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Central collecting and evaluating of major accidents and near-miss-events in the Federal Republic of Germany—results, experiences, perspectives

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Abstract

Lessons learnt from accidents are essential sources for updating state of the art requirements in process safety. To improve this input by a systematic way in the FRG, a central body for collecting and evaluating major accident (ZEMA) was established in 1993. ZEMA is part of the Federal Environmental Agency. All events which are to be notified due to the German Regulation on Major Accidents (Störfall–Verordnung) are centrally collected, analysed (deducing lessons learnt) and documented by ZEMA. The bureau is also responsible for the dissemination of the lessons learnt to all stake holders. This work is done in co-operation with the German Major-Accident Hazard Commission (Störfallkommission) and other international bodies like European MAHB. At the time being, over 375 events from 1980 to 2002 are registered in Germany. For each event, a separate data sheet is published in annual reports, first started in 1993. All information is also available at http://www.umweltbundesamt.de/zema/. A summary evaluation on the events from 1993 to 1999 is presented and some basic lessons learnt are shown. The results from root cause analysis underline the importance of maintenance, detailed knowledge of chemical properties, human factor issues and the role of safety organisation especially connected with subcontractors. The German notification system is described in detail and some experience with the system is reported.

Keeping in mind that collecting reports from notified major accidents is only a small amount compared with all the events which might be interesting to learn from, the German Major-Accident Hazard Commission has established a separate body, the subcommittee "Incident Evaluation", which is in charge with collecting and evaluating of minor and near-miss events. Since 1994, a concept for the registration and evaluation of those non-notifiable events was developed. From 2000 on, the concept has been put into operation. Its main elements are:

1. reporting of the incident by the plant operator to an information collecting point of its trust;
2. passing the anonymous report to the "Incident Evaluation" subcommittee;
3. evaluation and classification whether the incident is safety relevant or not and
4. publishing the relevant information to all interested stake holders, preparing of summary evaluation results in certain areas. Up to now, two brochures on "waste gas pipes" and "obstructions of pipes" were published.

Keywords: German Major-Accident Hazard Commission; Incident Evaluation

1. Notifiable accidents

1.1. Introduction

The experiences of analysis of major accidents are indispensable sources for the further development of the state of the art [1]. For this reason a systematic major accident notification system (ZEMA) was established in 1993 in the Federal Republic of Germany. ZEMA is incorporated in the Federal Environmental Agency and works on the basis of a State-guideline [2]. The essential tasks are:

- Collection, evaluation and forwarding of the messages according to the German Regulation on Major Accidents (Hazardous Incident Ordinance).[1]

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- Selection and preparation of the reports of the Federal Government to the consignment of the European Union after SEVESO-II-directive (overview see [4]).
- Collection and evaluation of comparable international events (overview see [3]).
- Editing annual reports and instant internet publishing.
- Exchange of lessons learnt with other organisations in charge of evaluating major accidents.

1.2. Notification system

In the German Regulation on Major Accidents (Störfall–Verordnung [16]) which enacts the European SEVESO II directive, a clear definition of reportable events is given. From the year 2000 onwards also, near-misses, which have a significant potential to learn from, are to be reported and registered in the ZEMA database. A definition of the "significant potential to learn from" is given by the German Major-Accident Hazard Commission and available on the ZEMA website (see below).

All respective events are reported to the responsible (local) authority by the operator. This transmits the message to the ZEMA in the Federal Environmental Agency. The messages which ZEMA receives are immediately given to all states as on-the-spot information to draw attention to. The investigation is carried out by the operator in close co-operation with the competent local authorities. If necessary, independent experts are getting involved. Those experts are appointed by the operator himself or on behalf of the competent authority. Fig. 1 shows the diagram of the notification system.

1.3. Database

In the ZEMA files, events qualified by the Hazardous Incident Ordinance and comparable events from other countries, in particular the EU, are registered exclusively.

Since the ZEMA has been established, some 400 events have been registered in the database Table 1. For each event, a data sheet is drawn up and published in an annual report [5–11]. As a basic principle, all data sheets are co-ordinated with the data suppliers.

Table 1
Summary of the events registered at the ZEMA (31.12.2002)

Period under review	Total number	Major accidents	Disturbances
1980–1992	73	29	44
1993	42	20	22
1994	34	12	22
1995	27	6	21
1996	30	8	22
1997	27	11	16
1998	38	16	22
1999	41	14	27
2000	24	11	13
2001	25	10	15
2002	22	7	15
Total	383	144	239

1.4. Data quality

The evaluations of events are carried out on the basis of notification formulas according to the Hazardous Incident Ordinance. Since 1991, an improvement in the quality of the messages has been noticed. Documents and reports of the operator, of authorities, trade co-operative associations and experts are increasingly provided in addition to the obligatory notification formula that has to be provided within one week after the accident (see Fig. 2). From 1998, the amount of additional material remains unaltered at some 80%. The notification formula is often seen as a check list rather than a report, with its positions explained in additional reports. A comprehensive figure of the process and the effects of the event can normally be derived from this reports. As for the investigation of causes, it should be mentioned that in most cases the reports are restricted to the predominant cause, e.g. an operating error. Lower-level causes ("root causes") are rarely regarded and scrutinised even more rarely. Improvement is still needed here to increase the quality of the lessons learned.

1.5. Evaluation of events 1993–2002

From the total number of events in the period 1993–2002 (313 events), the following conclusions and main points can be drawn. In spite of high-quality reasons, only the events from 1993 onwards were considered.

The trend in the number of notifications (Fig. 3) shows an increase in the events in the period of 1993–1994 compared with 1991–1992. This was mainly due to the revised notification system. For the standardised number of events (events per establishment and year) a minor decrease since 1993 has been detectable till 1995. The trend in the last 10 years leaves open, whether or not the level of random occurrences is already reached.

1.6. Event types

Nearly the half of the events (50%) were connected with substance releases (see distribution in Fig. 4).

In the *process industry* that states the field with approximately 47%, this cause became predominant by the failure of devices and mountings in the case of normal operation (see Table 3). Accidental releases caused by human failure were limited to start-off and shut-down processes as well as maintenance and repair. They were approximately three times less frequent as the technical causes.

In the range of *installations not associated to the core of chemical industry* (storage, refrigerating systems, waste treatment), the findings were vice versa. The releases caused by human failure are double as frequent as those originated by technical causes.

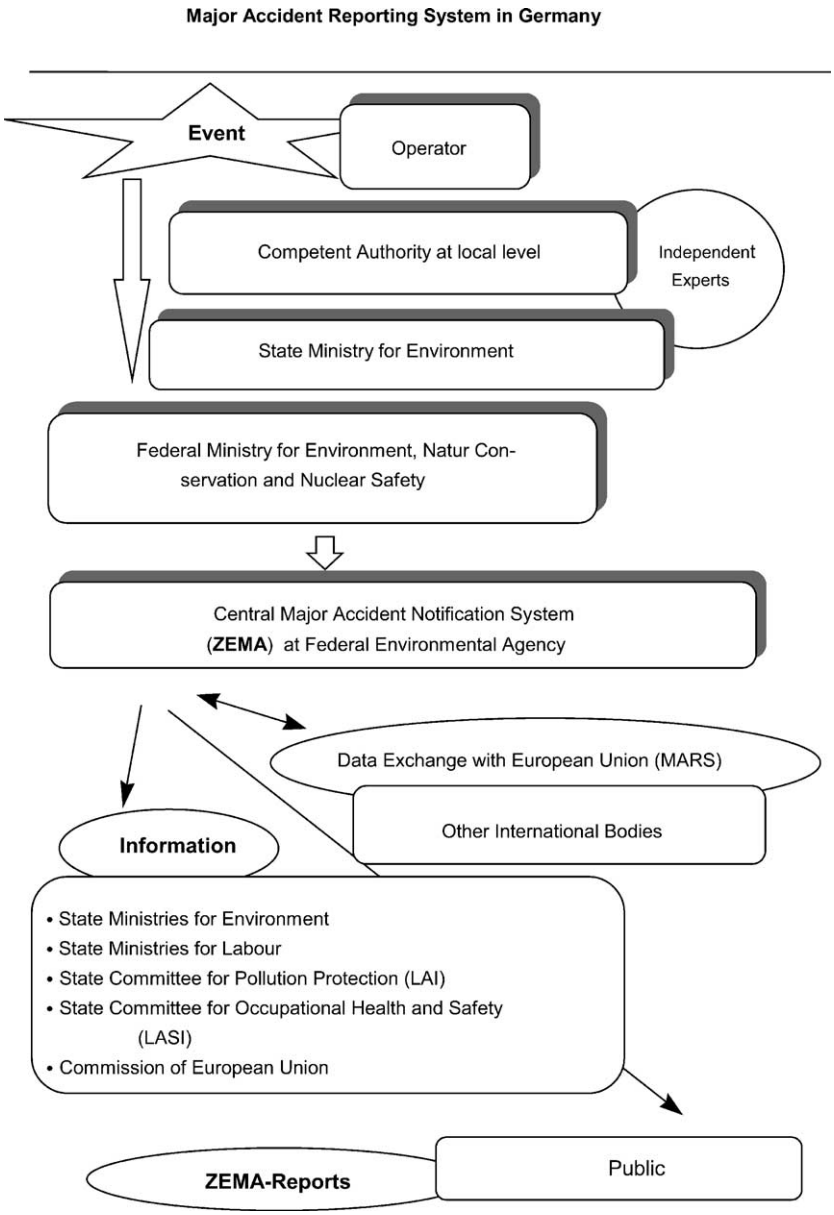

Fig. 1. Notification system for major accident reporting in Germany.

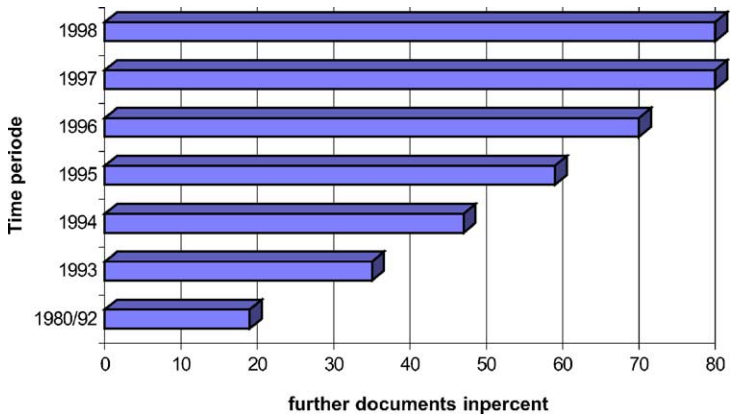

Fig. 2. Part the documents supplied in addition to the notification formula.

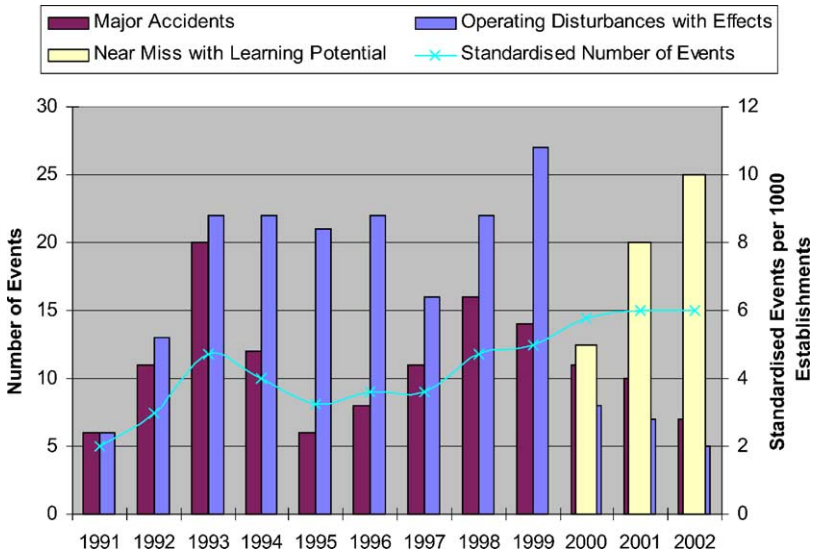

Fig. 3. Number of reported events from 1991 to 2002 (near-miss reporting starts from year 2000 onwards due to Seveso II directive).

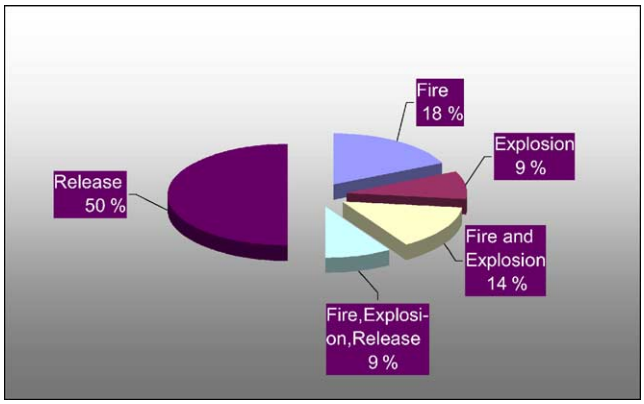

Fig. 4. Event types.

Explosions, associated fires as well as separated fires are the second main group of the events (see Fig. 4).

The more in depth analysis shows, that fires and explosions in *process industry* are merely triggered by human failure rather then by technical failure.

The conditions are in turn as you look to the *residual area*: explosions and fires were twice often triggered by technical failure compared with human failure.

The operating processes at the time of the events for every type of installation are shown in Table 2. With 47%, the process as the most frequent state in which events occurred was determined. Storage as well as maintenance/repair were represented with approximately 15%. The start-off and shut-down processes as well as loading had a part of approximately 10% each.

Adding all parts of "normal operation" you get approximately 70%, this is in the range of average operating time in this operating mode. Accidents seem, therefore in all operating states, to occur comparably often.

The more precise analysis of the causes indicates that technical failures are present at approximately 37% of the events, these are subdivided into failures of the container/flange (approximately 6%), of devices/mountings (approximately 21%), piping (approximately 3%) and mechanical damages, e.g. through corrosion (approximately 7%). Human failures occurred at approximately 25% of the events, where 9% were organisational mistakes, 13% operating errors and approximately 2.5% failures during repair works. Chemical reactions contributed with almost 18%. At approximately 10% of the events, the cause could not be determined (see Table 3).

Table 2
Event types 1993–2002

Operating processes	Relative part (%)
Process	47
Loading/unloading	10
Maintenance/repair	14
Start-off and shut-down process	10
On site transport	2
Storage	16
Unknown	1

Table 3
Primary causes (all events)

Cause	Events (%)
Human failure (organisational failure)	9
Human failure (operating error)	13
Human failure (during repair works)	2.5
Technical failure (container/flange)	6
Technical failure (devices/mountings)	21
Technical failure (pipes)	3
Technical failure (mechanical damage, corrosion)	7
Physical reaction	2.5
Chemical reaction	18
Environmental cause	1
Unknown	9.5

The analysis shows the following main areas of concern:

- Maintenance plays an important role in accident prevention.
- Even greater attention must be dedicated to the characterisation of the basic chemical reactions. This applies particularly to the areas which are not counted to the core region of chemical industry.
- The relatively high amount of the operating error stresses the needs of intensified qualification and intensified carrying out training sessions. Since an operating error always reflects the conditions in which this failure occurs, however, the safety management is also addressed.
- The observed presence of unknown chemical reactions as a cause for events shows shortcomings in expert knowledge and qualification. The analysis shows that unknown chemical reactions in the area of chemical industry are observed mainly during maintenance/repair, at the other areas this is true during "normal operation". Maintenance/repair are carried out often by third parties, often with lack of experience and insufficient knowledge of the conditions in the installation.

1.7. Material and environmental damages

The material and environmental damages are not so often specified in the documents. But concerning the material losses, it is very clear that most of the costs are within the enterprise; the overall amount was € 356 million and the outside damages were only of € 4.4 million;. However, often the given costs are not clearly defined, some include, e.g. costs of interruption of production also and not only material losses.

Information on environmental damage on the site was given in 3% of the cases, effects off site in 5%. In the majority of the events, no specification of the magnitude of environmental damage is available.

1.8. General conclusions

The following general conclusions may be drawn from the overall analysis:

- As primary causes, you can identify errors in the complex system switching process units. These system connections are often fuzzy in the event and lead to imperfect reactions which often develop to disturbances or accidents. The operating rules did not reflect these relations sufficiently.
- It was recognised in a whole series of events that the operating rules were provided as imperfect or not up to date and often did not reflect critical operating states.
- During maintenance operations, the personal (often external firms!) had no sufficient information. Significant communication problems also occurred with serious consequences.
- Lacking expert knowledge was observed not only during maintenance operations but also in cases where incompatible materials were stored or put together which finally led to irregularities.
- Imperfect operating actions were in particular observed in the case of deviations from routine tasks. These situations should be particularly addressed in the operating instructions and especially considered for training purposes.

2. Non-notifiable accidents

2.1. Introduction

Lessons can be learnt from non-notifiable accidents as well as from accidents notifiable due to German Regulation on Major Accidents and are independent from the consequences of the accidents. There are no fundamental differences in the causes of major or minor events too.

Therefore, the German Major-Accident Hazard Commission decided to register and evaluate non-notifiable incidents. From 1994 to 1997, the Commission's Data Working Group developed a concept for the registration and evaluation of such non-notifiable incidents. After testing this concept successfully in practice, a new subcommittee "Incident Evaluation" was established with the main purpose to put this concept into operation. The subcommittee consists of 16 representatives of several important social groups as industry, authorities, science, trade unions, environmental groups and employer's liability insurance associations.

2.2. The concept for the registration and evaluation of non-notifiable incidents [13,14]

The main elements of the concept for the registration and evaluation of non-notifiable incidents are shown in Fig. 5.

The plant operator sends a report on the incident to an information collecting point. Incidents notifiable due to the Regulation on Major Accidents [16] have to be reported to the Competent Authority which sends the incident report to ZEMA as central collecting point (see Section 1). Most of

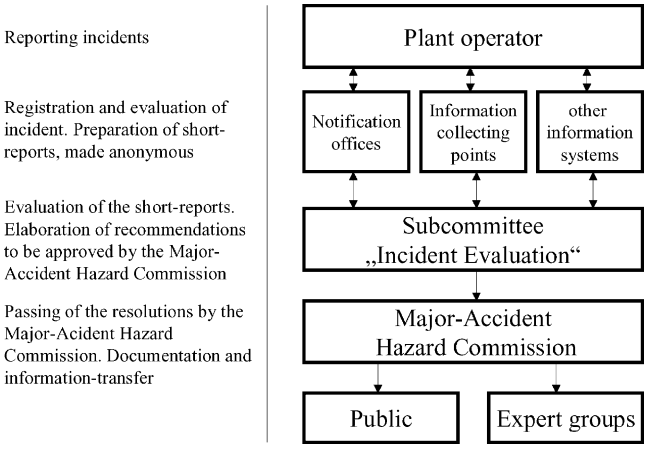

Fig. 5. Concept of registration and evaluation of non-notifiable incidents.

the other incidents have to be notified due to different laws and regulations. According to this, there are different collecting points. Even for near-misses, there is no determined notification procedure. So, in this case, the collecting points are dependent on voluntary reports of the operators.

The collecting points prepare short anonymous reports about each incident containing relevant information like event description, substances, causes, measures and as conclusion the lessons learnt. These short reports are sent to the subcommittee "Incident Evaluation" where they are discussed and evaluated. The subcommittee also has to guarantee that those reports are sufficiently anonymous. Before evaluation the reports are checked and prepared by a special collecting point located at the Federal Institute for Materials Research and Testing (BAM).

The evaluation by the subcommittee "Incident Evaluation" is carried out by of the following main steps:

1. On the basis of the available information, the aspects are worked out which are necessary for a clear technical, comprehensible and plausible documentation of the incident.
2. Causes and main weak points leading to the incident are determined with regard to those elements having a teaching effect or being of general interest. The causes are derived into direct and indirect causes.
3. Lessons learnt are described and recommendations for other plants are made if convenient.
4. For classification of incidents, there are three categories defined: safety relevant incidents, pool data and material data. As laid down in a special guideline of German State Committee for Pollution Protection (LAI) [2], incidents are classified as safety relevant if they lead to new insights with regard to:

   - substance properties;
   - design and fabrication of components;
   - failure of safety devices and systems;
   - failure of technical and organisational systems; and
   - efficiency of limiting the consequences of accidents.

   Incident reports become material data if there is not enough information for evaluation. All the other incidents are classified as pool data.

As a result of the evaluation, the subcommittee might get new insights corresponding to state of the art in safety technology, the development of technical rules or in general safe operation of industrial plants. In this case, recommendations are elaborated to be approved by the Major-Accident Hazard Commission and resolutions or reports are prepared for passing by the Commission.

At last, the information on the safety relevant incidents and lessons learnt are published by:

- reports of the Major-Accident Hazard Commission;
- articles and lectures;
- the public part of the database on the Internet (planned for the future); and
- special brochures in cases where incident evaluation lead to crucial points concerning substances or components of plants involved or causes identified.

So, expert groups and the public being interested in plant safety can find information about lessons learnt from accidents.

2.3. Database

After evaluation all reports of the incidents classified as safety relevant or pool data are put into a special database operated by the Federal Environmental Agency. Up to now the database contains 139 incidents, 23 of them are safety relevant. The reports contain information about the plants involved, event description, consequences of the incidents, substances, causes, emergency measures taken, measures drawn to avoid such incidents in the future by the operator or the Competent Authority and any other lessons learnt.

At present, the database is not available for the public but in the near future there will be a public part containing the reports of safety relevant incidents and a not public part with all pool data only available for the members of the subcommittee.

2.4. Experiences

As shown above, there is no legislation instructing plant operators or collecting points to give any information about incidents to the subcommittee. So, the work of the subcommittee depends on voluntary reports. There is no regular respective complete data flow. Furthermore, the operators and their federations fear that it will be detrimental to them if

1. in special cases, the public associates an incident report with a special operator, and
2. there will be tightening up of regulations or technical rules due to results of incident evaluations.

As a result of this, some fear the information given by the operator sometimes does not contain enough data. In this case event description and cause analysis may be incomprehensible and no clear lessons can be learnt. So the subcommittee has to make great efforts to point out that there are several benefits even for the operators that will outweigh any disadvantages. One of those benefits for example might be the data backflow to the operators so that they could learn lessons from accidents that took place in plants of other operators.

2.5. Conclusions

Up to now, the evaluation of non-notifiable incidents allow to draw the following conclusions:

- The concept for the registration and evaluation of non-notifiable incidents of the German Major-Accident

Hazard Commission was put successfully into operation by the subcommittee "Incident Evaluation" and work goes on in a sufficient manner. The appliance of the described concept confirmed the assumption that lessons can be learnt from notifiable incidents as well as from non-notifiable incidents.

- For successful operation, data flow has to be improved. Therefore, further data sources like ministries, industrial trusts, expert organisations or insurances were asked for cooperation. A lot of them gave positive answers.
- A great number of incidents happened due to human failure respectively disregard of regulations.
- As crucial points, waste pipes and obstructions of pipes were identified. Therefore, two brochures "Waste Pipes" as appendix of [14] and "Obstructions of Pipes" [15] were published. In these brochures relevant hazards and measures necessary for safe processing are described. The content of each brochure is illustrated by short descriptions of about 20 incidents. The aim of the brochures is to make plant designers, operators and inspectors sensitive for risks caused by deviations from normal process conditions and by mistakes in planning and maintenance.

Other crucial points are within sight.

3. Summary and outlook

The German system for collecting and evaluating notified events from hazardous installations has become a reliable institution. The ZEMA synthesised co-operation with the Bundesländer, the Major-Accident Hazard Commission, and the responsible European institutions. The interested public gets access to the information by the publication of annual reports, which are also available on the Internet at http://www.umweltdaten.de/ZEMA.

In future, near-misses are going to be detected and evaluated more systematically.

The Federal Environmental Agency promotes the development of suitable management modules for systematic detection and evaluation of all safety important events within the framework of the safety organisations in the chemical Industry [12]. Besides, a sophisticated database is provided by the Federal Environmental Agency to document the events. The database is fully compatible with the European Major Accident Reporting System (MARS, see [4]), which facilitates data transfer with other member states. It will also contain an active information system about "lessons learnt" from both accidents and near-misses.

With regard to lessons learnt also from non-notified events the German Major-Accident Hazard Commission established a subcommittee "Incident Evaluation" with the main purpose to put a concept for the registration and evaluation of non-notifiable incidents into operation. It has succeeded in establishing it's activities. Further information may be available under the ZEMA link given above. Two crucial points were identified leading to the publication of appropriate brochures.

In the next years, the subcommittee has to improve data flow because up to now the number of events registered is not big enough. The database has to be developed with the aim of becoming an important information source for the public and expert groups. Furthermore, the subcommittee will have a look on other crucial points which may be appropriate to give occasion to further brochures.

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