# A reflexive approach to dealing with uncertainties in environmental health risk science and policy[1]

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**Abstract:** Based on insights obtained through an analysis of an environmental health risk controversy, we developed a reflexive approach to uncertainty assessment, explicitly acknowledging the complexity of the knowledge production process. The approach aims at interactively exploring uncertainty in relation to different scientific framings, societal perspectives and policy options. The structure of the discussion scheme used for the exploration is based on the concept of 'pedigree of knowledge'. The discussion protocol is designed to guarantee conditions for a reasoned debate.

A workshop has been organised, during which the approach has been deployed to assess scientific studies, that had been produced in the context of a socio-political debate on possible health effects from waste incineration. The results obtained show the approach has potential to trigger a profound social debate and a negotiated management of risk. Pro-active use of the approach could enhance the quality and robustness of the knowledge input in policy making.

**Keywords:** complexity; controversy; environmental health; interactivity; pedigree; policymaking; problem framing; reflexivity; quality; uncertainty; waste incineration.

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## 1 Introduction: from evidence evaluation to uncertainty assessment

It is increasingly recognised that uncertainty in relation to risk science and policy can no longer be suppressed or denied, but has to be dealt with in an appropriate way.

At the level of the European Union, the European Commission's Report on Democratising Expertise (Commission of the European Communities, 2001) and its Communication on the Precautionary Principle (Commission of the European Communities, 2000) address uncertainty as a horizontal issue of relevance for a broad range of policies.

The operationalisation of this concern entails the development of frameworks to deal with uncertainty in policy relevant knowledge.

The dominant approach to the issue of uncertainty, the 'deficit model', considers the non-conclusiveness of factual information as provisional and typically leads to attempts to reduce uncertainty by means of an increased research effort, addressing more complicated problem formulations (Commission of the European Communities, 2004). These attempts generally go hand in hand with technical analyses – quantification of ranges and error-bars – of what is seen as unsolvable uncertainty, namely, uncertainty due to random variation in observations and natural phenomena.

Other approaches frame uncertainty assessment as 'evidence evaluation'. While sometimes acknowledging the negotiated character of knowledge, most of them (Intergovernmental Panel on Climate Change, 2001; World Health Organisation/International Programme on Chemical Safety, 2002) still pay primarily attention to the strength of particular results of scientific research.

However, uncertainties in the knowledge base, especially when expressed through the existence of different scientific opinions and/or divergent interpretations in the socio-political debate, can mostly not *automatically* be solved through additional research or reduced through comparative evaluations of research *results*.

Empirical studies (Shackley and Wynne, 1996; Shackley et al., 1998; van der Sluijs et al., 1998) show that, certainly when knowledge development can be considered still in the infant phase, *processes* within the scientific community and interactions of science with the 'external' world – policymakers, stakeholders, civil society,... – are crucial for the robustness of findings. These processes concern the framing of the problem, the choice of methods, the design of the strategy to gather the data, the review and interpretation of results, the distribution of roles in knowledge production and assessment, the function of the results in the policy arena, etc. .... Although the assumptions underlying the design of these processes are most often not openly discussed, they are important for the knowledge becoming 'contested' or, on the other hand, 'robust'. More research on complex issues can even lead to more intense controversy and less strong evidence if these assumptions are not adequately dealt with (Craye et al., 2001).

Based on these findings, we argue that it is not enough to analyse uncertainty as a 'technical' problem or merely to assess the strength of the evidence of scientific results. The production of knowledge and the assessment of uncertainty have to be considered in the context of the complexity of contemporary decision making and societal processes. Reflexive approaches to uncertainty assessment (inter)actively discuss uncertainty in relation to different societal perspectives and policy options. They explicitly address problem framing, as well, as institutional aspects of knowledge development. They openly deal with deeper dimensions of uncertainty such as indeterminacy, ignorance, assumptions and value loadings. They assess uncertainty in order to trigger a profound social debate and a negotiated management of risk. As such, the discussion of uncertainty could become a resource contributing to processes of institutional change instead of just being considered a problem for decision making.

We will explore in what ways and how methods based on the concept of 'pedigree of knowledge' can contribute to a reflexive approach to uncertainties. To this end, we will first detail the features of a reflexive approach to uncertainty assessment. Our reasoning will be based on an empirical analysis of a controversy concerning environmental health risks from a waste incinerator plant near the city of Antwerp (Region of Flanders, Belgium). The controversy eventually led to some reflexive effects. Important factors in this evolution – including the recognition of uncertainty – will be described. Secondly, we will briefly introduce the NUSAP/Pedigree scheme for the notation and communication of uncertainty. We will focus on interesting characteristics of this tool in view of its use in a reflexive approach.

Thirdly, we will comment in detail on a recent experience with interactive uncertainty assessment, using pedigree schemes as a structuring tool for discussion. Finally, the potential of this kind of process for deliberative risk governance will be assessed.

## 2 Developing a reflexive approach to uncertainty assessment

### *2.1 A controversy on possible health effects caused by waste incineration*

The Flemish Region of Belgium has known some intense controversies on environmental health risks in recent years. One of the most remarkable ones concerned the potential health effects of a waste incinerator's emissions on local population, near the city of Antwerp (Keune and Craye, 2004). Ever since its start up in the early 1980s, the incinerator had been the subject of complaints by local residents. Initially, these complaints were related to noise and dust pollution. They were not taken seriously by local public authorities, who were also the main shareholder of the incinerator. Around 1993–1995, local population and health workers jointly detected that, in a neighbourhood near the incinerator, an unusually high number of children had congenital defects. They pointed to the incinerator's (dioxin) emissions as the cause and demanded that it be closed. The incinerator's management, supported by the local authorities, deemed these accusations as 'irrational, meaning purely hypothetical and not scientifically proven'.

The opposition to the incinerator did not disappear and years of heated debate followed, involving citizens' committees, policymakers (both local and regional) and scientific experts. After an increase in media coverage of possible dioxin-linked health problems, the Regional Minister for the Environment decided to close the incinerator and only to authorise its re-opening when two conditions had been fulfilled: new equipment to cut the dioxin emissions to the legally prescribed norm should have been installed and scientific health impact studies should have confirmed that a re-opening would not be an immediate threat to public health in the neighbourhood.

Several scientific studies were commissioned, each entailing its own controversies and each delaying a more adequate reaction to the 'problem of non-acceptance'. Ultimately, the conflict evolved to a phase in which all parties realised that a business-as-usual style would not work any longer.

A process of dialogue was initiated, involving – for the first time – all interested actors. The seeming intractability of the issue was also the main reason for launching a larger scale Research Programme on Environment and Health, eventually leading to the creation of the Flemish Centre of Expertise on Environment and Health (CEEH). The Research Programme's results included recommendations on how to conceive anew the interactions between science, policy and society. These recommendations are being used to design communication and assessment strategies for the CEEH's ambitious biomonitoring programme (Keune, 2004).

The measures taken showed that a learning process had taken place, resulting in an enhanced reflexivity: well established approaches were questioned and new ways of addressing this kind of issue were opened.

### *2.2 The controversy's dynamics of reflexivity*

Analysing the start and the evolution of the controversy on the Antwerp waste incinerator, three interrelated factors can be distinguished that played a decisive role in its dynamics of reflexivity, namely: the complexity of the problem, leading to deep uncertainty regarding the phenomenon and its causes; the different framings of the risk among different actors, policy makers and experts; the institutional arrangement, establishing the rules that governed the interactions on this issue in policy, science and society.

The regional authorities' dealing with the case was initially inspired by a very modernist science-based approach to environmental policy making. It was based on the belief that 'science would speak truth to power', leading the regional environment minister to state confidently that 'everyone would agree with the conclusions the scientists would arrive at' (Craye et al., 2001). This created expectations among all actors that some 'factual information', coming about through 'good' research, would decide any discussion.

Scientists initially responded uncritically to these expectations. Their curiosity drove them to analyse such an 'appealing' research problem through their disciplinary framings. Being seen as relevant for policy makers also meant extra funding and resources. Their status and position would strengthen if they could deliver decisive advice in an eye catching socio-political issue.

Based on interviews and document analyses, our research revealed that the problem definition that was used in the authorities' approach was too narrow and was incompatible with the framings of interested actors, not least of which was the local citizens' committee.

Administrators and policy advisors were proponents of a planned environmental policy, which they saw endangered by uncontrollable outbursts of 'irrational protest'. Only scientific proof of a public health problem (the definition of which was left to technical experts and scientists) was a strong enough base to change the region-wide plans for waste treatment and disposal.

The local citizens framed the problem within their socio-historical experience of what constitutes good life in their residential green neighbourhood. Their reactions were the result of distrust in the authorities who had to manage the risk, built up through years of failed communication. The incinerator's management used 'cost efficiency' as a central referential point to judge any possible solution to the problem.

The actors' framings, including the more generic insights supporting their assessments and the deeper preferences they all wanted to realise, were simply ignored in the policy process. This process was based on a division of roles between strictly separate spheres of society: the experts had to give undisputable factual input, the public administration and elected politicians conceived policy plans based on the factual input and a weighing of the involved interests and sectors and the citizens democratically rendered legitimacy to the public authority and provided a social basis for the implementation of policy plans.

As the different framings were not recognised, there was no chance to achieve some robust insights acceptable to all the actors involved. Science was considered the only legitimate source of quality arguments but every actor used scientific information in a strategic way, to defend its own position. Actors used results supporting their position as 'authoritative facts', whereas results supporting the other's positions were dismissed as 'bad science'. This was possible as the *inherent* uncertainty (see its assessment in the following paragraphs) of all results obtained through research on the issue, was not openly acknowledged.

The citizens' committee did not give up its protest, getting ever more angry as it was formally denied any agency. The science-based approach that was followed, reflexively showed its inadequacy by triggering ever deeper divergence between the actors involved (Craye et al., 2001).

Confronted by this stalemate, the research and the policy-making communities initiated some actions, which were – at least partly – inspired by a threefold reflection: on the role knowledge can play in policy processes on these issues (including, notably, greater awareness of uncertainty); on the role policymakers themselves, experts and stakeholders, can and should play in the decision-making process; on the problem definitions used in science and policy, compared to the different framings held by the actors.

### *2.3 Re-conceiving methodological support to risk governance: the potential of uncertainty assessment*

Methodological support to risk governance, based on models of social learning and constructivist perspectives on risk experience throughout society, should aim precisely at such reflexive effects (Flyvbjerg, 2001). Its contribution is in enhancing the space of negotiation in policy processes that risk getting blocked when following narrow technical approaches. It can lead to new directions for change, both substantially and as regards procedures and institutions. In this way, the chances of developing more creative solutions as well as renewed mutual trust are increased.

Although the aim cannot be to organise conflict or controversy, it can be expected – following the case described – that deliberate attempts to create learning processes will function better if they contain destabilising, self-confronting elements for established practices.

Beck, whose writings are at the basis of the prominent place the concept of 'reflexivity' acquired in socio-political science, underlined the importance of a constellation of self-confrontation ('reflex') to open the way for political, public and academic reflection (Beck, 1992, 1996). In dealing with contemporary risk issues, the awareness of the deadlock induced by the policy approaches and societal behaviours of modern industrial society, is an essential element in processes of critical investigation.

The Antwerp waste incinerator case enables us to discern the features of a possibly successful approach: a process in which the focus is on uncertainty, in relation to how different actors frame an issue and in which, at the same time, institutional roles are questioned. The discussion of uncertainty immediately changes the role of expertise, traditionally only communicating factual knowledge claims. This intention to institutional change will even be reinforced if the assessment and discussion of uncertainty takes the form of a disciplined, reasoned debate. A debate which renders agency to a diversity of actors (experts, policymakers, stakeholders and concerned citizens) a forum that stimulates the expression of different opinions and a reasoned exchange of arguments.

In genuinely structuring the deliberation on uncertainty, the process should be opened to take into account the plurality of scientific and socio-political perspectives on the problem. The treatment of uncertainty should not be conceived as an analytical quantitative analysis. The definition of uncertainty used should also cover what is referred to as 'ignorance' and 'indeterminacy' (Wynne, 1992). The assessment should focus on the frame-dependent choices and assumptions that are made when developing policy relevant knowledge: discussing these can bring to the surface the deeper sources of divergence regarding knowledge claims.

Conceived in this way, interactively assessing uncertainty could become an initiator of reflexivity. Reflexivity then refers to a state and/or an attitude, created by an ensemble of processes, events, actions and measures, through which what is mostly accepted and not questioned is made the subject of study, discussion and deliberation leading to more openness, more possibility for societal debate and dialogue between policy, science and involved groups, enabling the construction of alternative policies or lines of action. Through reflexivity the content of current policy processes, including the problem definitions and supporting methodologies and approaches, as well as the patterns of interaction and the rules governing these interactions, are openly discussed. The latter touches upon the role taken up by different actors, the role of knowledge in the policymaking process and the institutional aspects of policy (supporting) processes in general.

## 3 The 'pedigree' concept

A reflexive approach needs a supporting tool to structure a deliberative process to explore uncertainty. This tool should help to avoid the deliberation being reduced to a mere technical and analytical discussion. It should acknowledge the inseparability of facts and values and facilitate the exploration of the intertwinement of uncertainty and problem framing. To be of practical use in an interactive setting, it should be fairly easy for a variety of actors involved, to get acquainted with its basics.

'Pedigree assessment' could become a valuable tool in such reflexive approach, provided it deals explicitly with framing and is used in an interactive way, not as a purely analytical device. Pedigree assessment emerged in the context of the NUSAP notation and discussion scheme for uncertainty in policy supporting scientific information (Funtowicz and Ravetz, 1990). The basic idea is to qualify quantities using the five qualifiers of the NUSAP acronym: numeral-unit-spread-assessment-pedigree. By means of NUSAP different types of uncertainty can be displayed and discussed in a well structured way. NUSAP's intention is to promote a critical reflection on the quality of policy supporting science among experts, policy makers and other interested actors.

NUSAP has been developed as an extension of the traditional notation and communication of scientific information. This characteristic can facilitate its integration in institutionalised practices, based on well-established frameworks. Taking the scientific information as a starting point, and focusing first on its more familiar technical-numeral aspects, NUSAP leads the users gradually into aspects of socio-technical and even political framings.

The first three letters of the acronym refer to a presentation of information by means of a number, a unit (f.i. cancers/year, ...) and a spread (f.i. a number of times the standard deviation when statistics have been used in the data collection and analysis). They deal with technical forms of uncertainty as inaccuracies in measurements, due to random variation.

The assessment qualifier gives an account of the reliability of the result and its spread. As such, it gives information on the methodological uncertainty, leading to more systematic errors. In the case of statistical analyses, this qualifier will be expressed through some confidence limit.

The most original and innovative contribution by the NUSAP system – and also the interesting one in view of our purpose – is the pedigree qualifier. A pedigree score is used to assess the production process of the scientific information. The yardstick for the scoring is a conception of 'quality' as 'fitness for function'. Pedigree assessment has the ambition to surface those aspects crucial for the quality of knowledge on complex issues, that usually stay hidden under the numbers and the error bars. It should deliver deeper insight into how assumptions and value-laden choices have been dealt with in the process of knowledge development. Pedigree addresses those 'deeper' forms of uncertainty, often labelled to 'ignorance' and 'indeterminacy'.

These forms of uncertainty have an epistemological nature. In a broad sense, ignorance refers to all kinds of gaps in our knowledge not covered by inaccuracy or unreliability. Indeterminacy refers to the basic condition that there exists not one a priori privileged approach to studying natural or socio-technical phenomena, leading to our knowledge always being somehow conditional and contingent. It is precisely through the various assumptions and choices – that make up a framing of a problem – that we (often unconsciously) determine what our knowledge will look like, but also what we will stay ignorant about.

A pedigree assessment is carried out using a pedigree scheme or matrix (see Table 1). The different columns in the matrix are called 'phases' and display the relevant aspects to consider. The rows are hierarchically ordered 'modes': these are qualitative labels describing the different ways in which the pedigree phase can be qualified for the particular production of scientific information that is being assessed. The modes are ordered from 0 to 4. In this way, a pedigree assessment leads to a pedigree score, obtained by choosing for each phase (aspect) the relevant mode (qualifying label). A higher score for a particular phase means the way this phase has been handled in the production process is expected to have increased the resulting quality of the information.

**Table 1** Pedigree scheme for the epidemiological study

| *Number* | *Problem framing* | *Data – definitions* | *Data – collection* | *Analysis* | *Review* |
|---|---|---|---|---|---|
| 4 | Negotiation | Negotiation | Task Force | Established | Extended |
| 3 | Scientific | Science | Direct | Discussion | External |
| 2 | Compromise | Pragmatic | Bureaucratic | Competition | Independent |
| 1 | Inertia | Symbolic | Indirect | Embryonic | Internal |
| 0 | Controversy | Unknown | Fiat | No information | None |

In earlier work, NUSAP has been used to complement quantitative uncertainty analysis with expert judgement of reliability (assessment) and systematic multi-criteria evaluation of the different phases of production of a given knowledge base (pedigree), using criteria such as proxy representation, empirical basis, theoretical understanding, methodological rigor and degree of validation (van der Sluijs et al., 2005a,b).

Assessing a pedigree is an inherently intersubjective activity. Not only the score to give, but even the definition of phases and modes can be subject to discussion. Ultimately, even 'quality', although it can be generically defined, can only obtain its concrete meaning as a standard in a particular context, through reasoned deliberation. Van der Sluijs et al. (2002) provide a systematic argumentative procedure for expert elicitation of pedigree scores that aims to minimise arbitrariness in the pedigree scoring.

The 'open ended' character of pedigree assessment should, however, be seen as a strength rather than a weakness. Providing and sharpening argumentation for specific pedigree scores can promote learning and deepen our awareness and understanding of non quantifiable policy-relevant uncertainties. At best, pedigree assessment can play a supporting role, through enhancing the 'space of negotiation' between experts, policy makers and stakeholders, in the production of robust knowledge. At least, it should increase our insight into some of the critical aspects in the production of scientific information. It can increase the transparency of the scientific input in the policy context and help to avoid naïve trust as well as bitter cynicism.

The NUSAP system, and its pedigree component in particular, reflect an epistemological perspective considering any scientific expression as an inextricable blend of complementary factual and value-loaded elements. Any scientific expression testifies what we know (the more or less robust knowledge claim on which consensus is constructed, based on choices and interpretations that are meaningful within scientific and socio-political framings of the issue) and what we do not know (the endless ignorance due to what we left out of our scope as a consequence of the very same choices, assumptions and interpretations made). It is precisely addressing this condition of complexity in knowledge production which can open ways to more reflexivity.

This basic reasoning behind the NUSAP/pedigree system, together with its simplicity, self-explanatory character and coherence, make it an interesting instrument for structuring a deliberation on policy-relevant knowledge. It can be used on the more holistic level of the appreciation of ignorance and uncertainty in expert advice 'as a whole', which gives it features of practicality and concreteness in the science-policy-society interface.

In that interface, the NUSAP/pedigree system will inevitably put the focus on a discussion of uncertainty. Using it interactively can be an intentional action towards institutional change (Deblonde, 2001; Goodin, 1996) by establishing other patterns of interaction; formal and informal socio-institutional rules can be changed through holding discussions along the lines of its philosophy. Pedigree assessment can invite one to consider a broader range of subjects than is normally the case: the problem definition used, the role of experts and other actors, the adequacy of the knowledge infrastructure, etc. In this way, pedigree assessment has promising features to be a supporting tool when seeking to address reflexively the issue of uncertainty in risk science and policy.

## 4 The use of pedigree in an interactive process to assess uncertainty

### *4.1 A workshop involving interested actors, policymakers and experts*

Using the controversy over the Antwerp waste incinerator as a test case, researchers from the European Commission's Joint Research Centre and the universities of Antwerp (UA-UFSIA), Utrecht (UU) and Amsterdam (UvA) held a workshop in June 2003 to explore how NUSAP/pedigree schemes can be used as a structuring tool to support deliberations on uncertainties in environmental health risk assessment. As the incinerator case is well-known among Flemish environmental health experts and civil society and the debate on it was beyond the phase of intense conflict, the timing and the issue were thought to be right to hold a fruitful experiment. Besides experts and actors directly involved in the socio-political debate at the time, we also invited scientists from RIVM, the Dutch public research centre providing policy support in the field of environment and health. Some representatives of Dutch stakeholders in environmental health issues were also invited. The expectation was that bringing in a broader range of participants would enhance the possibilities for collective learning.

After an introductory session, participants joined in three sub-sessions, each dealing with a scientific study that had been used in the discussions on the incinerator's impact on the environment and local health: an epidemiological study (Aelvoet et al., 1998), an exposure assessment (Schoeters et al., 1998) and a biomonitoring study (Koppen et al., 2001; Staessen, 2001). During the closing session, the experiences in the sessions with the interactive use of pedigree schemes were discussed and conclusions drawn.

### *4.2 Assessment of an epidemiological study*

With the contours of a reflexive approach in mind, pedigree schemes, as well as a discussion protocol, were developed to assess the three studies. Table 1 shows the pedigree scheme used in the uncertainty assessment of the epidemiological study. This study had been commissioned by the regional minister for public health after a first study had not met the expectation to give a clear answer about the causal link between the incinerator's emissions and the cluster of diseases. This first study included an inventory of the incinerator's emissions, an estimation of the local population's exposure, a toxicological test to investigate the incidence of pollution-induced defects at the chromosome level and a qualitative account of the children's diseases.

Although its conclusions tended to deny a causal link, the study's authors, as well as their opponents in the scientific community, pointed to the fact that 'no proof of link' was not a 'proof of no link'. On top of this, some scientists, mostly epidemiologists, criticised the approach and methodology of the study and questioned, in particular, the validity of its statistical analysis section.

As a consequence, the second research commissioned was dominantly epidemiological. It aimed at clarifying whether children in the neighbourhood near the incinerator incurred increased measurable risks (understood as 'probability') of getting pollution-related diseases, including congenital defects. The strategy, approach and methodology had been extensively discussed between researchers and technical experts from the administration and the Minister's cabinet.

Seeing the particularly pressing socio-political context and the sensitivity of the issue, the researchers preferred to use only already registered data in existing databases and not to start a new survey or collection of new data in the neighbourhood.

The choice of the study's end points was based on the availability of six relevant databases and a model of environmental health risks. This model took account of possible direct toxic influence as well as teratogenic and genetic effects. It was also assumed that the toxic effect could include physical problems as well as a delay in intellectual development.

The end points included indicators for which statistically significant differences between the exposed and a control group could point to problems of fertility (e.g. number of multiple births, ...), health problems of newborn babies (e.g.

malformations, ...) and medical and cognitive problems among children. The registrations used were data – collected in maternity hospitals – on newborn children. The data about children born from parents who, before the birth, had lived in the neighbourhood during the period of the incinerator's operation, were compared with those of a control group. Additionally, clinical exam data of schoolchildren from the polluted area were compared with those of a presumed non-polluted (at least not by waste incinerators) control area. Finally, data were analysed to check whether exposed children had any psychological and intellectual retardation. For reasons of privacy and since all these registrations had been made for reasons other than for examining the precise research question, some operations were necessary to produce the relevant data (e.g. record linking between several databases, ...). The data analysis was done according to well established statistical methods, including multiple testing for correction for possibly confounding variables.

Even before results had been communicated, the study's approach had already been publicly criticised: 22 Belgian and Dutch scientists wrote a letter to the Minister dismissing the validity of this kind of research. They argued that only a longer term and larger scale research programme could lead to relevant insights.

The study remarkably concluded that there was no statistically significant increase in congenital defects for children born from mothers who lived in the particular neighbourhood compared to the Flemish region. Such an increase could, however, not be completely excluded as the study lacked 'statistical power'. A more detailed 'power analysis' showed that it could reasonably be excluded that the number of congenital defects in the neighbourhood was more than twice the average number for Flanders. The study even found a statistically significant negative correlation between congenital defects and the length of mother's or father's stay in the neighbourhood!

Both of these remarkable conclusions supported the point of view of proponents of the incinerator. However, another result showed that mothers from the neighbourhood had statistically significant more multiple births. For the opponents of the incinerator, this pointed to a local fertility problem, as these multiple births could possibly be linked to medically assisted conceptions. Other fertility indicators displayed no statistically significant differences. In the workshop we limited the discussions to aspects of the study related to the perinatal indicators.

### *4.3 The pedigree scheme: phases and modes*

Through analysis of the study reports and interviews with their authors, the main phases to be covered in the pedigree assessment were devised. As in the first pedigree schemes published (Funtowicz and Ravetz, 1990) the choice of these phases reflects the complementarity between more cognitive and more social aspects in knowledge production for policy.

A phase related to problem framing was explicitly added. In this way, a discussion was triggered on the 'status' of the used problem definition in relation to other disciplinary framings and socio-political perspectives and on the 'process' through which the expert framing and other socio-political framings had (not) been matched. The discussion of this phase also had to include more generic insights and underlying convictions. It turned out that during the discussions on the other phases the participants often referred to the frame-dependency of certain choices, thus confirming the crucial importance of problem framing in relation to uncertainty. This proved somehow that in the still emerging environmental health science, ignorance and indeterminacy are the predominant forms of uncertainty, largely outweighing in importance methodological and technical aspects.

The other phases had already been used in earlier applications of the pedigree scheme. 'Data-definitions' relates to all those decisions, logically prior to actual enumeration, concerning the establishment of the relevant conceptual objects and the set of operating procedures. It deals with the question of how what has to be enumerated is defined and how the method of counting is determined.

'Data collection' deals mostly with the more technical aspect of quality of databases in relation to what has to be enumerated. Quality has also to be seen as influenced by the culture of the institute charged with the data collection. 'Analysis' highlights the reliability of the chosen method of analysis for the particular approach to the problem. It focuses on the scientific discussion about the choice of methods and on possible 'extra-scientific' reasons for preference of certain methods. 'Review' is related to the process of quality control of the research with particular attention to its interactions with the socio-political context in which the research took place.

The modes referred to how the process dealing with that phase was run. A higher ranked mode had to be interpreted as a better chance to increase the quality of the study along three dimensions that were deemed essential to achieve 'results fit for function' ('a serviceable truth'):

- scientific robustness, in a perspective of constructive knowledge development
- practical functioning of the science-policy interface to create a social basis for the policy measures and their knowledge base
- normative considerations on a legitimate knowledge support, i.e. taking account of plural perspectives and rendering agency to all actors involved.

The hierarchical ranking of the modes was sometimes the subject of discussion, which was not a surprise as 'quality' is a generic concept (on which all agree), whose dimensions and concrete meaning (on which there is no a priori consensus) as a standard in a particular context can only be filled in through deliberation.

By way of example the modes for 'problem framing' displayed three ways to handle clear controversy on it:

- 'Controversy' mode, score 0: there are opposing views on the approach and definition of the problem but it is ignored or deemed impossible to conduct negotiations to reconcile them. This controversy lives in society and works through in the policy and scientific approach.
- 'Compromise' mode, score 2: some two way communication is organised, although no real deliberation; the resulting framing was a result of bargaining leading to a compromise; no innovative framing was agreed upon and a simple mix was made of ingredients from each of the opposing framings; the discussion was closed without any actor being really satisfied with it; it is highly likely that the discussion on the framing will be reopened.
- 'Negotiation' mode, score 4: a deliberative process involving experts, policy makers and interested actors led to a framing which is congruent with the different perspectives.

In addition, the scheme foresaw in modes to deal with situations where a controversy was nonexistent or at least not evident:

- 'Inertia' mode, score 1: one of the actors determined the problem framing; it was not questioned further and it was not investigated as to whether there were diverging opinions because it was not evident that there would be.
- 'Scientific' mode, score 3: deliberation was not really seen as necessary as there was no obvious conflict; the framing used was robustly based with reference to the scientific disciplines, the policy process and a social map of actors.

### *4.4 The discussion protocol*

To organise the panel discussions in a way consistent with the intended goals of the workshop, the discussions were shaped as a reasoned, structured debate focusing on underlying assumptions and frame-dependent choices in the different studies. In each session, a discussion leader had to ensure that not only technical features of uncertainty would be covered. The choice of issues to be addressed, the type of questions to be used, as well as the composition of each discussion panel, all served to highlight and support the essentially discursive character of knowledge development and management of uncertainty. Figure 1 synthesises the protocol followed in the three sessions.

The panel had to assess the 'study as a whole' which made it impossible to display exhaustively and on a detailed level all the types of uncertainty involved. Following the protocol, two illustrative critical aspects were presented for each of the phases. These related to choices that had been made in the framing and the design of the study, and had subsequently been criticised by other experts and relevant actors (e.g. under the phase 'data definitions': 'how to define the exposed population?'). Also included were other aspects that had not been openly debated in the past but could have led to a more reflexive knowledge development had they been approached with openness (e.g. under the phase 'data definition': 'who is competent to define a congenital defect? A family doctor, a paediatrician, a parent, a professor in epidemiology, an operator of a database, the Ministry of Health,. . .?').

The protocol planned for two experts – the author of the relevant study and an 'opponent' or 'critical judge' – to introduce each topic, and then to explicitly extend the discussion to the views and reactions of the stakeholders, citizens and policy makers in the panel. The session leader and another social scientist, specifically trained in deliberative procedures and/or uncertainty assessment, had to guarantee that an informed and fair debate took place. To this end, the session leader presented some guidelines (included in the protocol). He also had at his disposal a catalogue of possible questions in order to (re)focus the discussion if necessary. These model questions were based on insights on the structure of arguments (Toulmin, 1958; van de Graaf and Hoppe, 2000), the content of actors' frames of meaning (Grin et al., 1997) and the different types of scientific debate and controversy when uncertainty is salient (von Schomberg, 1997).

**Figure 1** Synthesis of the protocol followed in the three sessions

- General introduction by the session leader, explaining the goals of the assessment and the guidelines for discussion.
- Short presentation of the study to be assessed by one of the authors.
- For each of the pedigree phases :

  Introduction to the phase and the critical aspects to be discussed by the session leader.

  Opening remarks by the author of the study on the critical aspects.

  Reply and comments by the scientist-'opponent'.

  Contribution to the discussion by all participants in the session.

  The session leader summarises the key points to discuss and uses cycles of why? questions. Assures conditions of reasoned and structured debate.

  Clarifications and debate on key points to discuss by all participants.

  Round up of discussion and introduction to the different possible scores for that phase by the session leader.

  Each participant gives a score and comments it.

  Discussion on the scoring and possibly achieving consensus.

- Final assessment : review of the complete score and possibility for final remarks by all participants.

They were intended to make the process more reflexive, both in terms of content, i.e. opening up the problem definition and the scope of argumentation, and in terms of process, i.e. placing the participants in new roles and rules of interaction. In this particular setting, the traditional and often institutionalised division between the scientist as a provider of facts versus policymakers and the public as defenders of values was challenged.

By using the set questions, the validity of assumptions had to be discussed as they could point to particular framings of the risk. They were intended to deliver insight into the deeper debate on plausible hypotheses, distinguishing it from the more factual discussions on the empirical basis and the methodological work. Included were cycles of typical why?-questions, e.g. 'What is the right (research) approach to this problem? … Why is this the adequate approach (asks for the definition of the (research) problem)? … Why do you define the (research) problem in this way (asks for underlying and supporting "theories")? … Why do you use these theories in this case (asks for the fundamental features of framing, the preferences and convictions)?'

The discussion of each phase in the pedigree scheme was concluded by giving a score reflecting which mode best described how the study 'performed' for this particular phase. The scoring itself was a collective exercise of negotiation which enabled the main points of discussion for each phase to be summarised, to explain why different participants suggested different scores and to clarify any ambiguity in the descriptions and labels of the modes.

Although a few participants expressed a feeling that the points (to be) discussed had somehow been forced within a matrix scheme, the majority appreciated the scheme's visual attractiveness. Alternatively, a well structured checklist, inspired by the 'pedigree' concept, could support the same objectives but it could be feared that it would not have the same self explanatory power in presentation and communication.

### *4.5 A low pedigree score reflecting low quality as 'fit for function'*

In the session dealing with the epidemiological study, it was concluded that the score (1–2, 1–2, 2, 2–3, 0) represented well the study's pedigree. The notation *n–m* signifies that no consensus was achieved on the scoring (some of the participants maintained a score *n* while others preferred score *m*).

The low score given to the epidemiological study was consistent with its failure to deliver robust insights and to play a relevant role in the policy debate at the time its results were communicated. In short, it was consistent with its quality for use in the socio-political context.

### *4.6 Themes discussed through the pedigree assessment*

#### *4.6.1 Incongruity of epidemiological and socio-political framings*

Whereas the problem definition used in the epidemiological study and the main components of the research design (choice of data sources, methods of data collection) had been intensively discussed between the research team, the administration's experts and the cabinet of the Minister of Public Health, the resulting framing of the issue failed to address the concerns of the local population and was quite meaningless from the perspective of the incinerator's management. The reactions on this framing ranged from 'an inadequate use of epidemiology' to 'a complete irrelevance of the epidemiological approach'.

In fact, the problem definition addressed in the epidemiological study implicitly called into question the existence of the cluster of congenital diseases in the neighbourhood by statistically testing whether these diseases' incidence in the area was significantly higher compared to the whole Flemish region.

For some critical experts and the citizens' committee, whose members included the more than 20 parents of children with serious diseases, this numerical fix to detect a 'real cluster' was an absurdity. They argued that the definition of a 'level of significance' is value laden. The incinerator's management stated that the study's framing already implicitly accused them if public health problems were detected, although there were numerous other sources of pollution in the area. The researchers claimed that they only investigated health problems and no causal chains, but the definition of exposed population coincided with the inhabitants of the area on which the dioxin 'cloud' from the incinerator came down according to emission model calculations and soil sample measurements. The management argued that a more global approach to the health problem would be more relevant.

### *4.6.2 Adequate use of epidemiology? Disciplinary fix and intra-disciplinary controversy*

Opponents of the study (including epidemiologists) argued that a more correct and relevant use of epidemiology would have been to test some hypotheses regarding the relationship between these diseases and possible causing factors (as would probably have been done if the discussion was not narrowly focused on closing the incinerator or keeping it open).

To them, it is more appropriate to use epidemiological statistics to make some statements about a population on the basis of the analysis of a sample and less to test the hypothesis of whether two populations are really different. In the latter case, the power of such studies is so low that the only conclusions you can make with high reliability are irrelevant. They questioned the relevance of conclusions like 'with a 90% probability we can say that no immediate public health disaster is taking place in that area'. They also argued that the study neglected other disciplines, such as pathology, possibly providing deeper insight.

### *4.6.3 A scientific and/or a political problem?*

Environmental groups, as well as the incinerator's management, considered the scientific reduction of the problem as a strategy to avoid a more far-reaching discussion on the issue, which could have more political consequences. Environmentalists thought that the study's approach was an attempt to deny the cluster's existence in order to avoid the drastic measure of closing the incinerator. The management claimed that the problem had to do a lot with spatial planning ('why do we have a policy admitting incinerator plants just besides a residential area?') and waste policy in general.

Both were very sceptical as to whether research can contribute anything relevant to deal with this kind of risk. Their scepticism even increased when several scientists said that the quality of the databases that are used in this kind of study was, in general, rather poor.

However, whether the uncertainty related to the use of databases was estimated as more or less crucial for the relevance of the obtained results, also depended on the framing of the problem which the study (had to) start(s) from, thus on the answers and insights the study was supposed to deliver. A researcher and policy maker involved in the study acknowledged that they had been aware that 'a perfect scientific investigation of the problem' was not achievable. However they still strongly believed that doing the study was essential to better map the public health features of the problem, in particular 'to see clear in the proportions of this problem'. Even if they agreed that it was, essentially, a political problem, this did not mean that – even 'imperfect' – scientific information could not contribute to better insight into the problem. They were confident that the scientific research on this kind of issues progressed step by step and was leading to ever better understanding. They still agreed with the study's conclusions, while admitting that on the communication side it had serious flaws.

### *4.6.4 The 'political sensitivity' of research methods*

The choice of method of analysis scored better in the discussion. It was agreed that for the chosen problem definition, the method was valid and had been accurately applied. The obtained results in terms of 'technical uncertainty' had been well presented. However, some argued that the chosen approach of multiple testing favoured 'false negative' outcomes, which made the choice of method intrinsically value laden.

### *4.6.5 The issue of agency. Who assures quality and how?*

At the time, the commissioners and researchers of the study had seen the actors involved mainly as a disturbing factor for a reasoned approach to the problem. The issue was so controversial then that they considered it impossible to involve them in the setting up and development of the research. This, however, led to the researchers making assumptions 'at the place of the concerned, the affected and the local experts', which was contested by all sides.

The fundamental mismatch between the framing of the study and socio-political views on the problem influenced the debate on the 'data' phases of the pedigree, namely on the choice of the study's end points and on the definition of data entries. The definition of 'congenital diseases' and of 'the exposed area or population' vs 'the control population' seemed to lead to fundamental uncertainty. Although it can be argued whether this uncertainty created a bias in the outcomes of the result, the more relevant question it brought to the surface was: who had the information and the experience to decide on these definitions?

Only data from birth clinics were used to count the congenital diseases, but parents had seen that symptoms of some of these diseases only appeared several months after the birth. These congenital defects were not recorded in the perinatal data base.

The use of emission models and soil measurements to define the exposure area was disputable as their results are very uncertain. They also reflect a static view on exposure, whereas exposure ideally had to be conceived more dynamically e.g. the place where people went to work, school, child nursery, etc., were equally as important for exposure as the place of residence. Local residents thought that using a school population as a control group is particularly difficult as some schools recruit pupils in areas of ten square kilometres and more. The members of such a control group can be subject to very different sources of pollution and different levels of exposure.

Confronted by the discussion on the quality of databases, their privileged status compared to data collections by non-recognised research teams or institutes (e.g. through 'popular epidemiology' initiatives) was questioned. However, all such 'local knowledge' had not been considered usable in the standardised research procedures.

Finally, as none of the participants in the session was informed about a review carried out on the study, a zero score was given for the review phase. Participants in other sessions afterwards commented that an informal review by colleagues had been undertaken, which, if it had been known during the session discussion, would probably have softened the verdict on that phase.

## 5 Conclusion: the potential of pedigree-based tools for deliberative risk governance

We implemented and tested a reflexive approach, based on the concept of 'pedigree of knowledge', to interactively explore uncertainty in environment and health risk studies in relation to different scientific framings, societal perspectives and policy options. In a workshop session with scientists, policy makers and stakeholders, an *expost* pedigree assessment of a controversial epidemiological study about the link between an incinerator's emissions and an observed cluster of diseases in the neighbourhood was carried out. The workshop confirmed the centrality of the issue of framing in this kind of environmental health risk assessment. Participants took more time to discuss the framing than any other phase. The non-scientists also felt that their contribution was most relevant with respect to framing and felt less need to intervene in the more technical phases dealing with the choices of data sources and of methods. However, they remained very interested and followed with attention the expert discussions on these issues. Similar workshop sessions addressing, respectively, an exposure study and a biomonitoring study showed the same pattern of engagement.

To some participants the workshop was a real eye opener: it raised awareness about the complexity of the issues studied, the inseparability of facts and problem frames by which these facts are conditioned, and the resulting inherent uncertainty in terms of indeterminacy, value loadings, and ignorance. Furthermore, the workshop clearly confirmed our hypothesis that non-scientists can make a valuable contribution to the critical appraisal of policy-relevant knowledge. This conclusion was shared by the scientists who had participated in the workshop. As participants got more and more convinced that in this kind of study few of the choices and assumptions were straightforward, meaning that they could be based exclusively on objective and factual information and insights undisputed among scientists, questions were raised about who is competent and 'entitled' to make the necessary choices.

In this sense, the workshop made openings that could lead to an enhanced reflexivity and collective learning. It showed the potential of the pedigree assessment to foster a deeper social debate and a negotiated management of environmental health risks than the mainstream technical approaches to uncertainty assessment are capable of.

Although the analysis here was done *expost*, many participants suggested the approach could be applied in a proactive and constructive way, that is before or during the phase in which policy supporting research is being developed.

Some participants argued that the method was still too science-centred, thereby limiting and sometimes devaluing the contributions by citizens and other lay knowledge providers. This point of criticism was perhaps based on a misjudgement of the tool's objectives as 'the one and only way to involve stakeholders and citizens in risk policy processes'.

In the workshop experiment, pedigree assessment served a double goal: bridging the scientific knowledge development with the different framings of the problem and repositioning the expertise in the policymaking process. Ideally, interactive pedigree assessment should be part of a broader process of deliberative risk governance, where due discussion platforms are foreseen to let actors express their risk experience and their relevant knowledge in their own language, often in a more anecdotal style. Interactive pedigree assessment will even gain in relevance if more efforts are made to increase insight into plural risk framings by letting actors express their views on solutions, own knowledge, convictions and beliefs in settings like focus groups. In the same way, in the kind of pedigree assessment we did, it is somehow presupposed that a state-of-the art synthesis of the relevant science had already been made.

This reveals that the need addressed by the interactive pedigree assessment is not, in the first place, the provision of a forum for participation, nor a scientific review to evaluate evidence. It is intended to broaden the scope of problem frames considered and to remedy the current lack of transparent interaction at the interface between science, policy and society.

Socio-political analyses of the functioning of our democratic institutions (von Schomberg, 1995) point to the necessity of providing stronger negotiation and deliberation opportunities between the spheres of policy, science and the public/civil society.

Traditional social theory conceived these spheres and systems as autonomous and mutually independent. Science could develop truth claims without interference from the other spheres. The other spheres authorised science's autonomous expert culture to produce, select and evaluate such claims.

This legitimacy was, however, implicitly based on mutual functional relations, which can no longer be maintained in view of the prevalence of controversies on many complex contemporary environmental health risks. The deep uncertainty involved in such complex issues renders impossible the differentiated, even separate, functioning of these spheres. Their strict autonomy even becomes a barrier for the proper functioning of democratic societies.

Whereas science was formerly considered to deliver to the policy sphere data on which there was a consensus, this is now rendered impossible because of persisting different opinions between disciplines. As science is under pressure to still give an authoritative factual basis to deal with complex problems, it is transformed into the opposite of its original and becomes a strategic resource in debates and conflicts.

Empirical studies showed that the successful functioning of scientific advice needs a lot of *boundary work* between the spheres, although this is mostly not publicly recognised nor communicated (Shackley and Wynne, 1996).

These analyses support the development of processes to integrate the validity claims of scientists, policy makers and the public. Although each of these spheres can discuss environmental health risk issues internally in their own discourses and framings, they can no longer independently and autonomously close these discussions, producing claims which are quasi-automatically recognised by the other spheres.

Settings for the expression of stakeholders' concerns on the one hand and for the delivery of expert views on the other, have to be complemented by processes of direct negotiation and deliberation to assess the various validity claims. Our experiment supports the potential of pedigree-based tools in this respect.

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## Note

[1] The views expressed in this article are those of the authors and do not represent necessarily those of the European Commission.