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**Uncertainty: cause or effect of stakeholders' debates?
Analysis of a case study: the risk for honey bees of the insecticide Gaucho®**

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Abstract:

The social construction of uncertainty plays a major role in environmental decision-making. Methods for assessing this aspect of scientific knowledge quality are lacking. Our analysis of the French debate on the risk that the insecticide Gaucho® (active substance: imidacloprid) forms for honeybees is particularly relevant to this theoretical and practical gap. Based on our analysis, we propose six knowledge-quality criteria that can assist in assessing the information communicated in a publicly argumentative process: reliability of the information – it must be based on all available scientific knowledge ; robustness of the information – it must take into account criticism; use of the information produced by other stakeholders; relevancy of the arguments for the issue under debate; logical coherence of the discourse; and legitimacy of the information source. Further, our findings deepen the understanding of the relationships between the social, economic, and institutional stakes of the parties involved in the debate and their strategies of “creating uncertainty”. Finally, we compare the findings of this case study with the twelve lessons drafted by the European Environmental Agency (EEA) in its report “Late lessons from early warnings”. These lessons can be applied to future policy in order to minimize the repetition of past mistakes and to draft further lessons.

Key words: uncertainty, risk assessment, pesticide, Gaucho®, imidacloprid, precaution

Introduction

The attention that scientific risk evidence receives from decision-makers strongly depends on the economic and social context in which the risk is identified (EEA, 2001). When the outcome of risk assessment involves high economic and social stakes for the actors concerned, the figures become tools for establishing the power balance in the political arena. A further complication today is that more and more parties (industry, academia, NGOs, interest groups, non-scientific experts, investigative journalism, etc.) are producing information relevant to risk decision-making. This makes it increasingly problematic to talk about ‘science’ (in general) and see its role as telling ‘power’ (decision-makers) ‘the truth’ (the objective facts) (Wildavsky, 1979). In order to clarify the status of the evidence, inside the scientific community and in the society, we use the concept of uncertainty. Uncertainty has multiple dimensions: technical (inexactness), methodological (unreliability), and epistemological (ignorance and societal (un)robustness) (Funtowicz and Ravetz, 1990). No terminology or typology of uncertainties is generic or agreed (Walker et al., 2003, van der Sluijs, 2006). In the present paper, the concept is understood in a broad sense. It refers to the phenomenon that the body of evidence from the scientific research is (perceived to be) inconclusive, regarding the magnitude and nature of adverse effects, the causal mechanisms and the probability of a risk which is subject to a societal controversy. Methods have been already developed for assessing quantifiable dimensions of the uncertainty (i.e. Monte Carlo analysis). However, methods for assessing qualitative aspects (such as the value loading of the research process) are still in the early stages of development (Van der Sluijs, 1997, 2006).

The rationale of the present paper is that, in a situation of controversy and uncertainty about risk, the role of science can be strengthened by systematic critical reflection on both the scientific quality of risk evidence and the argumentative quality of the discourse which is intended to inform decision-makers. These two levels of quality are elaborated in the methods section of this paper. The aim of the paper is to contribute to the development of tools for Knowledge Quality Assessment (henceforth KQA). These tools are essential for precautionary risk management in order to achieve a timely and adequate policy response to early warnings of severe new risks (UNESCO, 2005; Van der Sluijs, 2007). In the same line, the European Environmental Agency (EEA) drafted twelve lessons on precautionary risk management, based on fourteen historic case studies (EEA, 2001).

The dominant belief that inappropriate control of environmental risks is due only to insufficient scientific knowledge ignores the influence of political and societal contexts on risk management (Wynne, 1992). Stakeholders can strategically use science in public debates (for example, through selection of information sources according to one political agenda) and increase or distort scientific uncertainties (Hellström, 1996; van der Sluijs, 2006). Moreover, the existence of contradictory expertise can be the result of a ‘manufactured uncertainty’, which is intended to favor the settling down and prolongation of the debate. This strategy can obstruct or delay decision-making and maintain an economic situation advantageous for certain stakeholders (Michaels, 2005). To explore the phenomenon of the social construction of uncertainty and its role in discourses on risk management, this paper presents an in-depth analysis of the roles scientific evidence and social, economic, and institutional stakes have played in the vehement controversy in France over the past decade on the risks that Gaucho[®], a systemic insecticide, forms for honeybees. What makes this case particularly interesting for the history of risk management is that it covered, the first time, a precautionary principle that was applied in an environmental issue in France.

Systemic insecticides like Gaucho[®] (active substance: imidacloprid) comprise a new type of plant protection product. They are employed in seed-dressing and/or soil treatment and disperse to all plant tissues during growth. This dispersal offers long-lasting protection to crops like sunflower and maize from pests including sucking insects and harmful soil insects (Elbert et al., 1991). It can, however, expose non-target insects like honeybees to the active substance through contaminated pollen and nectar. Moreover, the exposure of honeybees to imidacloprid is possible for long periods, especially during flowering (e.g., several weeks for sunflower and maize). The effects of the repeated consumption of contaminated pollen and nectar can appear either immediately or after several days or weeks (delayed effects), i.e., after they have first been stored inside the hive as pollen or honey. In this respect, systemic insecticides differ from the ‘classic’ sprayed insecticides, which are present on the plant for a shorter period (several hours or days after spraying). Evidence of the risk caused by imidacloprid emerged when the substance’s effects on honeybees were first studied in independent research (institutes and universities, funded by public money) in the late 1990s (for a compilation of results available at different points in time, see Scientific and Technical Committee for the Multifactor Study of the Honeybee Apiaries Decline, henceforth SCT, 2003). Political measures, however, were not taken until a long and vehement social debate enforced policy intervention. This debate involved beekeepers, Bayer (the company that produces Gaucho[®]), researchers, the French Ministry of Agriculture, farmers, and the civil society. This debate started in 1994 when beekeepers noticed symptoms that they had not previously observed: in several days of sunflower foraging, honeybee populations were suddenly and massively falling. The honeybees almost completely disappeared far from the hives or they were dying by the thousands in front of the hives. These mortalities were accompanied by behavioral symptoms specific for intoxication and by a 40–70% loss in sunflower honey yield (Abeilles/tournesol, 1997, 1998; GVA, 2006; Chambre d’Agriculture des Deux Sèvres, 2000; AFSSA, 2002; Alétru, 2003). Since Gaucho[®] was used for the first time in the treatment of sunflowers in 1994 and the symptoms were recorded for bees foraging Gaucho-treated crops, the beekeepers suspected a toxic effect of this product on honeybees. Consequently, they asked Bayer to inform them about the potential toxicity of the active substance for honeybees. This was the start of a long series of scientific studies involving experts from Bayer, the Ministry of Agriculture, beekeepers, and independent researchers. Some of the studies yielded arguments supporting and others refuting the causal link between seed-dressing with Gaucho[®] and the symptoms

observed in honeybees. Still, other studies reported ambiguous findings. The symptoms continued to be observed after 1994. Their regularity over the years, their specificity for bees foraging on sunflowers, and the geographical extent clearly differentiated them from symptoms observed before 1994 during accidental intoxications with sprayed pesticides. All of the studies undertaken by Bayer during this period reported that Gaucho® did not form a risk for honeybees.

This environmental problem quickly revealed social and economic dimensions: the sunflower honey harvest fell significantly and the economic status of many beekeepers was severely affected.

The combination of the research findings obtained by independent research (1998), social pressure, and media attention led to the first application of the precautionary principle for an environmental issue in France. In January 1999, the Minister of Agriculture ordered a 2-year ban on the use of Gaucho® in sunflower seed dressing. This ban was renewed in 2001 for 2 years and again in 2004 for 3 years. Bayer continued to state that the use of Gaucho® as a sunflower seed-dressing had no effect on honeybees (GVA, 2006; Parlement Wallon, 2004; Bayer Cropscience, 2006). The beekeepers and most of the media have accused Bayer of “threats (...) and attempt of corruption” (Libération, 9 October 2000), of dishonesty (“Bayer attempted to cheat by presenting results that are not conform to the ones in the original reports a number of times to the Commission for Toxic Products¹” (GVA, 2006)), and of reaping a profit at the cost of both the environment and public health. During that period, the Minister of Ecology and the civil society supported the beekeepers’ arguments. The intoxication symptoms continued to be observed after the 1999 suspension of the use of Gaucho® in sunflowers. Two hypotheses were raised to explain this situation: (1) honeybees were still being exposed to the pollen of maize treated with Gaucho® and (2) imidacloprid persisted in the soils, i.e., the chemical was present in untreated crops growing in soil on which a seed-dressed crop had been grown one or several years earlier. In 2001, an interdisciplinary expert group, the Scientific and Technical Committee (SCT), was set up by the Ministry of Agriculture. Its objective was to assess the cause of the continuing decline in the number of honeybees. Evidence confirming the risk that imidacloprid formed for honeybees accumulated from independent research in the years that followed. However, in 2003, the Minister of Agriculture decided not to ban the use of Gaucho® in maize seed-dressing. (Note: maize is one of the most economically important crops in France. Moreover, seed-dressing with Gaucho® significantly reduces the amount of work needed to protect the crop from insect pests, which makes the insecticide interesting to farmers.) Later that same year, the final report of the expert committee was published (SCT, 2003). It concluded that the risk imidacloprid formed for honeybees is worrisome, when Gaucho® is used to seed-dress sunflower and maize. Nevertheless, it was not until May 2004 that the Minister of Agriculture also banned the use of Gaucho® in maize seed-dressing. As an indication of the severity of the risk, the most recent risk assessment for honeybees collecting pollen from maize seed-dressed with imidacloprid, expressed as the ratio PEC/PNEC² ranged between 500 and 600 (Bonmatin et al., 2005). Note that a ratio PEC/PNEC ≥ 1 is already equivalent to a risk (in this case, for honeybees).

Immediately after the Minister of Agriculture banned the use of Gaucho® on sunflower seeds, Bayer challenged the ministerial decision in the administrative court of Paris (March 1999). The case was passed onto the State Council (the highest administrative jurisdiction institution in France). About that time, several international consortia of seed producers (Monsanto, Novartis, Rhône-Poulenc, Pioneer, Maisadour, Limagrain) joined Bayer and formulated a similar case against the Minister’s decision. The beekeepers, organized into the UNAF³ defended the Minister’s decision in court. The State Council decided in favor of the beekeepers. Several other institutions were also called upon later to resolve the conflict: the Commission for the Access to Administrative Documents and courts all over France (where Bayer brought suit against several representatives of beekeepers’ syndicates for discrediting Gaucho®). The social tensions that accumulated during this ca. ten-year conflict are still present for two reasons. First, the position of Bayer has remained largely unchanged: “... it is clear that seed-dressing products based on imidacloprid pose, at most, a very weak risk for honeybees” (Bayer Cropscience, 2006). Second,

¹ The ‘Commission d’étude de la toxicité des produits antiparasitaires à usage agricole et des produits assimilés, des matières fertilisantes et des supports de culture’ is a body working with the Ministry of Agriculture, usually abbreviated ‘Commission for Toxic Products’ or ‘ComTox’, that is composed of experts in toxicology and eco-toxicology. This body is in charge of the entire range of pesticide products. ComTox is charged with analyzing the authorization dossier from toxicological and eco-toxicological points of view.

² Predicted Environmental Concentration/Predicted No Effect Concentration.

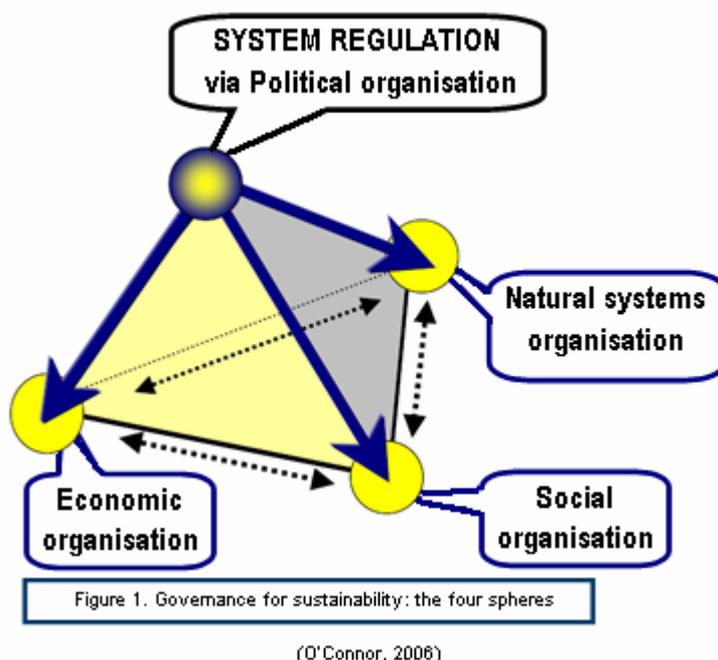
³ UNAF (Union Nationale de l’Apiculture Française) is one of the three of French beekeeping syndicates, representing about 22000 beekeepers.

imidacloprid is currently under evaluation by the EFSA (European Food Safety Authority) for inclusion on the list of active substances which may be marketed in the European Union.

Structure and methodology

In a social framework of scientific uncertainty and contradictory expertise, political choices are partly the result of the power balance. The “winning discourse” has a major role in determining how the impacts are defined, how the causes are established and which are the solutions implemented through political measures (Faucheux et Noël, 1990). The present case study evidences that, even when the scientific uncertainty reaches a low level, stakeholders seek to influence the interpretation of scientific evidence and through that political decision-making, according to their interests. This allows us to identify a type of uncertainty linked to stakeholders play. For its analysis, the distinction between two types of uncertainty is made in this paper:

1. Scientific uncertainty, which may have both a quantitative (imprecision) and a qualitative (limitations of methods or incomplete state of knowledge) dimension.
2. Social uncertainty, which is determined by the quality of the expertise (directly related to competence, institutional dimensions such as the institutional affiliation, financial dependencies, and expert responsibility) and by the stakeholders’ discursive strategies in selective use, framing, and interpretation of scientific evidence within the societal debate.



The present study is structured on two sections. In the first one, the debated scientific “objects” are identified. They were subject of advancement of the research during the events and were questioned by contradictory discourses: research hypothesis and methodology, exposure, effect dose, the properties of the substance and the effects on other components of the environment than honey bees.

For each of these “objects”, two axes of analysis are developed:

- The accumulation of scientific knowledge during the time;
- The comparative assessment of the significance that each scientific “object” takes for different stakeholders (beekeepers, Bayer, state bodies and public research) in the social debate.

In this first section, discourse analysis is used for evidencing the mechanisms underlying the social uncertainty and their influence on decision-making. For this purpose, a comparative evaluation of stakeholders’ statements is made against the following criteria: reliability of the information – it must be based on all available scientific knowledge; robustness of the information – it must take into account

criticism; use of the information produced by other stakeholders; relevancy of the arguments for the issue under debate; logical coherence of the discourse (lack of internal contradiction, of circularity of the arguments, etc.); and legitimacy of the information source (the competency and the institutional affiliation of the expert that produced it, the status of the journal that published it, etc.).

In the second section, the economic, social and environmental stakes underlying stakeholders' discourses are evidenced, in a structured way. For this purpose, the conceptual framework of the "tetrahedron of the four spheres of sustainability" (O'Connor, 2006) (Figure 1) is used. This tool, built for the analysis of sustainability issues, is based on a systemic approach which highlights the interdependency between economic, social and environmental dimensions. The economic sphere, often the principal focus of development policy discourses and indicators, depends for its viability on the vitality of the social and environmental spheres and, in the same time, affects them. The governance for sustainability targets the regulation of the relationships between the economic sphere and the other two ones. Interested in the process of construction of the political decision in a framework of contradictory discourses, our analysis establishes the sphere of governance as reference, space of debate where arguments related to the environmental, social and economic are confronting. The analysis of each of these three dimensions with the political one is therefore carried out.

Section three discusses the results of the analysis and suggests conclusions.

Section 1. How was scientific evidence of risk reflected in the stakeholders' discourses?

We clustered our findings into five groups: research hypothesis and the methods employed; honeybee exposure to imidacloprid; the lowest effect concentration; properties of imidacloprid: persistency in soils and presence in untreated crops; and impacts on non-target organisms and on the environment. They are discussed below.

1.1. Research hypothesis and methods employed

The regulatory procedure to assess the risk that sprayed ('classic') pesticides form for honeybees is based on acute toxicity (LD50)⁴. This value is then used to calculate a hazard quotient (HQ) (Rortais et al., 2005). The authorization dossier needed for marketing imidacloprid also contained only this indicator. This methodology for risk assessment, based on the idea of dose (of pesticide) per hectare, is not, however, appropriate in the case of systemic insecticides (GVA, 2006; Arnold, in AFSSA, 2002; SCT, 2003; Rortais et al., 2005; Halm et al., 2006), because it cannot account for many elements of toxicity that are highly important in the case of honeybees: chronic toxicity (Suchail et al., 2003), sublethal effects, and effects on the whole colony. If the risk assessment procedure commonly employed for pesticides is used, it is possible that new products will be falsely declared environmentally sound. The procedure of risk assessment chosen by the SCT for imidacloprid was based on the evaluation of the ratio PEC/PNEC (SCT, 2003). Because French authorization procedures did not use new research insights, this discrepancy between regulatory demands and scientific understanding still exists. Other hypotheses which are valid for sprayed pesticides but not for this new type of insecticide, have been equally questioned: the dose-effect relationship (Narbonne, in AFSSA, 2002; Suchail et al., 2003); the measure of honeybee intoxication by counting the numbers of dead honeybees in front of the hives (GVA, 2006); and the use of the employment dose to measure the effects of systemic insecticides (GVA, 2006).

1.2. Honey bees' exposure to imidacloprid

[1994]

Bayer claimed that imidacloprid applied on seeds cannot be present in flowers, because it disappears before the treated plants flower (GVA, 2006; AFSSA, 2002). The consistent association between the use of Gaucho® in treating sunflowers and the appearance of intoxication symptoms during sunflower

⁴ Lethal Dose 50: the dose that causes the death of 50% of the exposed individuals.

foraging, however, led beekeepers to suspect the presence of the substance in those parts of the plant utilized by honeybees. Based just on Bayer's dossier, the Commission for Toxic Products did not take into consideration all of the potential effects on honeybees before they granted marketing authorization.

[1995–1997]

All of Bayer's studies concluded that Gaucho® used in sunflower seed-dressing is harmless for honeybees (GVA, 2006; Curé in AFSSA, 2002). However, the significant lack of quality in Bayer's studies was repeatedly demonstrated by independent scientists. Beekeepers and local/departamental state services also carried out field studies and showed the occurrence of symptoms in areas of extended monocultures seed dressed with Gaucho® and the absence of other potential causes (Direction des Services Vétérinaires de la Vendée, le 29 septembre 1997; Chambre d'Agriculture de la Vendée, FDSEA de la Vendée, FDSEA des Deux Sèvres, 1999). The conclusion of the Commission for Toxic Products (11 December 1997), based on its first expertise report (Belzunces and Tasei, 1997), was ambiguous. Given the information available, the Commission said that it is not possible to conclude whether or not a causal link exists between the use of Gaucho® and the decline of honey yield found in certain regions.

[1998–1999]

The studies undertaken by Bayer during this period either could not detect imidacloprid or detected it, but could not quantify it (GVA, 2006; SCT, 2003). One exception was a laboratory study that quantified the substance in sunflowers treated with Gaucho® to be 3.3 ppb in pollen and 1.9 ppb in nectar (Stork, 1999, in GVA, 2006; SCT, 2003). According to Bayer, the results of field experiments would either prove or disprove the risk of an active substance, even if they did not confirm the results obtained in laboratory studies. The State Council, however, decided that the risk can be assessed if it is based on the results of both field experiments and laboratory studies. Reviews of Bayer's studies, conducted by independent scientists (honeybee specialists) showed major deficiencies, in particular a lack of scrupulosity: for example, inadequate experimental conditions (e.g., colony dimensions unrepresentative for the normal conditions of colony development, insufficient time allowed to observe foraging behavior); incorrect use of scientific terms (e.g., 'Chinese honeybee' is a term without scientific relevance); imprecise measurement methods; and deficient presentation of the results (e.g., lacking statistical tests, lack of replication, hazardous interpretation, laboratories are not named) (Arnold, in AFSSA, 2002; SCT, 2003). The first independent research program (INRA, CNRS and AFSSA, 1998) identified the presence of imidacloprid in plants during flowering and abnormal honeybee behavior at both treated and control sites. This last finding led the researchers to address the problem of imidacloprid's persistence in soils and its presence in untreated crops cultivated in soils previously used for treated crops (Bonmatin et al., 2000). The analytical techniques available at that time allowed the detection of imidacloprid, but not its quantification below 10 ppb. Throughout this period, beekeepers summarized the results of the studies conducted by Bayer, the Ministry of Agriculture, and independent research institutes and compared them with their own field observations. The beekeepers' objective was to make the results public in order to show the congruity of their own observations and the scientific results and to mobilize the civil society for support. The conclusion of the Commission for Toxic Products was ambiguous: the data examined did not allow the conclusion of an unquestionable effect of imidacloprid or its metabolites on honeybees or honey yield, nor did it totally exclude the effect of imidacloprid and its metabolites. Consequently, the Commission reported that additional studies are necessary (16 December 1998).

[2000–2004]

Bayer received precise results during this period (3.3 ppb in sunflower pollen and 1.9 ppb in nectar (Stork, 1999, in SCT, 2003)). Nevertheless, the company reported "an exposure between 0 and 5 ppb" (Curé, in AFSSA, 2002, p. 32). The value of 5 ppb is the quantification limit declared by Bayer for the dosage of imidacloprid in Gaucho®-treated sunflowers and maize. We, however, showed that Bayer had already obtained lower measurements (using radioactivity-based methods). In view of the relevancy of the existing knowledge, this 'semantic slip' blurs the message by strategically selecting among the measurements available. The underlying effect of this linguistic construct is to suggest imprecision: "in certain cases, the analysis revealed the presence of a residue, but only below the quantification limit" (Curé, in AFSSA, 2002, p. 32). Moreover, independent research had already reported (two years before)

available quantification and detection limits well below those used by Bayer: quantification limit at 1 ppb (pollen and nectar) and a detection limit at 0.3 ppb for pollen (Bonmatin, 2001, in [SCT, 2003](#)) and 0.8 for nectar (Lagarde, 2000, in [SCT, 2003](#)). Imidacloprid was measured in the pollen of sunflowers and maize in concentrations between 2 and 4 ppb. Beekeepers systematically present these results in order to assure transparency and to gain public credibility. In 2001, they summarized in detail the existing studies ([GVA, 2006](#)) and concluded: “in semi-controlled and controlled conditions, harmful effects are observed for concentrations strictly of the same magnitude as those which the honeybee inevitably encounters in the field during sunflower and maize flowering” (21 January 2001, www.beekeeping.com). Among the available results, the Commission for Toxic Products selected a measurement of 2–3 ppb for the imidacloprid present in the pollen and nectar of Gaucho®-treated sunflowers. The argument that the Minister of Agriculture used for not banning the use of Gaucho® in maize seed-dressing (February 2001), however, was that honeybees do not consume maize pollen. The scientific error contained in this conclusion was reconsidered the next year (September 2002) by the State Council, which consequently advised the Minister to reconsider his decision. The values validated by the SCT were 3.3 ppb and 3.5 ppb in the pollen of Gaucho®-treated sunflowers and maize, respectively, and 1.9 ppb in the nectar of Gaucho®-treated sunflowers. Recently published results of a survey initiated in French apiaries to monitor the weakness of honeybee colonies showed that imidacloprid had become a common contaminant of the environment (the most frequently found residue was imidacloprid: in 49.4% of the samples) ([Chauzat et al., 2006](#)).

1.3. The lowest effect concentration

[1997–2002]

In 1997, Bayer declared that the first biological effects appear at 5000 ppb. Two years later, however, the LOEC (lowest observed effect concentration) value identified by a Bayer study was well below this value: 0.5–7 ng/honeybee (20 ppb) (Kirchner, 1999, in [SCT, 2003](#)). In 2000, sublethal effects were identified at very low doses (0.075–0.21 ng/honeybee, i.e., 3 ppb in a solution containing imidacloprid) by scientists working in independent research (Colin and Bonmatin, 2000, in [SCT, 2003](#)). These researchers concluded that the environmental soundness of imidacloprid “is necessarily arguable” ([Bonmatin et al., 2000](#)). From the available results, the Commission for Toxic Products selected 12 ppb as the lowest effect dose. Beekeepers have continued to present the results of independent research, emphasizing that doses as low as 3 ppb and 6 ppb affect honeybees ([GVA, 2006](#)).

[2002–2003]

Bayer claimed that the lowest effect dose is 20 ppb, but failed to mention that this result was obtained during an open-field study. Thus, the company stated that for the studies “made on complete colonies in the open field... the first negative effects are not observed at 20 ppb. The first observed effect of imidacloprid is a refusal to feed from the contaminated source and thus the end of foraging” (Curé, in [AFSSA, 2002](#), p. 32). This claim inadequately reflects the results of the respective study (Kirchner, 1999, 2000, in [SCT, 2003](#)), in which the effects observed in the open field, and caused by 0.5–1.4 ng/honeybee (20 ppb), were not the refusal of feeding, but a decrease in the frequency of wagging dances (which is correlated to recruitment in the colony for a food source), a change in dance precision (concerning the direction), and the occurrence of trembling dances (which is an inhibiting behavior for foraging recruitment and often observed in intoxicated bees) (Kirchner, 1999, 2000, in [SCT, 2003](#)). This contradiction can be attributed either to Bayer’s inability to interpret the results of the study or to strategic behavior on the part of Bayer. One of Bayer’s main arguments for claiming the absence of effects of Gaucho® on honeybees was that field experiments do not confirm the symptoms observed by the beekeepers (Curé, in [AFSSA, 2002](#); Tossen, in [Parlement Wallon, 2004](#); [Bayer Cropscience, 2006](#)). The studies available during this period and validated later by the SCT recorded measurements well below those reported by Bayer for both laboratory and tunnel or flight-room studies. A number of studies reported the following sublethal effects for imidacloprid: 0.075–0.21 ng/ honeybee (3 ppb); 0.15–0.42 ng/honeybee (6 ppb); 0.25–0.7 ng/honeybee (10 ppb), and 0.31–0.87 ng/ honeybee (12.5 ppb) (Colin, 1998; Colin and Bonmatin, 2000; Decourtye and Pham Délegue, 1998; Pham Délegue and Decourtye, 2000; in [SCT, 2003](#)). Based on the results produced by independent research, the beekeepers supplied

arguments in support of their demand to ban the use of Gaucho®. Three of the available results for the effect dose of imidacloprid were validated in 2002 by the Commission for Toxic Products and ranged from 0.15 ng/ honeybee (laboratory) to 7 ng/honeybee (open field).

1.4. The properties of the molecule (persistence in soils, presence in untreated crops)

[1994]

Even though its half-life greatly exceeded European norms, Gaucho® was authorized for marketing.

[1997]

The Commission for Toxic Products confirmed the half-life of imidacloprid to be 2–3 times longer than the one accepted by European norms (Belzunces and Tasei, 1997). The French jurisprudence, however, stated that, despite its half-life in the soil, a substance may be authorized if it is “scientifically proven that, in the relevant field conditions, the accumulation in the soil is insufficient to cause an unacceptable level of residues in the following crops, and that there is neither unacceptable phytotoxic effect for the following crops, nor unacceptable effect on the non-target species.” In this case, the benefit of the doubt with regard to the lack of precision of what ‘acceptability’ means was to Bayer’s advantage, not that of the environment.

[1998–2001]

Results obtained in 2000 showed the persistence of imidacloprid in soils and its presence in untreated crops growing on soils where a crop treated with Gaucho® had been previously grown (SCT, 2003). Assessment of the available documentation led the Coordination of French Beekeepers⁵ (GVA, 2006) to conclude that the substance is found in amounts of about 10 ppb in soils (the year of treatment). Subsequently untreated crops absorbed the chemical in concentrations comparable to those present in the treated crops.

[2003]

The scientific evidence validated by the SCT confirmed the presence of imidacloprid in soils that were used for crops seed-dressed with Gaucho®. The average levels found were 10.25 ppb the year of treatment and 4.4 ppb the year following the Gaucho®-treated crop (SCT, 2003).

1.5. Impacts on other organisms and on the environment

Bayer judged the risks that imidacloprid forms for the environment to be either nonexistent or ‘acceptable’ (Bayer, 2001). Available scientific knowledge, however, indicated negative effects on other insects (including pollinators), birds, and aquatic organisms. Both researchers and beekeepers insist that the honeybee, in this case, represents a bioindicator for the state of the environment. The Minister of Ecology also held imidacloprid responsible for the bird intoxication observed in France after 1995 (GVA, 2006). Imidacloprid authorization data in several countries has shown different toxicity levels for birds, pollinating insects (particularly honeybees), fish and other aquatic organisms, and mammals (pesticides authorization registers for Portugal, Belgium, Spain, Canada, and the United States, websites visited in January 2006).

Section 2. Social, economic, environmental and institutional stakes underlying stakeholders discourses

2.1. Stakes for the economic governance

The *chemical industry* has increased its global sales tenfold since 1970, and the OECD scenarios for the year 2020 anticipate a continuation of this trend. Presently, it is the third-most important economic sector in the world. The European chemical industry holds the first place in this sector, followed by that of the

⁵ The Coordination of French Beekeepers (Coordination des Apiculteurs de France) represented the interests of all three national beekeeping syndicates.

USA. Last years' strategy of the chemical industry was to transfer the production of basic substances to non-OECD countries and focus, in Europe, on specialty products (agrochemistry, pharmacy, biotechnologies, etc.) (OECD, 2001). The winners on the European market will, therefore, be the ones having a high innovative capacity. New active substances have to be marketed as quickly as possible, particularly in the field of agrochemistry. Risk assessment of 'new substances' before marketing, however, has classified about 70% of them as dangerous (Donkers, 2005). The French agrochemical industry has an important position both as the producer and as the seller of pesticides, because France is the number one European consumer of these substances.

The strategic behavior of the agrochemical industry is determined both by these economic factors and by the regulatory environment. The Directive 91/414/EEC stipulated a reassessment of the active substances contained in plant-protection products already on the market in the EU at the starting date of the directive. The industry responded to this directive by developing a new generation of plant-protection products (neonicotinoids, including imidacloprid and phenylpyrazols). Since the risk-assessment procedure proposed by the directive is inappropriate for these new insecticides, these substances may receive market authorization despite their potential environmental risks. This, therefore, may provide the respective companies with the competitive advantage of fast market introduction (see Section 3). Another aspect of the industrial strategy relates to the alliances between big companies in order to control specific market shares. An important part of global production is assured by the number of multinationals inside the chemical industry and the tendency is still towards mergers (OECD, 2001). Size has become essential for profitability, i.e., to absorb growing research and development costs. Total average expenditures for the development of a new product are about 50 million US dollars (Assouline and Joly, 2001). The benefits with regard to systemic insecticides largely justify the investment. One example is Régent TS® (active substance: fipronil): sales of this systemic insecticide earned 122 million euros for Aventis CropScience in 1998 alone (Hicks, 2000). Similarly, insecticides containing imidacloprid are among those sold the most globally. Financial investments are also accompanied by investments in partnerships with seed producers and distribution networks. Through the merger of Rhône-Poulenc with Hoechst, the newborn Aventis became number one on the global insecticide market (with a share of 17%) and the European leader in plant-protection products (24% of the market) (Hicks, 2000). Its agrochemical division was sold to Bayer in 2002. The financial importance of imidacloprid for Bayer is immense: in 1998, sales of the four pesticides containing imidacloprid reached 800 million DM. In 2005, France was the number one European market for Bayer CropScience Monde and the number three globally (www.bayer.fr).

Farmers and seeders

In France, the maize seed branch generates an annual turnover of about 650 million euros. This makes maize the number one crop in the country and France the European leader of maize production and the primary global exporter (Maïz'Europ', 2006). The agricultural sector has since been divided by the two sides of the debate: syndicates representing intensive agriculture have joined forces, with regard to interests and arguments, with agrochemical companies, while the syndicate La Confédération Paysanne supports the honeybee's role as bioindicator, the high economic stake represented by pollination by bees, and the need of a partnership between farmers and beekeepers.

Beekeeping sector

In 1994, the French beekeeping sector consisted of 1370220 beehives and 84800 beekeepers. In 2004, there were 1360973 beehives, but 15200 fewer beekeepers (GEM-ONIFLHOR, 2005). Because of the decrease in the average yield/hive and the increase in colony mortality during this period, beekeepers had to increase the number of hives per exploitation in order to compensate for their losses. The apparent stability of the number of hives between 1994 and 2004 does not correctly portray this replacement of lost hives. Many small producers (i.e., those owning less than 70 beehives) were unable to cover their losses and had to abandon beekeeping. Until 1994, a stable productivity had allowed French beekeepers to face the competition with imported honey. Severe losses in the yield of sunflower honey started in 1995 (Coopérative France Miel, in GVA, 2006). The statistics indicated a strongly decreasing tendency (-46%) in sunflower honey yield between 1992 and 1999 for the French regions Deux-Sèvres and Poitou-Charentes (GVA, 2006). In addition, an audit of the beekeeping sector showed a decrease of 3000-4000

tons of honey on the national level between 1997 and 2004 ([GEM-ONIFLHOR, 2005](#)). Added to these losses, i.e., losses due to the replacement of hives and the decrease in honey production, were the expenses made for research (beekeepers were contributing their financial resources from the European support to beekeeping, which are normally meant to develop the sector, to research programs assessing the risk of Gaucho®). Additional expenses, including attorney fees, were incurred when the debate went to court.

2.2. Stakes with regard to the ability of the political system to perform the arbitrage between social, economic, and environmental spheres

During the Gaucho® debate, the attitude of the French governmental departments oscillated between opacity (refusal to release public documents), hesitation (contradictory or ambiguous statements), and open negation of the statements of researchers and beekeepers. This enhanced the mistrust of the beekeepers and the civil society, who then accused the government of a technocratic approach to expertise, incompetence, and favoritism towards the agrochemical companies ([AFSSA, 2002](#); [GVA, 2006](#)). The concerns of these two groups were justified in January 2000: despite the manifold results issuing from independent research that established the harmful character of imidacloprid for honeybees, the Minister of Agriculture renewed Gaucho®'s authorization for 10 years. Moreover, this occurred during the period when the annulment procedure of this authorization was before the State Council.

2.3. Stakes to assure environmental justice

The press often highlighted the unequal power of the two 'discourse coalitions' involved in the debate to influence decision-making: one side comprised the French agricultural sector, the number one chemical industry in Europe, the chief branch of European seed-producers, and the goodwill of the Ministry of Agriculture, while the other was made up of honeybees, beekeepers, researchers, and the civil society. The response strategy of the beekeeping sector was characterized by cohesion inside the group (among the different syndicates) and extreme assiduity. The sector's excellent communication strategy, focused on logic and scientific arguments, favored the visibility of the stakes involved. Moreover, the sector received support from the civil society, not only because the financial status of the beekeepers has been severely affected, but also because their stakes were human, relating to dignity and social recognition. They affirmed the right to reject decisions that concerned them but in which they were not involved and refused to allow priority to be given in decision-making to the criterion 'economic weight' to the disadvantage of 'equity'.

2.4. Stakes for the implementation of environmental policies

In a letter published in *Le Point* on November 21, 2003, Yves Schenfeigel, head of the Bureau for the Regulation of Pesticide Products (Ministry of Agriculture), revealed the failure of the administration to assure the efficiency of the authorization process: "three public servants for dealing with 20000 demands of authorization per year, a joint management of the risk assessment with industrials, lack of transparency in the procedures... in the field of risk assessment, the domain of pesticide residues in aliments is insufficiently covered." In consequence, "it is impossible for the bureau to accomplish its missions". This fact may explain why the authorizing body failed to adequately evaluate the indices of the potential risk of imidacloprid contained in the authorization dossier (the LD50 was among the lowest known, the half-life in soils was very high).

Moreover, the Ministry of Agriculture was in a conflict-of-interest situation because it was simultaneously responsible for two sectors that often have contradictory demands (beekeeping and agriculture). The French Committee of Prevention and Precaution confirmed this in 2002 by showing the need for changing the patterns of managing pesticides' risks to health and the environment ([Comité de prévention et de la Précaution, 2002](#)).

Section 3. Discussion and conclusions

A first result of this research refers to methodological aspects. Social uncertainty plays a vital role in decision-making, but within the new field of knowledge quality assessment, methods for its evaluation are still in an early phase of development (Van der Sluijs, 2006). This research experience could be a starting point for further research in this field, because our analysis allowed to formalize six criteria of quality of information communicated in an argumentative policy process:

1. Reliability of the information – it must be based on all available scientific knowledge

When uncertainty is at the heart of a social debate and knowledge is being sought to support that debate, it is vital that all statements weigh the most recent information found and include findings from scientific sources other than the actor's own expertise. Arguing from an epistemological point of view stresses the key importance of what Dunn (2001) called 'context validation', i.e., the information used in decision-making should cover the complete set of relevant knowledge present in a particular policy context. In other words, the scope of the knowledge considered must be broadened in order to minimize the possibility that important aspects are overlooked.

In the present case, many of the pesticide producer's conclusions were the result of a stake-driven selection of the results made available by experts, without scientific criteria for validating the choice made. For the non-expert audience (the general public and policy-makers), these arguments may seem as valid as any issuing from scientific work. For the independent researchers, however, the scientific quality of several of Bayer's conclusions was highly arguable. The selective use of knowledge can be legitimate only as long as it is clear what information has been omitted and why, following a process of review and argued selection, that information is considered less relevant to the case.

2. Robustness of the information – it must take into account criticism

The 'experts' contradictions', which were so often evoked during the years of the Gaucho® debate, were due partly to the lack of standardized procedures (SCT, 2003) and partly to the failures of communication between the scientific community and the regulatory bodies. About 20 years before the Gaucho® debate, researchers had already started reporting that LD50 alone was not sufficient to study the risk that pesticides form for honeybees (AFSSA, 2002). These warnings were ignored by the French government. Similar cases included asbestos and mad cow disease: decision-makers also ignored the signals coming from scientists (EEA, 2001).

3. Use of the information produced by other stakeholders

The use of information produced by all stakeholders in the construction and assessment of the knowledge used for decision-making is vital in the management of social processes associated with environmental risks. Stakeholders can contribute to knowledge production in a number of ways: for example, by contributing knowledge on local conditions (e.g., the consistent association between sunflower foraging and symptoms) which may help determine which data are strong and relevant and which symptoms require further investigation (e.g., symptoms observed by beekeepers caused independent research to address specific target points of honeybee intoxication); by providing personal observations which may lead to new foci for empirical research addressing dimensions of the problem that were previously overlooked (e.g., exposure pathways via pollen and nectar were deemed impossible before beekeepers reported intoxication symptoms); by identifying new indicators that better match the problem as experienced by the stakeholders (e.g., beekeepers' observations led to including chronic sublethal effects in the assessment of risk); by thinking creatively about the mechanisms and hypotheses regarding the causal links between observed symptoms and possible causes (e.g., persistency in soils may explain the intoxication seen in bees foraging on untreated crops); and by scrutinizing and improving assumptions made in risk assessments so that they better match real-life conditions (e.g., Bayer's field studies ignored the fact that the diet of intoxicated honeybees was dictated by the several square kilometres of sunflower monoculture: i.e., it provided very little or no alternative diet. The honeybees in Bayer's field experiments

had an alternative diet within their range of flight). By ignoring local beekeepers' knowledge and by repeatedly displaying an ambiguous attitude, the French Ministry of Agriculture repeated previous history of mismanaged environmental problems and contributed to the reinforcement of the conflict (De Marchi and Ravetz, 1999; EEA, 2001). By means of press releases and demonstrations, beekeepers systematically called for the application of the precautionary principle, because the wait for conclusive evidence on imidacloprid intoxication was severely affecting their livelihood.

4. Relevance of the arguments for issue under debate

The information communicated in an argumentative exchange must be relevant for the subject discussed. Some arguments, however, may try to displace the focus of the debate to completely different contexts or issues. For example, Bayer's conclusion regarding the absence of any risk of imidacloprid for honeybees made no reference to the relevance of the results obtained "in different regions of the world" (Bayer Cropscience, 2006), neither for large-scale sunflower and maize monocultures, nor for the specific situation in France.

5. Logic coherence of the discourse

The absence of internal contradictions in a discourse is vital for mutual trust among the stakeholders and is an essential factor for successful risk governance. For example, the findings of the SCT report, presented by Hervé Tossen to the Walloon Parliament, were as follows: "The report of the Scientific and Technical Committee in France is the first of the three steps of the multifactor study and consists of a new review of the existing data. No new information concerning the use of Gaucho® on sunflowers and maize emerged from the Committee's report". Compared to previous studies, however, this SCT report was the first to clearly demonstrate the risk imidacloprid, used in sunflower and maize seed-dressing, forms for honeybees. Hervé Tossen added: "The researches and intensive studies realized by independent institutes and by Bayer confirm that Gaucho® is safe for honeybees. [...] For maize, risk assessment was carried out and also concluded that there was no risk" (Parlement Wallon, 2004, p. 13). It is clear that the results of the SCT report and Bayer's conclusions are contradictory. Once acknowledged, this type of language trick, often called a 'semantic slip' by the beekeepers during the debates, discredits the stakeholder who uses it and significantly reduces his/her opportunities for meaningful communication with the other stakeholders.

6. Legitimacy of the information source

The responsibility, impartiality, and independency of Bayer researchers have often been questioned by the independent researchers. In fact, they signalled procedural errors, incorrect reasoning, and a lack of understanding of honeybee biology. Moreover, the case of the systemic insecticide Gaucho® raised questions about the choice of experts working in expert committees that represent a certain institution, with regard to their freedom, independence, and competence. In the case of imidacloprid authorization, for example, not one of the 50 members of the Committee for Toxic Products was a honeybee specialist and these specialists were underrepresented in the Honeybee Working Group set up by the Committee. This definitely limited the ability of the Committee to judge on honeybee issues.

A second result deals with the broader question of the lessons that can be drawn for the future management of similar risks.

To what extent do we learn from history? This case confirms once more that, when vested short-time interests blind policy action, deep social conflicts become unavoidable for reversing this pattern of environmental decision-making. Among the EEA "late" lessons, most were ignored in the political process described here (repeated failures in building a national monitoring network, any consideration of the local knowledge in the expertise, of the values of different social groups, the disrespect of the regulatory independence of interested parties, reinforcement, instead of reduction of the institutional obstacles to learning and action, ambiguity and 'paralysis by analysis' etc.)

A main lesson from this case study is that it is a pitfall to assume that existing methods for dealing with risks of existing technologies are also appropriate for dealing with new risks, coming from new technologies. In our case, the nature of the risk posed by systemic pesticides is radically different from the one associated to sprayed insecticides. Nevertheless, the same tools for assessment (LD50) were used, a mistake that slowed down the advancement in the knowledge about the effects on honey bees of imidacloprid. This lesson can be framed as following: When dealing with new technologies, verify if the methods available for the assessment of their risks are appropriate.

Another pitfall is to underestimate the problems related to the means and efforts needed for the implementation of policies. In our case, an important problem of capacity for dealing with the demands of authorisation for new pesticides (~ 20 000 per year) can be observed. Moreover, the Ministry of agriculture was subject to a situation of conflict of interests, being responsible in the same time for the interests of the agricultural sector and the regulation of risks issued from its activity. Policy-makers need to provide adequate human and financial resources for rendering efficient the state structures and therefore reinforce their ability to control business sectors. They should also assure that the responsibility for the regulation of the risk associated to the activities of one sector does not resort under the same state body that is responsible for the economic interests of that sector.

A similar case regards the institutional restructuring which took place in the UK, as a consequence of the mad cow disease. Charged both with consumer protection and with the defence of farmers' interests, the British authority who had to manage the case, the Ministry of Agriculture (MAFF) failed in its both missions. In consequence, the manner in which risks for the human health and the environment were assessed and managed in the UK changed and the Food Standards Agency has been created (EEA, 2001).

Following the tradition of the technocratic pattern of French decision-making, the Ministry of Agriculture has initiated scientific studies in a short time after the problem became an issue of public debate. At least one EEA lesson could have been fruitful. Nevertheless, the bad image of this Ministry in French society, the ambiguity of its statements and the contradiction between its results and those issued from the public science, all contributed to deepen the lack of social acceptability of the official expertise (compare to the concept of social robustness of knowledge, as introduced by Nowotny, 1999).

This insight help us draw another important lesson: Assure the independency and the competence for the given issue of the experts that you engage, as well as the complete transparency of the research process and the public availability of the results. Explain the reasons for your decisions, the economic stakes that they involve and how do they answer to the demands of those concerned.

A final lesson might relate to the effectiveness of the research efforts, when dealing with new risks. Our case showed that, lacking of a common framework and clear articulation of regulatory knowledge needs, different laboratories used different methodologies. This made the comparison between the results more difficult. In order to avoid this situation, knowledge needs for policy advice have to be clearly described, objectives have to be set and guiding methodological framework has to be developed.

Finally, conclusions can be drawn about the capacity of contemporary democracies to answer societal demands. Principles of democracy, social equity, ecological responsibility – all of these challenge the liberal criteria for decision-making: financial profits – but for whom? profitability of agriculture and industry – at the cost of the profitability of beekeeping? and at what social and environmental price? The case of Gaucho® versus honeybees is symbolic for the actual crisis (sign of a transformation?) frequently seen in representative democracies.

References

- Abeilles/tournesol. Compte rendu de la Réunion Abeilles/tournesol du 24.10.1997. Paris: ACTA; 1997. 10 pp.
- Abeilles/tournesol. Compte rendu de la Réunion technique du 31 juillet 1998 à Luçon; 1998. 3 pp.

Alétru F. Observations description et analyse des troubles comportementaux des abeilles sur cultures de tournesol; 2003. 16 pp. AFSSA (Agence Française de la Sécurité Sanitaire des Aliments).

Analyse des phénomènes d'affaiblissement des colonies d'abeilles. Paris: AFSSA; 2002. 102 pp.

Assouline G, Joly P-B. Rhône Poulenc Agrochimie: an uncertain future. AgBioForum, J. Agrobiotechnol Manage Econ 2001;4(1):26–33.

Bayer. Expert overview on Imidacloprid, with reference to Cox, Caroline (2001), Insecticide Factsheet/Imidacloprid. Northwest Coalition for Alternatives to Pesticides (NCAP). J Pestic Reform 21(1):15–21.

Bayer Cropscience. Dossier Abeille et agriculture, Dossier Gaucho et les abeilles. <http://www.bayercropscience.fr>. Last visited in January 2006.

Belzunces L, Tasei J-N. Rapport sur les effets des traitements de semences de tournesol au Gaucho® (imidaclopride). Impacts sur les peuplements des colonies d'abeilles et sur les miellées. Paris: Commission d'Etude de la Toxicité des Produits Antiparasitaires à Usage Agricole et des Produits assimilés, Ministère de l'Agriculture; 1997. 27 pp.

Bonmatin J-M, Bengsch ER, Moineau I, Lecoublet S, Colin ME, Fleche C. Effets des produits phytosanitaires sur les abeilles, Programmes 1999 et 2000. Rapport de résultats no. 3 au. Paris: Ministère de l'Agriculture et de la Pêche; 2000. 32 pp.

Bonmatin J-M, Marchand PA, Charvet R, Moineau I, Colin ME. Quantification of imidacloprid uptake in maize crops. J Agric Food Chem 2005;53:5336–41.

Chauzat M-P, Faucon J-P, Martel A-C, Lachaize J, Cougoule N, Aubert M. A survey of pesticide residues in pollen loads collected by honeybees in France. J Econ Entomol 2006;99(2):253–62. Chambre d'Agriculture des Deux Sèvres. Enquete miel de tournesol; 2000. 5 pp.

Chambre d'Agriculture de la Vendée, FDSEA de la Vendée, FDSEA des Deux Sèvres. Résultats de l'étude sur le problème de la chute de récolte de miel de tournesol (1996–1999); 1999. 1 pp.

Comité de prévention et de la Précaution. Risques sanitaires liés à l'utilisation des produits phytosanitaires; 2002. Paris, Available at: http://www.fne.asso.fr/PA/eau/dos/PPP_Phytos.pdf.

De Marchi B, Ravetz JR. Risk management and governance: a postnormal science approach. Futures 1999;31:743–57.

Donkers R. Reach – the European Union proposal for chemicals management. 9th annual CMS workshop, San Francisco; 2005. Available at: http://www.chemicalstrategies.org/pdfs/Presentations_05/RDonkers_REACH_Breakout_5.pdf.

Dunn WN. Using the method of context validation to mitigate type III errors in environmental policy analysis. In: Hisschemöller M, Hoppe R, Dunn WN, Ravetz JR, editors. Knowledge, power, and participation in environmental policy analysis. Policy studies review annual New Brunswick: Transaction Publishers; 2001. p. 417–36.

EEA (European Environmental Agency). Late lessons from early warnings. Copenhagen: EEA; 2001. 211 pp.

Elbert A, Beckert B, Hartwig J, Erdelen C. Imidacloprid – a new systemic insecticide. Pflanzenschutz Nachr 1991;44:113–36.

Faucheux S, Noël J-F. Les menaces globales sur l'environnement. Paris: La Découverte; 1990. 124 pp.

GVA (Galerie Virtuelle Apicole). Apiservices – Le Portail Apiculture. Dossier Intoxications. www.beekeeping.com. Last checked on 20th February 2006.

Funtowicz SO, Ravetz JR. Uncertainty and quality in science for policy. Dordrecht: Kluwer; 1990. 229 pp.

GEM-ONIFLHOR. Audit de la filière miel: Partie I. Reactualisation des Données Economiques Issues de l'audit 1997; 2005. 67 pp.

Halm MP, Rortais A, Arnold G, Taséi JN, Rault S. A new risk assessment approach for systemic insecticides: the case of honeybees and imidacloprid (Gaucho®). Environ Sci Technol 2006;40:2448–54.

Hellström T. The Science–Policy dialogue in transformation: model-uncertainty and environmental policy. Sci Public Policy 1996;23(2):91–7.

Hicks B. Aventis – a new leader in life sciences. Pestic Outlook 2000;11(3):116–8.

Maïz'Europ'. L'importance économique de la filière semences de maïs. http://www.agpm.com/marche_eco/chiffres_production_maïs.php#I0000924f. Last visited in April 2006.

- Michaels D. Industry groups are fighting government regulation by fomenting scientific uncertainty. Doubts is their product. *Sci Am* 2005;96–101.
- Nowotny H, Scott P, Gibbons M, Salomon J-J. Re-thinking science, knowledge and the public in an age of uncertainty. Cambridge, Polity: Malden, MA, Published in the USA by Blackwell, 2001, 278 pp.
- OECD. OECD environmental outlook for the chemicals industry;2001. 168 pp.
- O'Connor M. Building knowledge partnership with ICT? Some lessons from GOUVERNe and VIRTUALIS. Saint-Quentin-en-Yvelines: Cahier du C3ED, vol. 06-01. 2006. p. 11–2.
- Parlement Wallon. Compte-rendu analytique de la séance publique de la Commission de l'Environnement, des Ressources Naturelles et de la Ruralité. Séance de 12 February; 2004. Available at: www.menacechimique.be.
- Rortais A, Arnold G, Halm M-P, Touffet-Briens F. Modes of honeybees exposure to systemic insecticides: estimated amounts of contaminated pollen and nectar consumed by different categories of bees. *Apidologie* 2005;36:71–83.
- Suchail S, Belzunces LP, Vaissière BE. Toxicité aiguë de l'imidaclopride et de ses métabolites chez l'abeille domestique *Apis mellifera*. *Abeilles Fleurs* 2003;643:27–30.
- SCT (Scientific and Technical Committee for the Multifactor Study of the Honeybee Apiaries Decline). Imidaclopride utilisé en enrobage de semences (Gaucho®) et troubles des abeilles, rapport final. Paris: Ministère de l'Agriculture, de la Pêche et des Affaires Rurales; 2003. Available at: <http://www.agriculture.gouv.fr/spip/IMG/pdf/rapportfin.pdf>, 106 pp.
- UNESCO. The precautionary principle. Paris, France: UNESCO; 2005. 54 pp. Available at: <http://unesdoc.unesco.org/images/0013/001395/139578c.pdf>.
- Van der Sluijs J.P. Anchoring amid uncertainty; on the management of uncertainties in risk assessment of anthropogenic climate change. Ph.D. Thesis. Universiteit Utrecht, 1997, 260 pp.
- Van der Sluijs JP. Chapter 2.1. Uncertainty, assumptions, and value commitments in the knowledge base of complex environmental problems. In: Guimarães Pereira Â, Guedes Vaz S, Tognetti S, editors. *Interfaces between science and society*. London: Greenleaf;2006. p. 67–84.
- Van der Sluijs JP. Uncertainty and precaution in environmental management: insights from the UPEM conference. *Environ Model Softw* 2007;22(5):590–8.
- Walker WE, Harremoës P, Rotmans J, Van der Sluijs JP, Van Asselt MBA, Janssen P, et al. Defining uncertainty. A conceptual basis for uncertainty management in model-based decision support. *Integr Assess* 2003;4(1):5–17.
- Wildavsky AB. *Speaking truth to power, the art and craft of policy analysis*. Boston, Mass.: Little, Brown; 1979. 431 pp.
- Wynne B. Uncertainty and environmental learning. *Glob Environ Change* 1992;2:111–27.