RM, policy, and academia), country of residence, group affiliation (industry, regulators, NGOs, trade unions and interested academics) and gender. An invitation mail to participate at the survey has been sent to each stakeholder included into the database, and a reminder was sent in case of no reply. At the end, responses were given by 64 experts from 20 EU member states and Switzerland. The distribution of expertise was balanced (industry (10), risk manager (6), risk assessor (14), international (9) and national regulators (11), academic researcher (12) and gender distribution (54, 69 % male and 45, 31 % female). Participants from Italy (14), France (8) and Germany (7) were slightly overrepresented in terms of EU member states.

Data were also filtered by 'interest groups' (risk assessors, risk managers, national or international regulators and industry). This has allowed us to highlight the different points of view of the actors interviewed, giving us some indication on the needs on which we have to focus in their perspective.

Given the number of countries participating, the balanced background and mixed expertise, results have been used as a good basis for phase 2. Indeed, the overall purpose of the survey was to identify main factors that make RA less effective and to take them into account for a qualitative discussion to formulate some recommendations on future developments and modulations of how the RA processes should be organised.

Phase 2—stakeholder face-to-face meeting (roundtable)

The roundtable was organised in Brussels in 2013 with in total, 15 selected participants with expertise in different disciplines, ranging from sociology to economy and philosophy, assessors and regulators. These experts were invited to share their knowledge on topics that could have influence on the RA process as how social science could help in the identification of the qualitative component of the risk analysis process and could influence economics and the definition of uncertainty.

The event has been divided in two phases. In the first phase, results of the activities already performed in the project, outcomes of the explorative survey and relevant theoretical information were presented in order to reach a common understanding before the group interaction.

In the second phase, experts were allowed to an open discussion managed by a moderator encouraging participants to express their views and debate on the issues.

Results

Phase 1—exploratory stakeholder survey

Results of the survey are summarised below and grouped in the different parts the questionnaire was divided:

1. Factors limiting the RA phase

   Stakeholders' survey confirms that there are some factors limiting RA process linked on how the knowledge is produced. Most important seems to be (Fig. 1 Q5)

   - The data on the variability of environmental (and human) exposure in space and time are missing.
   - Standard scenarios used for the assessment are not always relevant or are not context specific.
   - Statistically based tools capable to quantitatively assess uncertainties are not available.
   - The assessment is hazard-driven process rather than exposure-driven process and there are difficulties in sharing human and environment data.

   The answers related to the questions on methodology used in the RA (Fig. 2 Q6 part A) and on the characterisation phase (Fig. 3 Q7 part B) of RA confirm the difficulties previously highlighted. Models and computational tools are not sufficient to represent the complexity of use and are not flexible to represent different scenarios, user knowledge on models and computational tools is limited, lack of scientific basis or knowledge to express effects in terms that are of relevance for protection of human health (i.e. mortality and morbidity) or the environment (i.e. ecosystem services) and lack of available data (epidemiological, nutritional, etc.) to assess risk benefit in the characterisation phase of RA

   Stakeholders have indicated that the results of the RA extrapolated to the whole population may not be representative of societal needs.

   Attitude towards risk, certain vulnerable groups (e.g. children living and growing on farms) and immigrant workers and their difficulties to understand proper use are not properly considered (Fig. 4 part C Q8). On the contrary, only few respondents select the importance of ethical considerations in the process (e.g. excluding test on animals or exclusion of certain category) as factor having an influence on the effectiveness of pesticide RA.

   If we filter the data taking into account only the views of respondents who declared themselves to be risk assessor, information do not change significantly but can give us some qualitative indication on the needs on which we have to focus in order to improve the RA phase.

   The 72 % of risk assessors indicate the lack of scientific basis or knowledge to express effects in terms that are of relevance for protection of human health (i.e. mortality and morbidity) or the environment (i.e. ecosystem services) as factors limiting the effectiveness of risk analysis.

   Academic researchers selected the same option.

2. Factors limiting RM, monitoring and mitigation measure

   The survey confirms that there are factors limiting the effectiveness of the RM phase. These are still mainly linked to how the knowledge is produced and how the

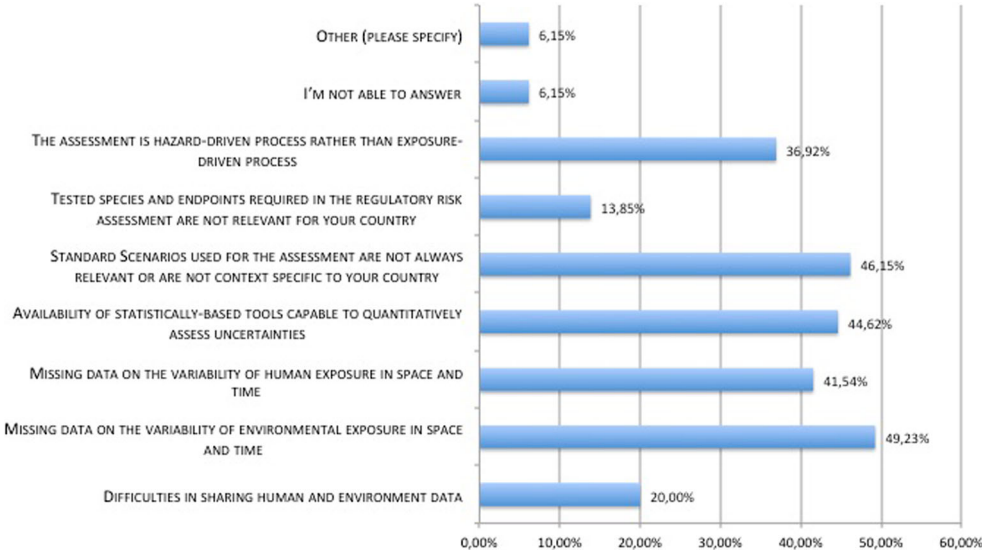

Fig. 1 Question 5. Please choose amongst the following factors related to the quality of data provided for the risk assessment, those that you consider they have an influence on the effectiveness of the pesticide risk assessment in your country (you can choose more than one option). Total responses 172

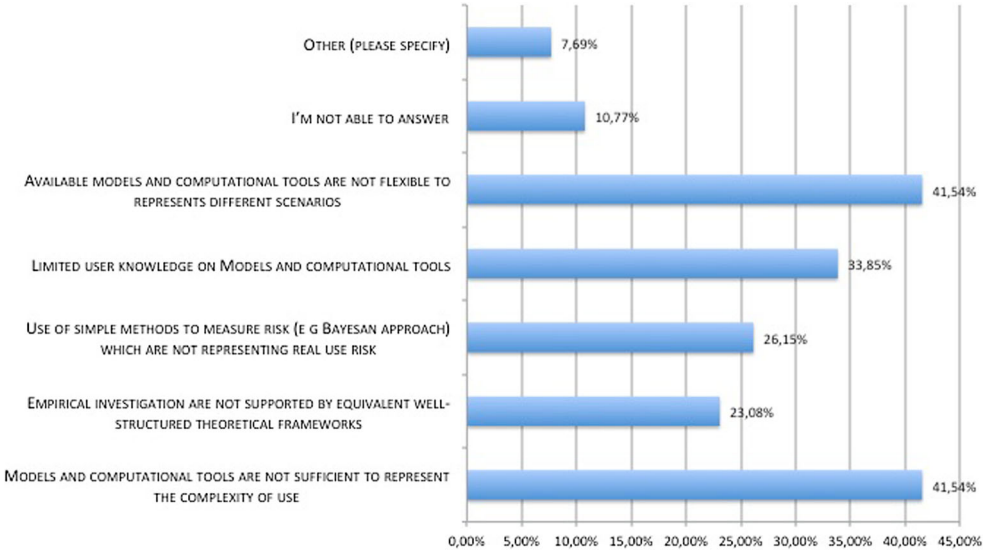

Fig. 2 Part A question 6. Please choose amongst the following factors related to the methodology used in risk assessment, those that you consider to make an influence on the effectiveness of pesticide risk assessment in your country (you can choose more than one option). Total responses 120

knowledge produced in the RA phase then is interpreted and used for establishing monitoring programs (Fig. 5 part A graph Q9) and/or mitigation measures and also confirms an influence of socio-psychological factors (Fig. 6 part B graph Q10).

In particular, the following were identified as main factors that make an influence on the effectiveness of pesticide RM:

- Availability of context specific data (e.g. pesticide usage data, spatial and temporal treatment data, ecological information, community distribution, natural spatial and temporal characteristics and trends in background levels)
- Trust in pesticide use data methodology and reliability of data on use
- Consistency between mitigation measures and local conditions of use
- Accuracy of communication between institution or structure involved

These answers are coherent with the other two options selected by the participants as factors limiting pesticide RM that indicate

- Availability of information on innovating technology to be used in the mitigation measure
- Availability of data on real-life conditions of the target population

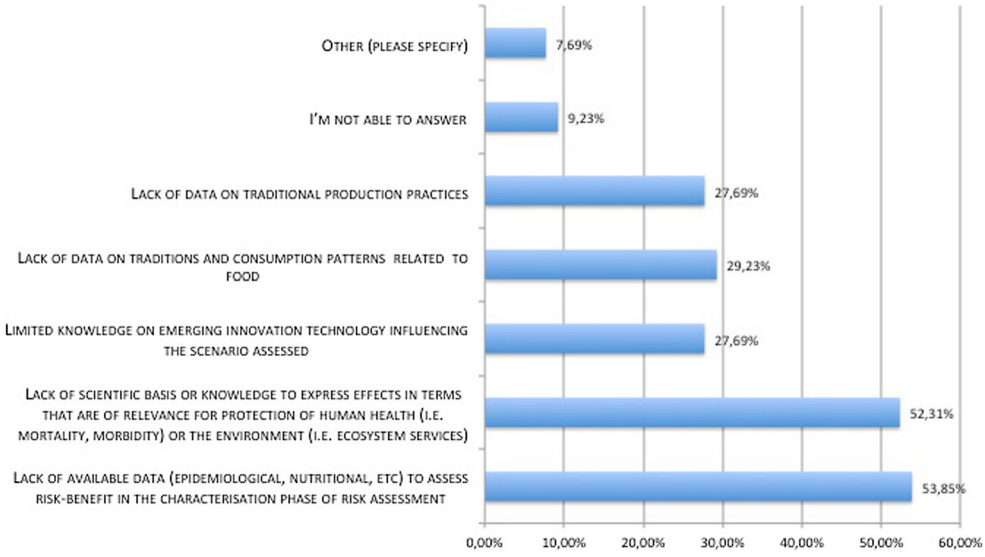

Fig. 3 Part B question 7. Please choose amongst the following factors related to the characterisation of risk, those who you consider that have an influence on the effectiveness of the pesticide risk/benefit assessment in your country (you can choose more than one option). Total responses 135

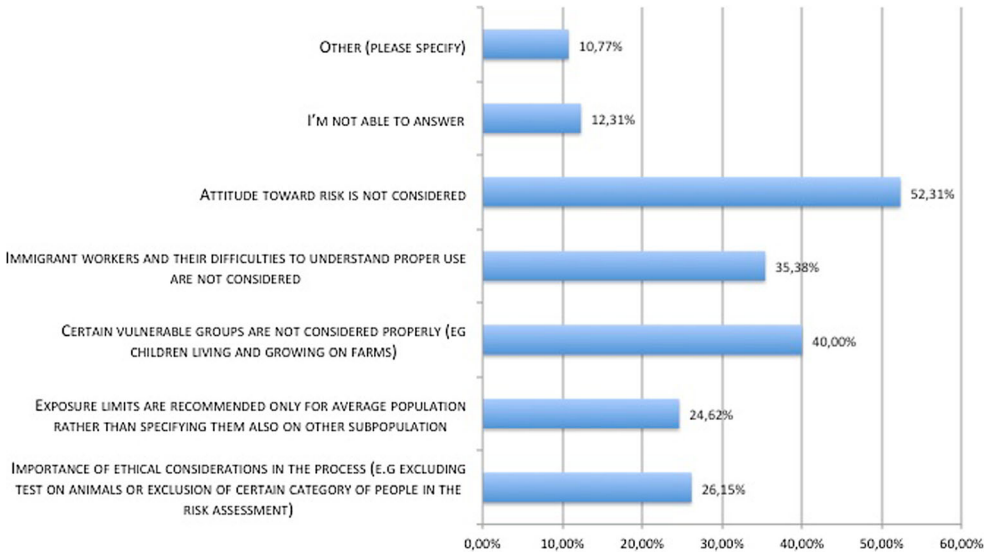

Fig. 4 Part C question 8. Please choose amongst the following factors related to cultural aspects, those that you consider to have an influence on the effectiveness of pesticide risk assessment in your country (you can choose more than one option). Total responses 131

Perceived risks and emotional reactions of the public are considered as factors influencing the effectiveness of RM by 37.7 % of participants.

This indicates that there is an interest in an interdisciplinary approach in RM that involves also other different scientific disciplines.

If we analyse data from the risk manager point of view, the 83.3 % of respondent selected the availability of context specific data and consistency between suggested RA mitigation measures and local conditions of use as the main factors limiting the effectiveness of RM process relating to monitoring programs and mitigation measure confirming the gap between the RA outputs and RM needs.

In details, regarding monitoring data trust in pesticide use data methodology and reliability of data on use were selected by 50 % of risk managers participating the survey.

Regarding mitigation measure availability of data on real-life conditions of the target population and perceived risks and emotional reactions of the public were selected by 66 % of risk managers participating the survey.

From the national regulator point of view, the 72 % of respondent selected the option 'consistency between mitigation measures and local conditions of use' as the main factors limiting the effectiveness of RM process relating to mitigation measure.

Instead, if we analyse data from the industry point of view, the 'accuracy of communication between institution or structure involved' result as the main factors limiting the effectiveness of RM process relating to monitoring programs and 'availability of information on innovating technology to be used in the mitigation measure' the main factor

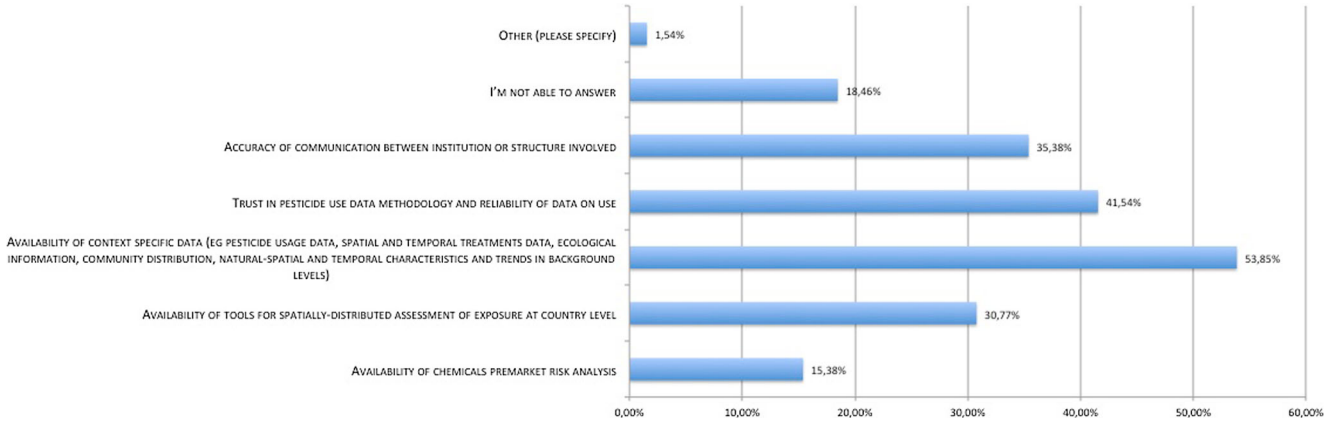

Fig. 5 Part A question 9. Please choose amongst the following factors related to monitoring programs, those that you consider to make an influence on the effectiveness of pesticide risk management in your country (you can choose more than one option). Total responses 128

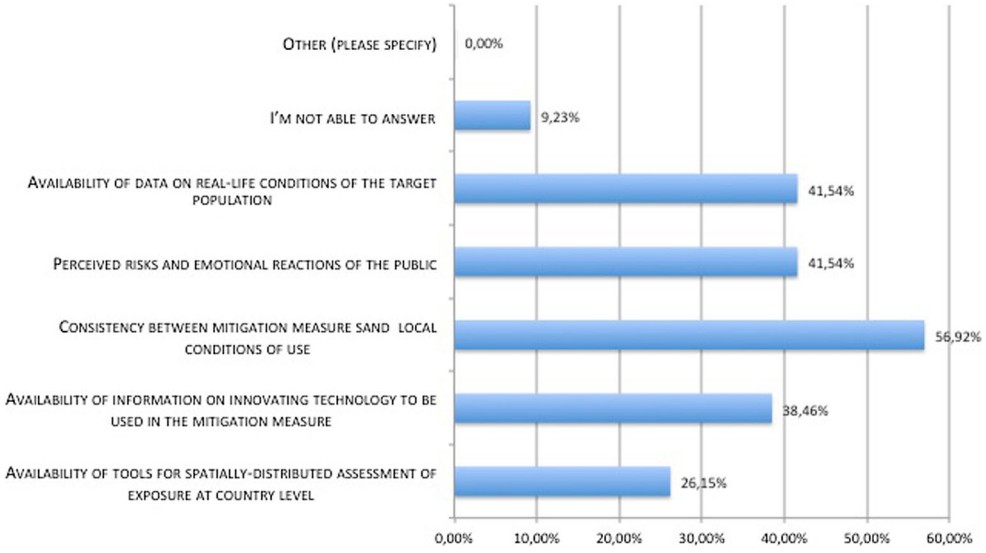

Fig. 6 Part B question 10. Please choose amongst the following factors related risk mitigation measures, those that you consider to have an influence in choosing the right solution for pesticide risk management in your country (you can choose more than one option). Total responses 139

having an influence in choosing the right solution for pesticide RM.

3. Policy and administrative influence and economic issues

For the questions in this category, the respondents considered that important factors making an influence on efficacy of RM phase are (Fig. 7 graph Q11)

- Involvement of pesticide users in educational or training programs
- Availability of human and financial resources in administration
- Costs and administrative burden on farmers and business
- Farm productivity and profitability

The 55.38 % of the participants are of the opinion that RM responsibility is not clearly distributed between authorities. This aspect is particularly important for risk assessors and national regulators (more than 70 %). Instead, it is a factor not considered so important from the academic point of view.

4. Communication

Factors selected by participants that limit the effectiveness of pesticide risk analysis in respect of the communication phase are mainly (Fig. 8 graph Q13)

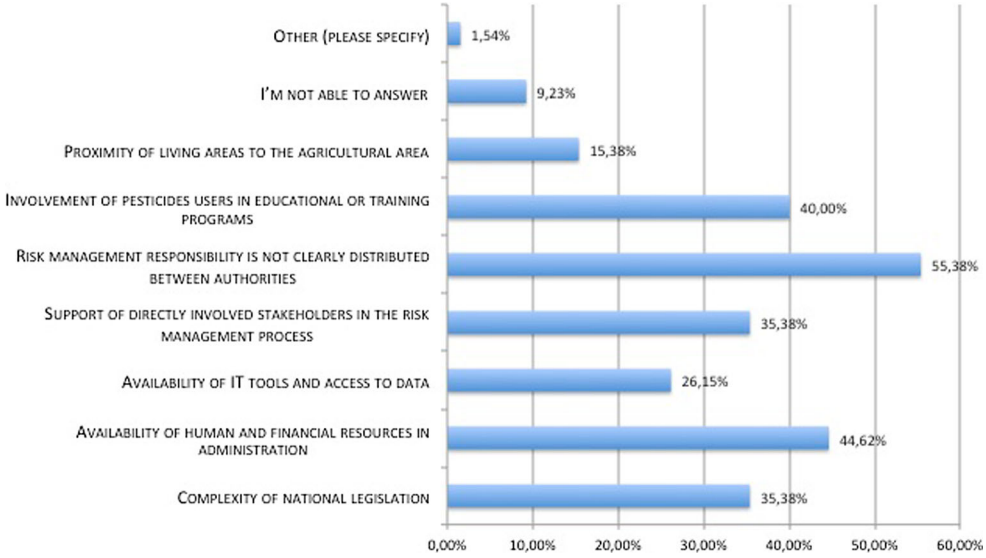

Fig. 7 Question 11. Please choose amongst the following factors related to policy and administrative influence, those that you consider to make an influence in choosing the right approach in the pesticide risk management in your country (you can choose more than one option). Total responses 171

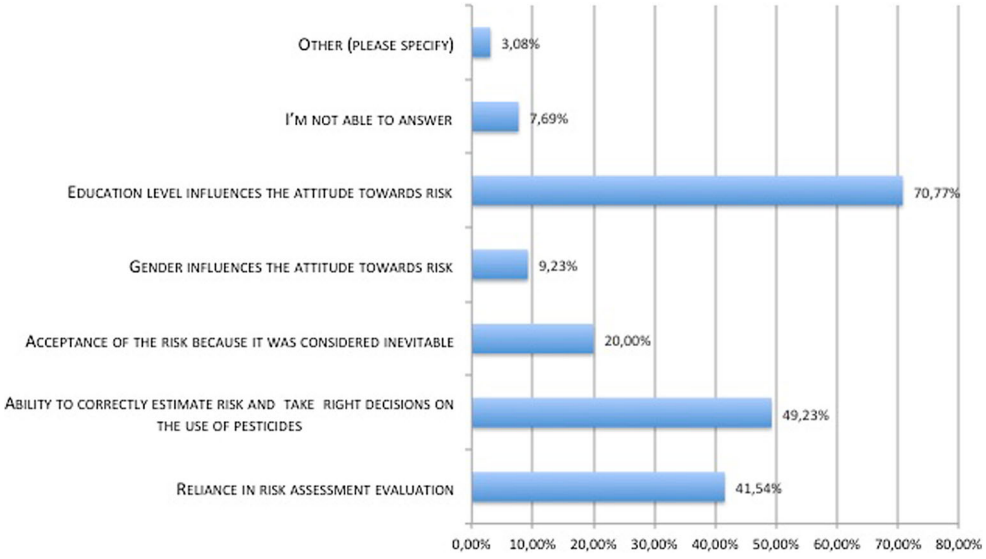

Fig. 8 Question 13. Please choose amongst the following factors related to culture and traditions, those that you consider to better describe the attitude on risk analysis in your country (you can choose more than one option). Total responses 131

- Poor communication between different entities that produce information and data.
- Experts of different disciplines that give contradictory messages.
- Involvement of a one-sided viewpoint in the public debate.
- The information is not accessible to all target population.

Experts of different disciplines gave contradictory messages especially for the 'industry' participants (77 %) and national regulators (72.23 %), which are the subjects that usually receive the information. Involvement of a one-sided viewpoint in the public debate was the main option selected by international regulators (56.6 %).

The 41.54 % of participants consider reliance in RA evaluation a factor related to culture and traditions describing the attitude on risk analysis in coherence with the statement that education level influences the attitude towards risk (for the 73 % of participants).

Ability to correctly estimate risk and take right decisions on the use of pesticides are also selected by the 49.23 % of the participants as factors describing the attitude towards risk. Otherwise, these factors are linked to the level of education. The pesticide use education is a societal need that we have to take into consideration.

A significant example on disconnection between those who produce targeted innovation and who manage is the industry point of view that selected the 'availability of information on innovating technology to be used in the mitigation measure' the main factor having an influence in choosing the right solution for pesticide RM.

Principles guiding the evaluation are related to social behavioural aspects linked to responsibility, trust and reliance that can strongly influence the choice of the approach to be taken and the attitude towards risk and confirm that value disparities are the key factors.

Regarding ethical issues, the survey has indicated that the results of the RA extrapolated to the whole population may not be representative of the particular risk, and vulnerable groups (e.g. children living and growing on farms) and immigrant workers and their difficulties to understand proper use are not properly considered, but few respondents select the importance of ethical considerations in the RA process as factor having an influence on the effectiveness of pesticide RA. This is in contrast with what has been previously expressed and reveals the lack of confidence on the issue.

The results indicate that there is an interest in an interdisciplinary approach in risk analysis that involves also other different scientific disciplines but also that this aspect have not yet been fully explored and the role of socio-behavioural factors have not been fully recognised amongst all stakeholders.

Phase 2—stakeholder roundtable

The general conclusion of the roundtable was that some changes are needed to strengthen the credibility of the process of RA and improve the effectiveness of policies. Some issues have been therefore identified, and in some cases, practical tools to improve the process were suggested. The main outcome of the discussion and of the theoretical information

provided by the experts is summarised in the following seven points:

1. It has been the general feeling that early consideration of the social-behavioural factors influencing the risks, associated to the use of certain chemicals, can improve the efficiency of the RA process. However, the decision on the level and details of considering such factors should be made context specific and in relation to the properties and context of use of the chemical concerned. Applied behavioural sciences can complement the existing RA throughout its process by providing support in better problem formulation (i.e. target population or ecosystems; use patterns; knowledge and information levels of users and risk perception) and fine-tuning the RA or targeting RM and RC. However, introducing new elements to an already complex process needs to show a certain level of caution as to avoid that the process becomes so difficult to operate that in the end, it does not deliver on the ultimate objective of protecting efficiently human health and the environment.
2. The improvement of measuring risk perception is one of the most important issues we have to take into account to increase trust in the RA process. Despite the evidence-based approach of the RA process, results could be sometime controversial due to different beliefs and views, biases in processing scientific evidence. The risk perception has its own role in the political debate regarding the level of acceptance of certain risks. Risk managers play an important role in the management of risk perception of different target groups in function of the results of RA, local regulation, availability of context specific data and resources and of the management of the societal conflicts in case of uncertainty prevalence or high stakes. There are several possibilities to get data and valuable information on risk perception that we can use for RM. Experiments are preferable, followed by surveys. However, in order to be relevant, surveys should have external validity in the daily life of the people involved; otherwise, there is a high risk of biased results. Alternatively, the usefulness of using focus groups is sometimes questionable because results strictly depend on people you select.
3. Decision makers need good, clear, assessable and understandable information to make regulatory decisions; however, this is not sufficient due to obstacles generated by bounded rationality, bounded ethicality and ideological extremism, which limit the quality of the decision. The sociological reality is that some people react to real information and others to noise or random information that is totally useless for their own purpose. Even if good information is produced, certain categories of people cannot be really reached. Hence, involvement of social sciences to early predicted behavioural aspects related to the use patterns of certain chemicals or related to risk perception would allow to better target the risk analysis process to produce more accurate predictions of the risk and more efficient suggestions for its management and its communication.
4. It was reaffirmed that although it widely recognised the importance of the RA and RM separation of responsibilities and functions, it is important to guarantee their interaction ensuring that an informed RA meets the needs of the RM. Valuable information may emerge during any stage of RA and RM so the two processes should not be sequential but should be dynamic and flexible. The problem at formulation stage should also involve determining RM goals and identifying the responsibility and resources and include also those socio-behavioural factors that can affect the results of the RA. The stakeholder participation early in the process can help to better define scenarios and population exposed. Therefore, the process will also be able to assess if there is a need for social behaviour aspects to be taken into account, but one must be careful not to increase the complexity of the entire system. There is no real rule on how to conduct a public consultation and how many or which types of stakeholders should be involved, whilst the process should be context specific, and the basis for deciding on the appropriate level of stakeholder involvement in the process strictly depends on the dominant characteristic of the risk we are assessing. A tiered approach was suggested; simple risks may require little consultation on the nature of the risk itself. Complex and uncertain risks may benefit from wider dialogue amongst directly affected stakeholders or supply chain.
5. To overcome the cognitive barriers without attributing to the risk assessor skills and responsibility that are not part of his cultural background, the importance of integration of the social sciences has emerged in the whole process that could support

   - The improvement of RA result communication in order to support 'non-expert' to judge the credibility of the overall RA activity. The CORA (Wiedemann et al. 2013) framework was suggested as useful tool to strengthen the trust of the RA report,
   - To reach an agreement and to eliminate biases or conflict of interest in cases of conflicting view and different RA conclusions.
   - To weight in appropriate way different kinds of evidence.
   - To communicate uncertainty.

6. Ex ante or ex post approach?

   Regarding, in particular, pesticides, RA authorisation process does not include socioeconomic evaluation

except for very few cases. Pesticide RA as currently done is a deterministic and quantitative process that does not address socioeconomic and behavioural aspects. Mitigation measures are considered in order to reduce risk, and the authorisation is bounded to good agricultural practices. But '*risks analysis is not just about technical assessment and optimisation of the risks as quantified entities*' (Slovic and Risk 1993; Kasperson et al. 1988).

The results of RA done in the authorisation process are not questioned, so pesticide risk trends for human and environment are strictly linked to the compliance with the rules and good agriculture practice.

7. Experts are also subject to biases, heuristics and a number of other influencing factors.

Being aware of these potential pitfalls, social sciences could be of support in the integration of different inputs in RA. Evidence maps, an approach for characterising scientific evidence, are suggested as useful tool. They are '*designed to depict the reasons leading experts to their conclusions about a* (*potential*) *hazard or risk. Evidence maps provide a graphical representation of the arguments that speak for or against the existence of a causal relationship between exposure to a* (*potentially*) *hazardous substance or condition and the biological effects that are considered*, *as well as the conclusions that are drawn and the remaining uncertainties*' and '*should be accompanied by a description of the process through which they have been generated*' *and require knowledge of RA methodology* (Wiedemann et al. 2011).

Discussion and conclusion

Science can seem to lose its connection to society and its needs, *and sometimes its objectives are not fully understood*, *even if they are well intended* (*European Commission*, *Science in Society* (*SIS*), http://ec.europa.eu/research/science-society). Even if at qualitative level, the stakeholder activities deployed in the HEROIC project indicate and confirm that there is a need to try to solve or generate acceptable solutions to the issues identified in this document, relevant in affecting the overall pesticide risk analysis process. One of these issues is related to the integration of social science in the process and the acceptance that the process should be more iterative. The analysis confirms the influence of socio-psychological factors and the cultural ones on the overall quality and effectiveness of ex ante risk evaluations and that the risk assessors are attribute skills and responsibility that are not part of his cultural background and need support to communicate in a better way uncertainty and RA results.

Indeed, the majority of regulatory recommendations or guidelines indicate that (i) RA outputs should be expressed in terms of value-relevant impacts on humans and ecosystems rather than in terms of the somewhat technical surrogates often used in the routine risk characterisations and (ii) be more policy and management relevant to facilitate the dialogue and the acceptance of the risk amongst all stakeholders (SCHER 2011, 2013).

The analysis of this issue does not necessarily lead to a radical change of the pesticide RA framework. Integration with socioeconomic analysis and inclusion of socio-behavioural issues at the problem formulation stage may initially increase the complexity of integrations between disciplines but in turn will provide a better and more useful estimation of the risk. This will also ensure a common language and facilitate the translation of risk evaluations into socioeconomic impacts. A more holistic approach to risk analysis, which also considers the cost of risk reduction and the benefits of risk mitigation measures to society, would reinforce transparency of the process, reduce risk aversion amongst politicians and the public and drive a more efficient use of RM resources.

In conclusion, it was learned that the challenge the society is setting for those involved in the RA is to ensure more transparency, on input data quality, assessment procedures and on resulting uncertainty (Wilks et al 2015). This should allow better RC with the aim to regain consumer/public trust and to give unambiguous guidance for improved RM. To achieve such ambitious goals, the 'risk analysis community' has to deal with the fact that '*even science is not a monolithic block*' (P. Wiedeman personal communication) and some changes are needed to strengthen the credibility of the process of RA and improve the effectiveness of policies without disrupting the process itself, which, as it is currently structured, however, has led to a number of advantages. The pesticide chemical RA phase should take as much as possible into account the social-behavioural factors and the 'applied behaviour science' input, in order to better define the problems at the formulation stage, and the type of information risk assessor has to provide, and to better inform risk manager in addressing different societal needs taking into account the acceptability of risk across different communities and country.

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References

Brigg DJ (2008) A framework for integrated environmental health impact assessment of systemic risks. Environ Health 7:61. doi:10.1186/1476-069X-7-61

Cooke RM (1991) Experts in uncertainty: opinion and subjective probability in science. Oxford University Press, New York/Oxford

Jolibert C, Wesselink A (2012) Research impacts and impact on research in biodiversity conservation: the influence of stakeholder engagement. Environ Sci Pol 22:100–111. doi:10.1016/j.envsci.2012.06.012

Kasperson RE et al (1988) The social implication of risk: a conceptual framework. Risk Anal 8;N°2

Mack N, Woodsons C, MacQueen K, Guest G, Namey E (2005) Qualitative research methods: a data collector's field guide. USAID, USA

Pahl-Wostl C, Tabara D, Bouwen R et al (2008) The importance of social learning and culture for sustainable water management. Ecol Econ 64(3):484–495

Pery ARR et al (2013) Perspectives for integrating human and environmental risk assessment and sinergie with socio-economic analysis. Sci Total Environ 456-457:307–316

Remoundou K, Brennan M, Sacchettini G, Panzone L, Butler-Ellis MC, Capri E, Charistou A, Chaideftou E, Gerritsen-Ebben MG, Machera K, Spanoghe P, Glass R, Marchis A, Doanngoc K, Hart A, Frewer LJ (2014) Perceptions of pesticides exposure risks by operators, workers, residents and bystanders in Greece, Italy and the UK. Sci Total Environ 505C:1082–1092

Rohrmann B (2008) Risk perception, risk attitude, risk communication, risk management: a conceptual appraisal, keynote at the congress of The International Emergency Management Society TIEMS-2008 in Prague/Czechia. Text included in the conference publication. Global co-operation in emergency and disaster management

Rowe G, Frewer LJ (2005) A typology of public engagement mechanisms. Sci Technol Hum Values 30(2):251–290

Sacchettini G, Calliera M, Marchis A, Glas R, Butler-Ellis C, Machera K, Gerritsen-Ebben R, Spanoghe P, Capri E (2015) New risk indicators approach for operators, workers, bystanders and residents for a sustainable use of plant protection product. Environ Sci Pollut Res. accepted 15.06.2015

SCHER (Scientific Committee on Health and Environmental Risks) (2011) Improvement of risk assessment in view of the needs of risk managers and policy makers available on http://ec.europa.eu/health/scientific_committees

SCHER (Scientific Committee on Health and Environmental Risks), SCENIHR (Scientific Committee on Emerging and Newly Identified Health Risks), SCCS (Scientific Committee on Consumer Safety) (2013) Making risk assessment more relevant for risk management

Scott J (2010) A manual for stakeholder consultation: Jordan. USAID Jordan Economic Devel- opment Program, www.SABEQ-Jordan.org

Slovic P, Risk P (1993) Trust and democracy. Risk Anal 13(6):675–682

Special Eurobarometer 419 (2014) Public perceptions of science, research and innovation. European Union ISBN 978-92-79-40609-6

Wiedemann PM, Schults H, Spangenberg A, Krug HF (2011) Evidence maps: communicating risk assessments in societal controversies: the case of engineered nanoparticles. Risk Anal 3, n.11

Wiedemann PM, Boerner F, Durrenberger G, Estenberg J, Kandel S, van Rongen E, Vogel E (2013) Supporting non-experts in judging the credibility of risk assessments (CORA). Sci Total Environ 463-464:624–630

Wilks MF, Roth N, Aicher L, Faust M, Papadaki P, Marchis A, Calliera M, Ginebreda A, Kühne R, Schüürmann G (2015) White paper on the promotion of an integrated risk assessment concept in European regulatory frameworks for chemicals. Sci Total Environ 521–522:211–218