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## *Interoperability and Automated Mapping*

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### **Deliverable 5.2**

*Early Warning Systems:*

*From national to international networks*

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# Early warning systems: From national to international networks

## *Proposal for EURDEP early warning procedures*

### 1. General remarks

This paper focuses on early warning functions of systems monitoring gamma dose rate (GDR). Gamma dose rate networks are installed in all European countries and data in these systems are collected in the EURDEP data base.

In principle, systems for monitoring the environmental radioactivity have to fulfil the following tasks (e.g. chapter 2.6 of AIRDOS report):

- Monitoring data for the assessment of the (background) exposure to population
- Detection of abnormal situations (events) with enhanced dose rate and/or enhanced artificial radioactivity in the environment due to an accidental release or un-peaceful impact using the so-called early warning functions on these networks
- Delineation of affected areas with enhanced dose rate and/or enhanced artificial radioactivity in the environment
- Hazard and risk mapping: providing data for decision support systems to assist the assessment of the distribution of doses to the public

Thus, monitoring networks run in different modes.

- Routine mode of operation: monitoring data at the normal level of environmental radioactivity; routine data collecting procedures and routine data check procedures are performed
- Alert mode of operation: after the detection of an abnormal situation, experienced personnel has to evaluate the situation and has to decide about further actions
- Intensive mode of operation: an abnormal situation has been confirmed by authorised staff; measured data are collected for further decision making purpose based on delineation and risk mapping

Of course, routine mode could be switched directly to intensive mode. However, the focus of this paper mainly deals with techniques needed to switch from routine mode to alert mode of operation. The objectives of this early warning function of the monitoring systems could be described as follows:

- Detection of enhanced level of dose rate
- Filtering of false alarms
- Warning of experienced personnel; evaluation of the situation
- Decision on adequate actions (as soon as possible)

For routine monitoring, mapping tools should use measured gross dose rate data. However, delineation of affected areas should rely on net dose rate calculated from measured data and background dose rate at a given station. The detection task relies on the observation of enhanced values. In this paper, the concept of net dose rate is used for this purpose.

For situations with severe accidental release, where protective measures (e.g. sheltering indoors) have to be taken into account, the first three steps of such warning procedures should be possible within few hours on national level. On the European level early warning procedures should be available as well (see discussion in chapter 4). Data measured in the gamma dose rate networks operated by all EU member states are regularly send to the EURDEP database operated by the REM group of the JRC in Ispra/Italy. In the following investigation a strategy will be described to apply simple procedures based on the data available at the EURDEP database to reduce early warnings false alarms to a minimum.

## 2. Characterisation of GDR data available at the EURDEP database

The ability of a given monitoring system for detection of an abnormal situation depends on different properties of the monitoring system. In principle, events could be detected where measured dose rate exceeds the lower limit of detection (LLD). For a given devise, this value correlates with the sensitivity of the probe, the time interval for the measurements and the variability of background radiation at a given site (see AIRDOS report chapter 8). As has been described in the AIRDOS project, different types of detectors (GM counters, proportional counters, scintillators and semi conductor based counters) are used in European countries. The sensitivity of these different detector types shows a big variation. However, most detector types have a sensitivity in the order of 10 cps per  $\mu\text{Sv/h}$  (counts per seconds for unit dose rate, cf. AIRDOS report chapter 5.1) and correspondingly a LLD in the order of 0,01  $\mu\text{Sv/h}$ .

In addition national monitoring networks have different reporting intervals for routine and emergency mode of operation and their spatial density is very heterogeneous. Thus, national early warning mechanisms follow specific procedures due to the national strategies (Table 1).

Country	Probe	Number of sites	Reporting interval	Measuring time / min.	Detection limit $\mu\text{Sv/h}$ ( $\mu\text{Gy/h}$ )
DE	TechniData GS05	2150	24 h	1 / 10	0.013
FI	TechniData AGS421	300	10 min	1 / 10	0.01
NL	Bitt RS03	163	1 h	10 / 10	0.001
SE	Sievert	7	2 h	15 / 15	0.01

Country	Name	Warning level $\mu\text{Sv/h}$ ( $\mu\text{Gy/h}$ )	Action
DE	ODL	0.05-0.1	Spontaneous reports
FI	USVA	0.4 10 100	Alarm sent to STUK's office on duty. Emergency reading is triggered
NL	NMR	0.2 2 20 40	Alarm RIVM, investigate (NMR1); alarm RIVM and fire brigade, investigate (NMR2-4)
SE	SSI	0.3	Compare doses between two floating 24 h periods

Table 1 a + b: Different aspects of national dose rate monitoring networks and early warning systems (data from AIRDOS report).

For example, the German monitoring system has the following strategy: In routine mode of operation, measured dose rate is transmitted once per day at 2 o'clock in the morning to EURDEP. Probes measuring enhanced dose rate perform spontaneous reports. All incoming spontaneous reports are analyzed in the central server and the network will be switched to intensive mode synchronously in time. In the intensive mode of operation, the reporting interval is reduced to a value of 10 min and might be changed to 1 hour in the late phase on an accident.

Following table 1b, the early warning system of Finland implements three different warning levels. The first warning level is defined with  $0,4 \mu\text{Sv/h}$  for all stations which exceed the range for normal background radiation in Finland by a factor of 2 to 4. In the German early warning system the warning levels are calculated individually for each station taking into account the typical background radiation level at the station and statistical effects.

On the other hand, the ability for the detection of an abnormal situation depends on the spacing of the monitoring system. The probability for the detection of local size events with a spatial extension less than  $10 \text{ km}^2$  is low. For medium size events with an extension between  $100 \text{ km}^2$  and  $10000 \text{ km}^2$  this detection probability depends on the spatial density of the network. For an event with the spatial extension of  $100 \text{ km}^2$ , this probability is in the order of about 50 % for some central European countries and less than 10 % in most European countries. Fig. 1a shows the spacing parameter for each European country.

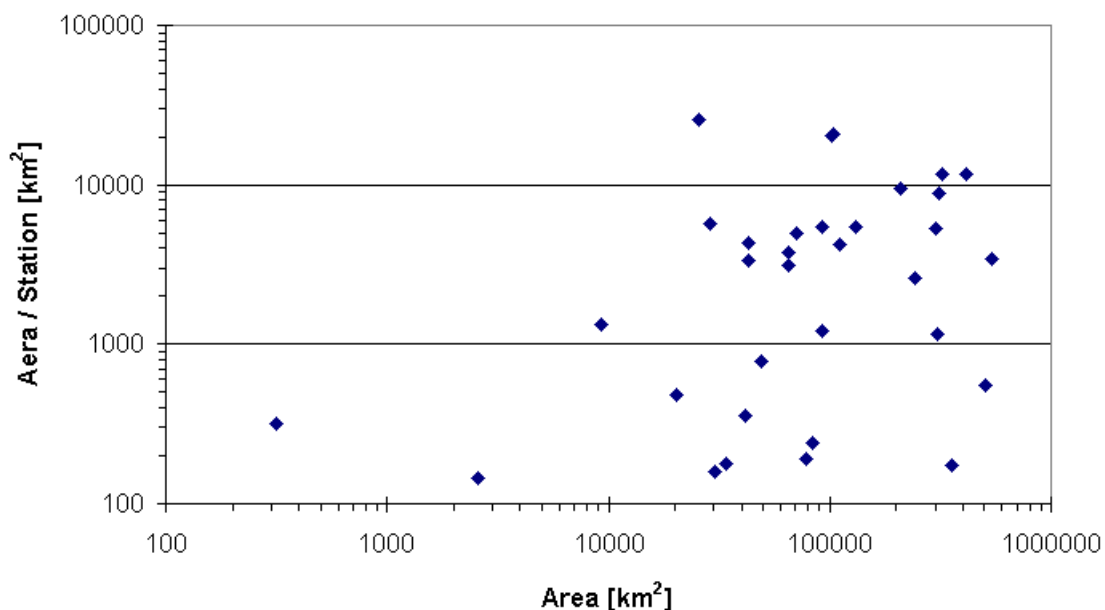


Fig. 1 Spatial density (area per monitoring station) of dose rate monitoring networks for European countries. Data from table 2.1 of AIRDOS report.

### 3. Techniques to detect anomalies – experience from German system

A measuring stations sends a spontaneous report, whenever the measured dose rate exceeds a specific level. This so called warning level is individually defined for each station and is set "as low as possible". The main features are:

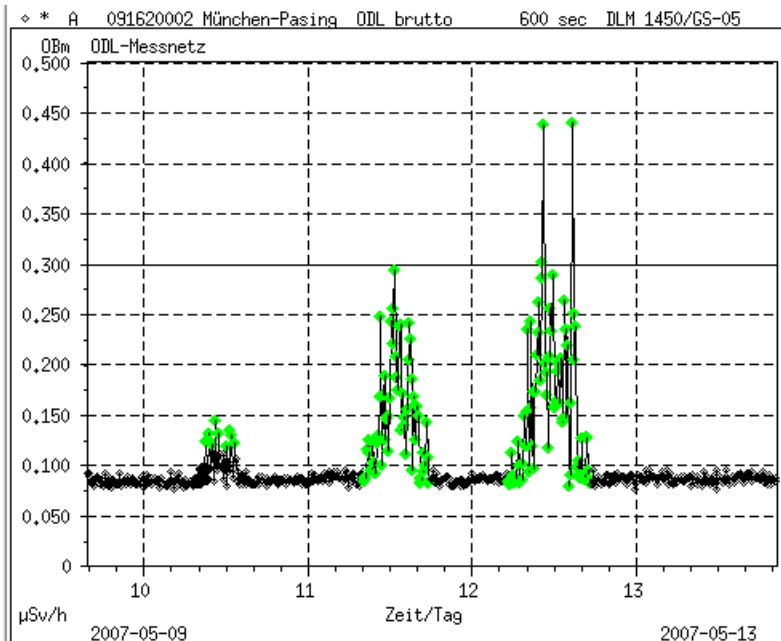
- Step 1: To detect any increased level of radioactivity, in all GDR monitoring stations mechanisms are implemented to identify data which exceed a given alert threshold. These data are immediately transmitted to the central server unit of the monitoring network, generating a so called spontaneous report. The alert threshold for a given station is defined individually by typical mean value of the dose rate at the station and the variability of measured data in normal situations. Thus, the threshold depends on the sensitivity of measurement system as well as site specific influences and varies between 0.05 and 0.1  $\mu\text{Gy/h}$ .
- Step 2: Alert function: The software of the central server unit of the monitoring network performs an automatic early warning check subsequent to each spontaneous reports and at least every 10 minutes. All incoming spontaneous reports will be checked using the space/time window algorithm. A network internal alert will only be generated, whenever spontaneous reports from neighboring stations with a distance of less than 30 km have been reported in a time interval of up to 1 hour.
- Step 3: Evaluation of the situation – Generation of an alarm: If a network internal alert is generated, the staff member on duty has to evaluate the situation as fast possible. For this purpose, the time evolution of the data of the monitoring stations with enhanced data has to be checked. Again additional data has to be considered e.g. from neighboring dose rate stations, from other radiological networks, meteorological stations or from precipitation radar system.

Step 4: Emergency mode of operation: Authorized personnel (e.g. from governmental authorities) have to confirm the network internal alert. In case that the alert seems to be due to radiological effects, the IMIS information and monitoring systems is switched to the emergency mode of operation.

### 3.1 Technical events

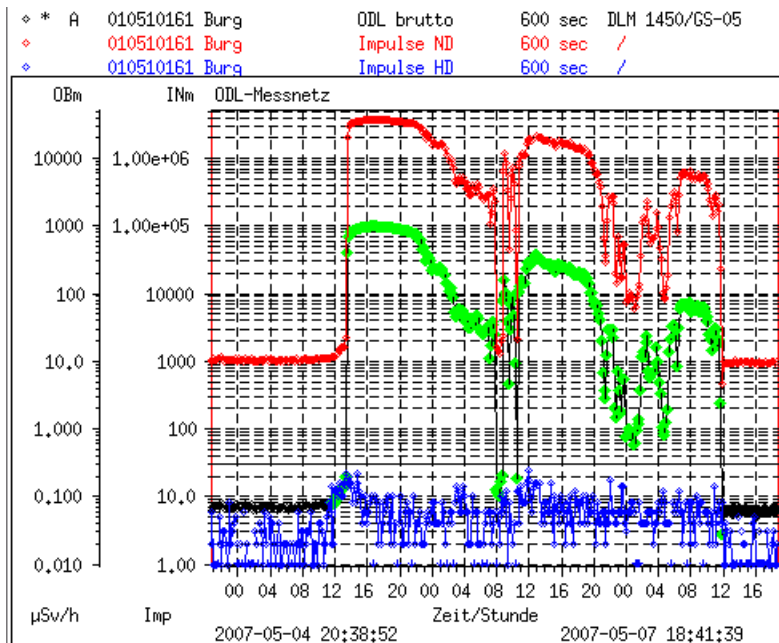
In the first generation of detection systems designed in the mid 80th the probe mounted outside of the building was connected with the data logger inside the building using a wired connection. The length of the cable was up to 100m and the pulses of the GM or proportional counters were send over the cable to the data logger. One of the basic function of the data logger was to count the incoming pulses over a period of 1 to 10 minutes up to 1 or 2 hours, to calculate the dose rate from the count rate and to store the averaged dose rate over a period of several days up to some weeks. Typically no or rather simple data validation procedures had been implemented. Due to the set-up of the complete system electromagnetic interference or distortions could significantly increase the count rate and a sudden increase of the dose rate was detected. These technically generated events in general had a characteristic time behaviour, but only poor mechanisms where implemented on board of the detection systems to distinguish them from events due to increased dose rate in the environment.

Two typical technical events are shown in figure 2 and 3.



*Fig. 2 Example for the time evolution of dose rate (10 minute data) several technical events. This type of technical perturbations of the data typically occurs during windy days and indicates problems of low dose GM counting tubes.*

Most devices used in European networks consist of at least two GM tubes (cf. Chapter 5.1 of AIRDOS report). The probes used in the German monitoring network consist of a low dose (rate) GM tube and a high dose (rate) GM tube. The sensitivity of the first tube is 800 times higher than the sensitivity of the second. Thus, comparison of observed counting rates is a well established technique to distinguish between increased dose rate due to radiation and measured data influenced by technical perturbations. Such comparison is performed on data loggers of the first generation of German monitoring installation. The result is indicated by technical status information. This method is applicable for measured dose rate (1 min values) above about 10  $\mu\text{Sv/h}$ . The second generation of data loggers enables direct comparison of observed counting rates, in this case the method is applicable for enhanced dose rate (10 min values) above 1  $\mu\text{Sv/h}$  (cf. Fig 2).



*Fig. 3 Example for the time evolution of dose rate (black line and green symbols) showing a sudden increase. Red and blue lines show observed counting rates of low dose and high dose GM tube. Both channels show enhanced counting rate, however, low dose counting rate indicate dose rate up to 1000  $\mu\text{Gy/h}$  and high dose counting rate fits to dose rate below 3  $\mu\text{Gy/h}$ . The faulty probe was replaced on 2007-05-07.*

### 3.2 The space-time/window algorithm

One way to verify the increased dose rate measured is the comparison of data obtained from neighbouring measurement stations. In Germany for example the so called time/space window algorithm was implemented which turned out to be an effective way to eliminate false alerts due to the fact that the stations are close enough (with a typical distance of 15 to 18 km) that within one hour the meteorological conditions on both stations are almost identical or at least follow the same tendency. During normal weather conditions with a mean wind speed of 3 m/s a cloud moves within one hour over a distance of 11 km which is close to the typical distance of neighbouring dose rate measurement stations. Technical effects generate isolated increased dose rate values whereas high dose rate levels due to meteorological effects typically are found one almost all stations close to each other. This algorithm still used today in the German dose rate network helps to eliminate network internal alerts due to technical reasons almost completely. The incidence rate of false alerts is below 1 percent.

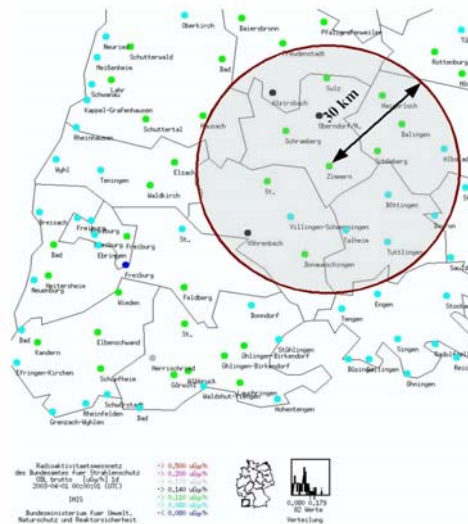


Fig. 4 The spatial definition of the space/time window

The main advantage of this early warning approach is, that false alerts can be avoided. The space/time window of the alert function effectively filters enhanced data due to technical perturbations. This approach is appropriate for spatial dense monitoring networks with large numbers of probes with frequent incidence of perturbed data.

### 3.3. Single Station warning procedures

The disadvantage of this procedure is, that local events with radiological evidence cannot be detected. For this reason, additional single warning algorithms must be implemented with higher warning levels to minimise false alerts. Whenever the measured data will pass a threshold of for example 1  $\mu\text{Gy/h}$ , a spontaneous report will be generated which immediately triggers a network internal alert.

An other possibility is to implement optimised validation procedures valid for single stations. All data measured at an single station will be checked internally using advanced technical procedures. Again any spontaneous report generated immediately triggers a network internal alert.

This approach has the advantage, that it is more general, e.g. it is independent of the density of GDR stations of the network, and can be used even when the distance between stations is larger than 30 km. In this case, when the mean distance between two stations is much larger than the typical way a cloud will pass under normal weather conditions meteorological effects between different stations have no longer a common origin and the time/space window algorithms can no longer be implemented. The disadvantage of this approach is, that adequate filter algorithms to avoid false alarms have to be designed and implemented.

Warning algorithms on the European scale have to rely on single station warning algorithms since the density of the individual national networks are very patchy and will allow to use a time/space algorithms only in a few regions.

#### **4. National and European early warning systems**

National early warning systems:

- Step 1: Spontaneous reports: Immediate spontaneous reports in case of enhanced GDR with an threshold for net dose rate below 0.2  $\mu\text{Sv/h}$  (or routine polling time interval below 1 hour).
- Step 2: Alert function: The software of the central server unit of the monitoring network performs an automatic early warning check. A network internal alert will be generated, if the net GDR exceeds the warning level of 0.2  $\mu\text{Sv/h}$  for 1 hour. In addition, a network internal alert could be generated, when net GDR exceeds the level of 0.1  $\mu\text{Sv/h}$  at neighboring stations with a distance of less than 30 km within 1 hour.
- Step 3: Evaluation of the situation – Generation of an alarm: If a network internal alert is generated, the staff member on duty has to evaluate the situation as fast as possible. For this purpose, the time evolution of the data of the monitoring stations with enhanced data has to be checked. Again additional data has to be considered e.g. from neighboring dose rate stations, from other radiological networks, meteorological stations or from precipitation radar system.

Decision needed:

- Available information is sufficient for generation of an alarm
- Available information is sufficient to quit the internal alert
- Available information is insufficient; check the internal alert on step 4 of the evaluation

Alternative: automatically working checking procedures

- Step 4: Emergency mode: Authorized personnel (e.g. from governmental authorities) has to confirm the network internal alert. In case that the alert seems to be due to accidental release or un-peaceful action, the systems is switched to the emergency mode of operation.

#### **Alternative 1: European early warning information system**

- Step 1: nothing to do
- Step 2: network internal alerts from contributing countries are indicated by the EURDEP system
- Step 3: information about the evaluation procedures for network internal alerts from contributing countries are indicated by the EURDEP system
- Step 4: information about confirmed alarms from contributing countries are indicated by the EURDEP system

The system would inform all contributing countries about situations with anomalous enhanced dose rate. The evaluation procedures and the decisions are fully performed on national scale. No staff on duty is necessary on European level.

### **Alternative 2: Active European early warning system (rather unrealistic)**

- Step 1: Immediate upload of enhanced measured data by early warning systems of contributing countries
- Step 2: Generation of internal European alert similar to procedure on national levels
- Step 3: Immediate upload evaluation status for enhanced measured data by contributing countries  
Decision on European level?
  - Available information is sufficient for generation of an alarm
  - Available information is sufficient to quit the internal alert
  - Available information is insufficient; check the internal alert at the next time step of evaluation
- Step 4: Confirmation of an alarm on European level? Actions?

The system could trigger early warnings by itself on the basis of enhanced data from the national systems. The evaluation procedures and the decisions are partially performed on European scale. Staff on duty is necessary on European level.

## **4.2 Generation of internal alerts**

The software of the central server unit of the monitoring network routinely performs an automatic early warning check. This check procedure will generate a network internal alert, if the net GDR exceeds a certain warning level for a given minimum time period. The proposed warning level is 0.2  $\mu\text{Sv/h}$  and the proposed time criteria is 1 hour.

In chapter 5, it is demonstrated by experience from the German monitoring network, that the proposed criteria is helpful to avoid false alarms. Natural rain (wash-out) events very seldom exceed the level of 0.2  $\mu\text{Sv/h}$ . The authors believe, that this is true also for other European countries. Enhanced data due to technical perturbations are typically short-lived. Thus, the duration of an event could be used to filter false alarms by technical perturbations.

In addition, a network internal alert could be generated, when net GDR exceeds a warning level in a given space-time window. For example, alerts could be triggered, if enhanced data exceed the level of 0.1  $\mu\text{Sv/h}$  at neighboring stations with a distance of less than 50 km within 2 hours.

### 4.3 Evaluation procedures in situations with internal alerts

The evaluation process should fulfil the following tasks:

- Generation of an alarm as early as possible
- Avoiding false alarms as effective as possible

The proposed warning level grants, that internal alerts due to natural rain (wash-out) events occur very seldom. To avoid false alarms due to technical perturbations, two main techniques are used in the German monitoring network:

1. Daily performed routine checks of measured data to indicate technical problems with the probe; typical behaviour of time series of dose rate in case of malfunction (classification of malfunction types).
2. Using probe technical status of measured data or if possible, comparison of counting rates of both GM tubes (see chapter 2). This method is applicable for measured 10 min average dose rate above 1  $\mu\text{Sv/h}$ .
3. In the case that the probe has 2 low dose tubes integrated in addition to the high dose rate the count rate of both low dose tubes should be identified within the count rate dependend statistical error. This method is applicable for the whole range of the low dose rate tubes.

Since the probability for the coincidence of perturbations at different neighbouring sites is low, the decision on the generation of an alarm could be assisted by the space-time window algorithm already described.

Technique 1 should be applicable in all European monitoring networks. However, technique 2 is applicable only, if the design of the devices (probes and data loggers) support such an comparison method.

Thus, the evaluation procedure could be performed using the proposed decision tree (Table 2). The first criteria would generate an alarm, if the observed dose rate exceeds the LDD after 2 resp. 5 hours and the temporal behaviour of the time series of data shows no indication for technical perturbation.

Table 2 Proposed decision tree for generation of an alarm depending on the information available using different criteria.

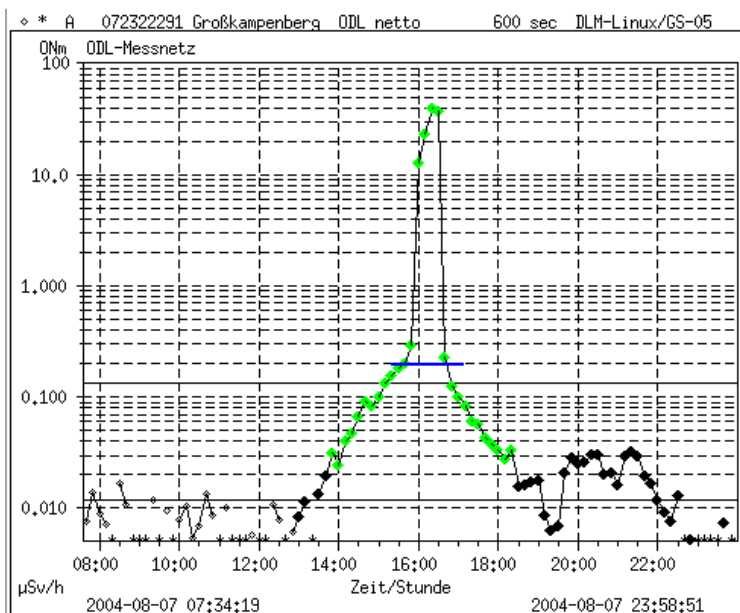
Criteria	Observed net dose rate [ $\mu\text{Sv/h}$ ]	
	0,2 – 1	> 1
<b>Duration of the event (Temporal behaviour)</b>	<b>Alarm after 5 h</b>	<b>Alarm after 2 h</b>
Technical status indicates radiation event		Alarm
Tech. status indicates technical perturbed data		No alarm
Warning level exceeded at different sites (space-time window)		Alarm
Warning level exceeded at different sites and no indication for rain event	Alarm	Alarm

## 5. Investigation of events with enhanced data

The implementation of outlier detection procedures on an European scale using the EURDEP database can only be performed using the data provided by the national networks. The interpretation of the technical status of this information has to be done by the member states themselves, since the diversity of probes used and the difference of their technical set-up allows not to deal with the status information itself. Ideally data are send in routine and emergency situation every hour to the EURDEP database. The data will be validated in the different countries using automatic procedures, but since false data cannot be excluded totally the status is typically set to “unverified”.

### 5.1 Peak detection mechanism

For the discussion of the different behaviour of naturally enhanced and technically perturbed data the data for all 2150 station in the German GDR monitoring network have been investigated using an peak detection mechanism. This peak detection mechanism is characterised such that is based on 10 min data. In this study it is performed for monthly time periods. For each single station, each 10 min value is compared with the corresponding median value of dose rate during the given month. Net dose rate is calculated from total dose rate subtracting the median value. If the net dose rate exceeds a certain threshold value (warning level), the 10 min value is marked as increased. The first value above the threshold is marked as start of an event and the duration of the event is determined counting the number of all subsequent data above this threshold.



*Fig. 5 Peak detection mechanism applied to a time series of 10 min net dose rate data. The blue line indicates enhanced data above the warning level 0.2  $\mu\text{Sv/h}$ ; the duration of the corresponding event is 70 minutes.*

In the following investigation all net dose rate data above  $0.05 \mu\text{Sv/h}$  in the years 2004 to 2006 have been analysed using the peak detection algorithm.

This procedure has been applied to all data from the database and finally they were sorted due to the status which can only have two distinguish values of “valid” or “invalid”. Valid events were added to the list of rain events and the results of data with status “invalid” have been sorted to the list of technical (perturbation) events. The result of this procedure is shown in figure 6.

The observed number of events from all operational stations in Germany is less than 1500 events per month (see Table 2). Thus, the incidence rate is less than 0.025 events / (station day). Events exceeding the  $1 \mu\text{Sv/h}$  threshold have an incidence rate up to 0.001 events / (station day). Most technical perturbations on measurement equipment are shorter than 1 h.

## 5.2 Natural enhanced radioactivity – rain events

In this chapter the frequency, duration together with the maximum net dose rate of rain events of single GDR stations will be discussed. Data are taken from the German GDR network, but since the radiological phenomena discussed – even those which show regional dependencies - are due to global effects, the results can in general be used at least for all central European countries.

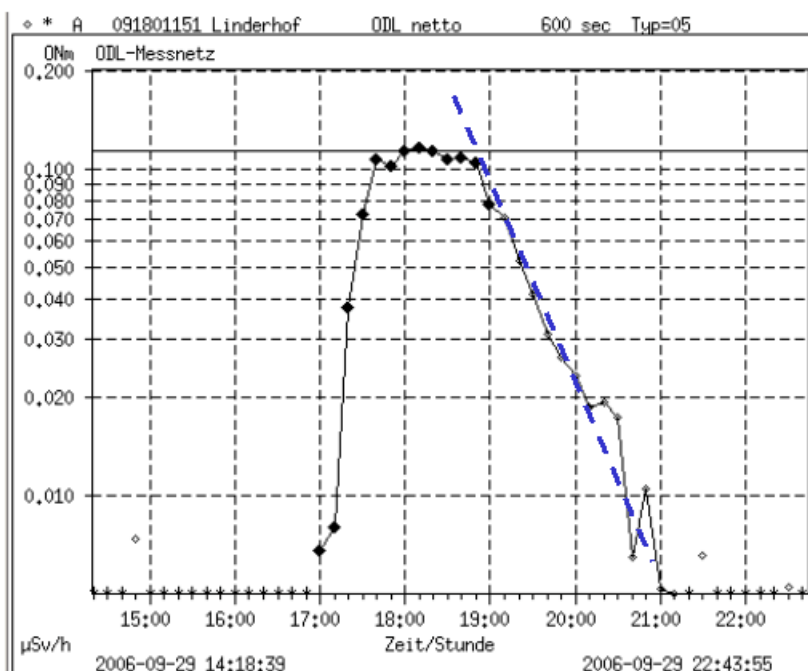


Fig. 6 Typical rain event with enhanced net dose rate above  $0.1 \mu\text{Sv/h}$ . The threshold of  $0.05 \mu\text{Sv/h}$  is exceeded by 2 hours.

### 5.2.1 Duration of rain events

Rain events detected by enhanced dose rate occur if natural activity in air is washed out. The increase of dose rate is dominated by the Rn-222 daughters Bi-214 (half live 20 min) and Pb-214 (half live 30 min). After the rainfall stops the enhanced dose rate will decrease with an effective half live of 30 min (see Fig. 6).

The duration of rain events as function of the maximum peak value has been investigated.

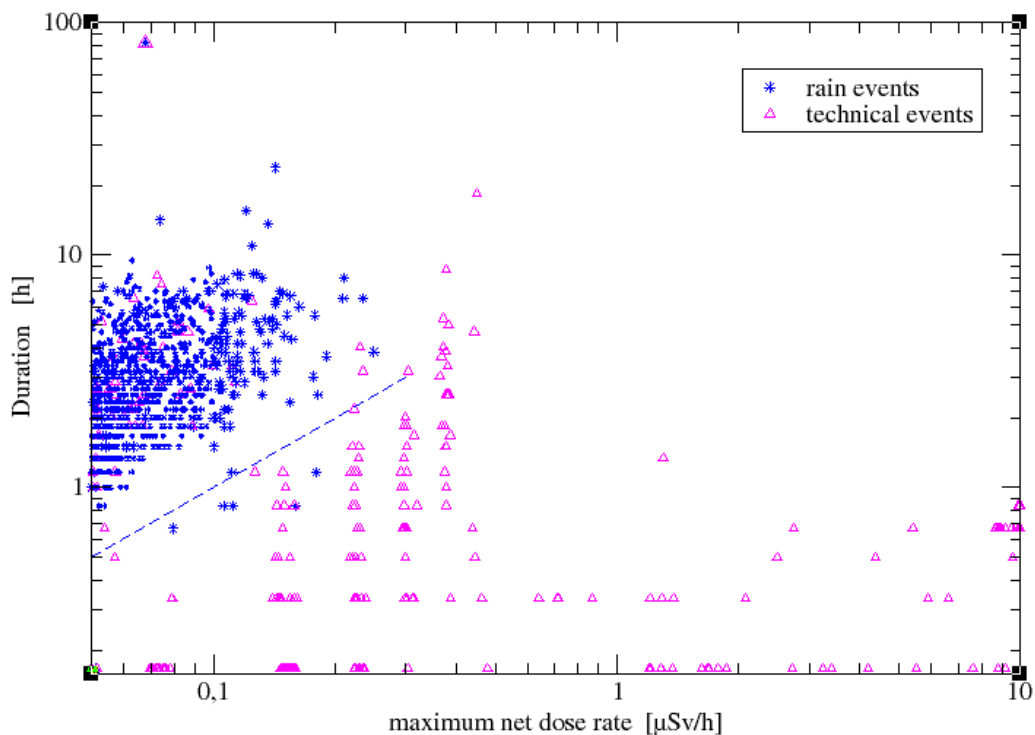


Fig. 7: Duration vs. maximum net dose rate for events from all monitoring stations in Germany in September 2006 exceeding the threshold level of  $0.03 \mu\text{Sv/h}$ . Technical events (magenta) and radiological events (blue) are distinguished as described above. The dotted line shows the minimum duration for rain events.

The dominant information from figure 6 is, that using a double logarithmic presentation of duration versus maximum net dose rate, natural and technical effects of enhanced data seem to be separated by a straight line with slope 10. This corresponds with the discussed radiological behaviour of rain events.

Thus, short lived events below this lower limit for the duration of rain events could easily be classified as technical events. The differentiation between technically disturbed and valid data is obtained as a result of the network internal data validation procedures. These procedures are in general applied automatically based on generic procedures of the measurement stations. The general goal of the following

discussion is to look for additional parameters depending on the duration and the maximum dose rate allowing to differentiate between technical and natural effects.

Concerning the technical perturbations it is assumed, that the behaviour of the detection systems used in the German gamma dose rate network can be generalised and used for all GM-tube and PC based detection systems.

### 5.3 Frequency, duration and maximum net dose rate for single station events

In the following investigation, all events with enhanced net dose rate above 0.05  $\mu\text{Sv/h}$  are analysed.

Month	2004		2005		2006	
	Rain	Technical	Rain	Technical	rain	Technical
Jan	14	152	40	108	46	78
Feb	15	162	11	75	8	77
Mrz	15	120	191	115	29	101
Apr	189	132	168	105	105	103
Mai	288	150	304	138	78	102
Jun	108	172	418	160	771	155
Jul	1284	232	1022	182	840	160
Aug	1028	188	916	111	396	124
Sep	198	122	1285	117	875	145
Okt	323	98	177	102	114	83
Nov	52	102	86	81	46	94
Dez	30	99	17	66	7	62
<b>Total</b>	<b>3544</b>	<b>1729</b>	<b>4635</b>	<b>1360</b>	<b>3315</b>	<b>1284</b>

Table 3. Monthly frequency of rain events and technical events from all operational monitoring stations using a threshold of 0.05  $\mu\text{Sv/h}$

As can be seen from table 3 the yearly number of technical events was in the order of 1500 events. The monthly frequency was between 62 and 232 events. Seasonal influences for technical events are not very pronounced. The incidence rate was 0.002 events / (station day).

However, the total number of rain events is in the order of 4000 events per year. The frequency of rain events depends on the season and on the region (background dose rate). During summer, the total number of events reaches 1300 events / month. Thus, the corresponding incidence rate is 0.02 events / (station day). Regional dependencies are found, since in the south east region, the incidence rate is up to 0.03 events / (station day).

The total number of events per year for specific regions shows a typical behaviour influenced by continental air in a region far from the sea and less increased radon concentrations in areas close to the sea. The activity concentration in the air in regions far away from the sea have been passing over long areas where the total activity concentration could be enhanced by accumulating radon emitted from the

ground. But the seasonal behaviour is almost independent of this effect and shows a minimum in winter and the maximum in summer. Therefore the probability for rain events exceeding a given warning level can be described in general, although some regional and seasonal effects have to be considered.

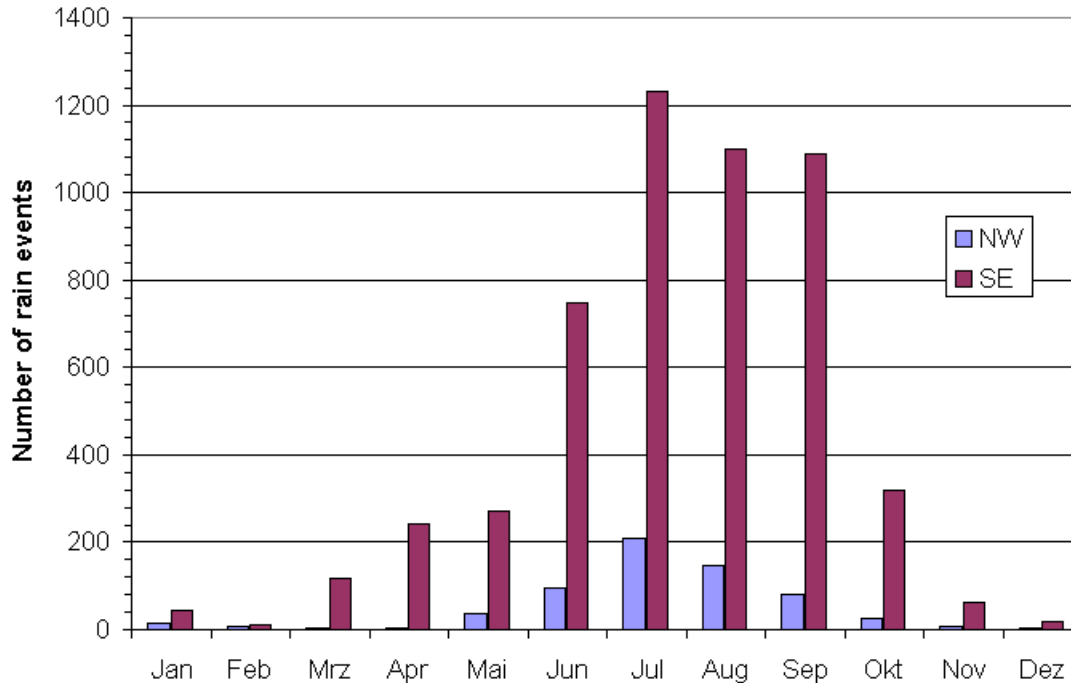


Fig. 8 Monthly frequency of rain events for all stations of Germany, for north west region (435 stations of Niedersachsen, Hamburg und Schleswig-Holstein) and for south east region (400 stations of Bavaria) in the years 2004 to 2006.

#### 5.4 Investigation of the amplitude of peak events

In the following investigation the discrimination of naturally enhanced and technically perturbed data will be studied due to the amplitude of both effects.

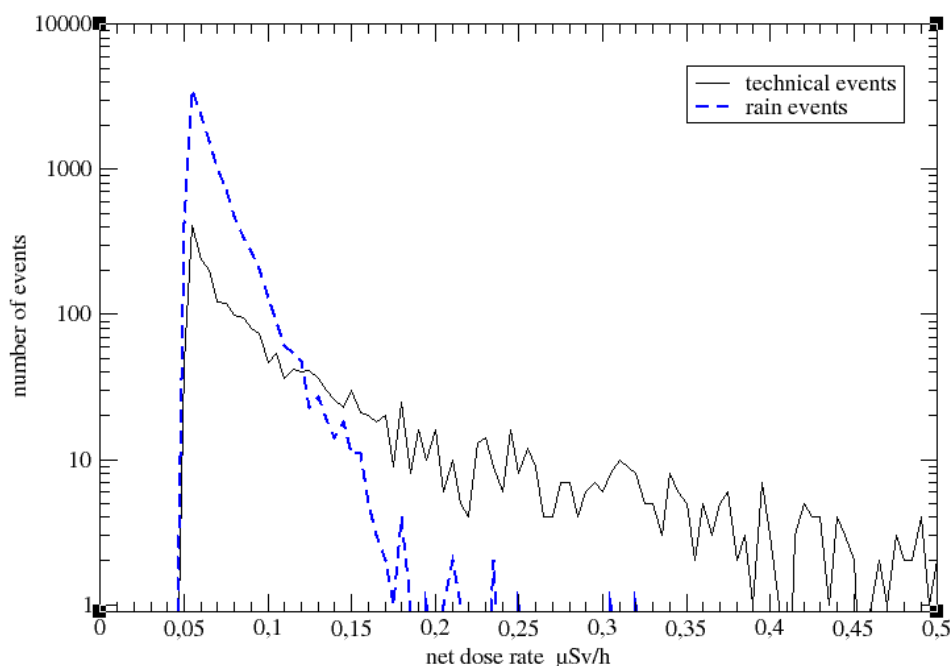
net dose rate $\mu\text{Gy/h}$	Rain	Technical
0,05 - 0,07	8949	1021
0,07 - 0,1	2146	513
0,1 - 0,15	369	358
0,15 - 0,2	30	163
0,2 - 0,5	10	306
0,5 - 1		122
1 - 10		1493
> 10		397

Table 4. Frequency of rain events and technical events from all operational monitoring stations (years 2004 – 2006) depending on the amplitude (maximum net dose rate).

As already mentioned, the increase of the dose rate due to rain events seldom exceed  $0.2 \mu\text{Sv/h}$  rain events (see Fig. 9). Thus, false alerts due to rain events could be effectively filtered using a warning level of  $0.2 \mu\text{Sv/h}$ .

The result of the above described analysis procedure allows producing frequency distributions of maximum net dose rate. As can be seen from figure 9 the minimum value of  $0.05 \mu\text{Sv/h}$  observed in both curves corresponds to the lower cut-off level used for this investigation. Radiological events typically have maximum net dose rates up to  $0.17 \mu\text{Sv/h}$  and only a few events with levels  $0.23 \mu\text{Sv/h}$  can be found. This results corresponds to the well known fact, that wash-out effects of radon daughter products lead to increased levels of natural radioactivity on the ground with maximum levels around  $0.2 \mu\text{Sv/h}$ .

For technical events the maximum net dose rate reaches values of up to  $0.5 \mu\text{Sv/h}$ .



*Fig. 9 Distribution of the maximum net dose rate for two classes of events reported by BfS monitoring network in the period 2004 - 2006 exceeding a given threshold of  $0.05 \mu\text{Sv/h}$ .*

In case of the maximum net dose rate observed at the Schauinsland mountain in Mai 1986 due to the Chernobyl fall-out levels of  $0.3 \mu\text{Sv/h}$  were detected and it is well known that for example in some areas in Austria levels of up to  $1 \mu\text{Sv/h}$  have been reported.

In general it can be concluded from this investigation, that the maximum net dose rate cannot be used as indicator for the differentiation between technical and radiological effects. The net dose rate in a radiological emergency situation is expected to be well above the maximum level possible in natural situations and would thus be in the range of technical effects of the detection system.

## 5.5 Investigation of the duration of peak events

The following investigation focuses on the discrimination of naturally enhanced and technically perturbed data due to the time dependency of both effects.

Duration min	Warning level	
	0.2 $\mu\text{Sv/h}$	10 $\mu\text{Sv/h}$
10 – 30	4121	272
40 – 60	120	58
70 – 120	52	22
> 120	80	45

Table 5. Frequency of technical events from all operational monitoring stations (years 2004 – 2006) depending on warning level and their duration

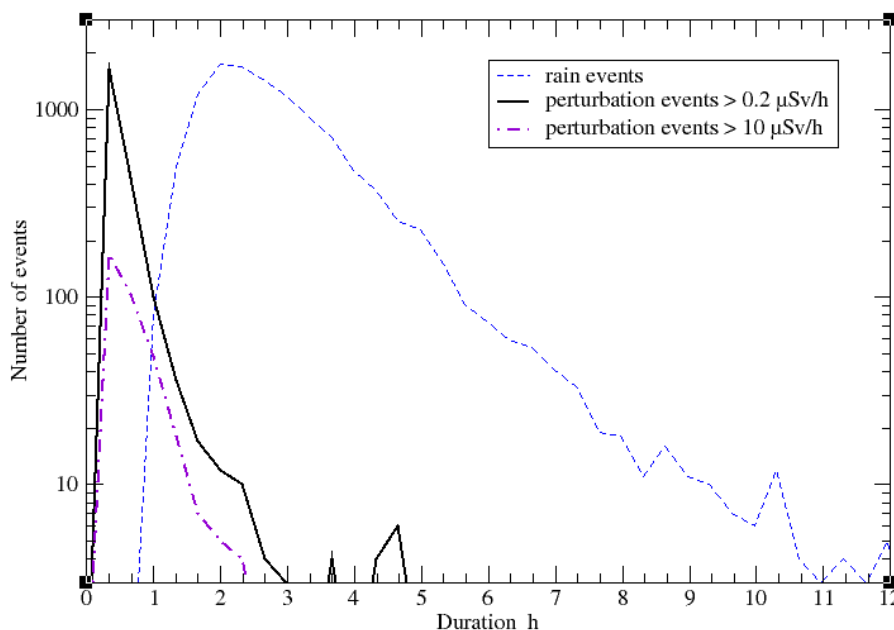


Fig. 10 Distribution of the duration of all events reported by BfS monitoring network in the period 2004 - 2006 exceeding the given warning levels. Blue dotted line show the distribution of the duration of rain events above the threshold of 0.05  $\mu\text{Sv/h}$

In figure 10 the number of events is shown on the ordinate on an logarithmic scale, whereas the duration of the events is plotted on the abscissa. The difference of the timely behaviour of rain events and technical perturbation events turns out to be significant:

- rain events have a duration of at least one hour and will typically last 3 hours up to more than 10 hours.
- only about 10 percent of perturbation events will last longer than one hour, 1 percent will last longer than 2 hours.

Thus a simple procedure can be proposed to distinguish between both kinds of events. This procedure is to wait 1 or 2 hours and the possibility to have false negative events will be 3 or 2 percent. Thus, the expected incidence rate of false negative alerts would be less than 50 cases per year.

## 6. Experience from simulation of scenario data

Using the RODOS decision support system, scenario data (simulated dose rate) have been calculated to produce realistic test data sets for INTAMAP. RODOS scenario data assume an accidental release e.g. from a nuclear power plant (NPP), the calculations could be performed with realistic weather conditions for atmospheric dispersion of contaminated air and for deposition of radioactivity as well.

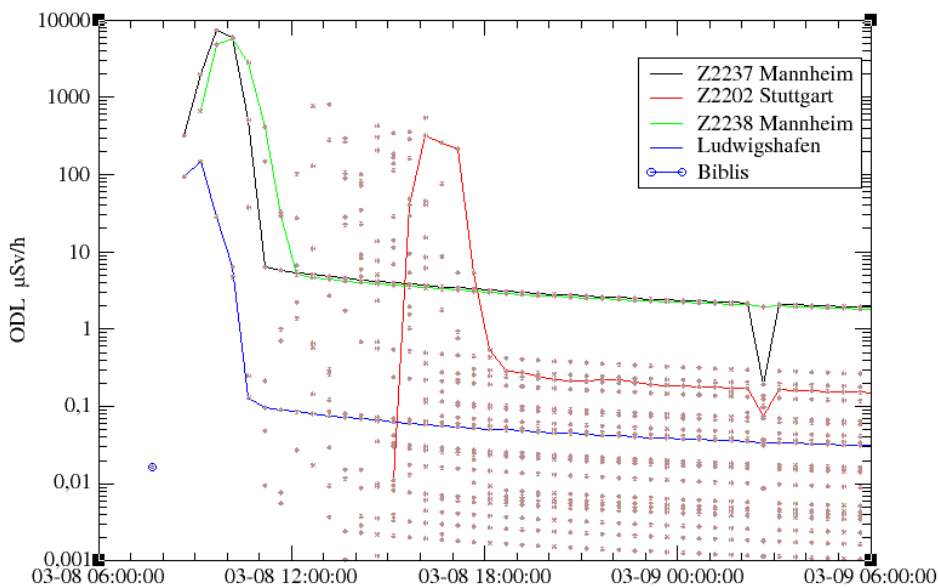
### 6.1 Analysis of RODOS Scenario 1: Accidental Release from NPP

The scenario corresponds to a core melting accident with a venting release to reduce the pressure in the confinement. Typically, noble gas inventory release is near 100 % in core melting scenarios. For a controlled loss of coolant accident, the assessed release for noble gas inventory was in the order of 0,05% (cf. DRS A) Iodine release is in the per cent region. Release of radionuclides on aerosols are effectively reduced by filter system. The assumed release lasted one hour.

**Table 6** Source Term: F5/AF from the German risk study phase B

Activity released [Bq] for groups of CALCULATION nuclides per time interval (time = hours after start of release)				
Time [hrs]	Activity release [Bq] for			
	Noble gas	Iodine	Aerosols	Specials
1	1.01E+19	3.53E+16	2.21E+13	0.00E+00

During the passage of the contaminated cloud, the dose rate is dominated by noble gas activity. The maximum value of simulated dose rate for measurement sites of the German network reaches 10.000  $\mu\text{Sv/h}$ . Due to atmospheric dispersion, this phase of cloud passage lasts 2 to 3 hours. After the passage of the contaminated cloud, iodine and aerosol activity deposited on ground causes enhanced dose rate up to some  $\mu\text{Sv/h}$ . This enhanced dose rate decrease due to the decay of short-lived radionuclides with an initial effective half-life of some hours (see Fig 11).



*Fig. 11 Simulated GDR at real monitoring sites in the 100-km region around the NPP Biblis for RODOS scenario 1 (dots). Solid line indicate time evolution of the GDR for selected monitoring sites.*

In the given scenario, simulated dose rate for real monitoring sites exceeds the warning level about 2 hours after the start of the release. Thus, the suggested warning criteria would trigger an alarm about 3 hours after the start of the release (see Fig. 11).

The findings of this scenario are valid for similar accidental situations with release of noble gas radionuclides. During passage of the contaminated cloud, it could be derived that net dose rate will certainly exceed the warning level of  $0.2 \mu\text{Sv/h}$ . However, scenario with reduced release of Iodine (below about  $1\text{E}+15 \text{ Bq}$  for similar weather conditions) would influence the warning function after this phase. In this case, after the passage of the cloud the dose rate would decrease below  $0.2 \mu\text{Sv/h}$ .

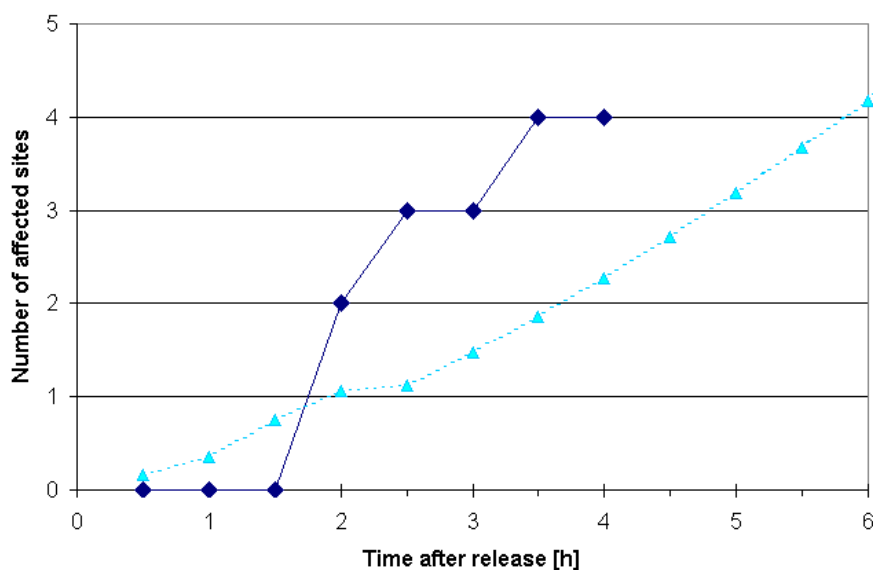


Fig. 12 Time evolution of the number of affected monitoring sites due to RODOS scenario 1. Solid line show the observed number of sites where simulated data exceed  $0.2 \mu\text{Sv/h}$ . Dotted line indicates the expected number calculated from the time evolution of the affected area in units of the area per monitoring station.

## 6.2 Analysis of RODOS Scenario 2: Transport accident

This scenario shows the impact of an accidental release of radioactivity caused by a heavy traffic accident of a vehicle during transport of a high radioactive source. It assumes release of  $10^{14} \text{ Bq}$  Cesium-137 and realistic weather conditions from April 10, 2007. Real weather data indicate dry deposition conditions. The RODOS calculations were performed with one hour average values for air activity concentration, thus simulated dose rate also represent 1 hour averages.

From scenario data, an effective wind speed of about  $10 \text{ km/h}$  could be derived for the cloud passage phase. In this phase the spatial extension of cloud is in the order of about  $100 \text{ km}^2$ . However, the warning level of  $0.2 \mu\text{Sv/h}$  would be exceeded up to down wind distance of about  $20 \text{ km}$  from the site of the release.

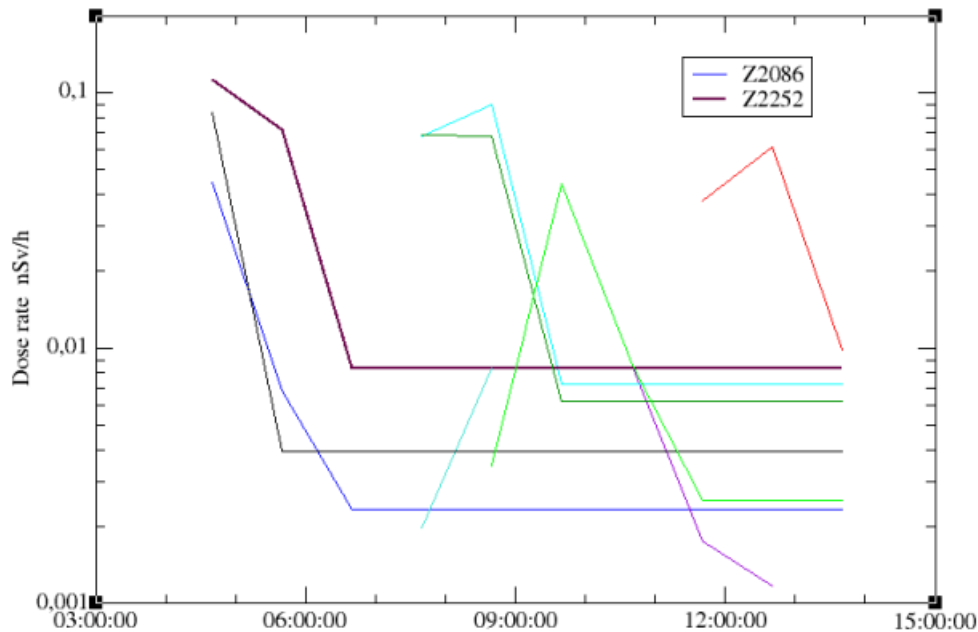


Fig. 13 Simulated GDR at real monitoring sites in the 100 km region around the NPP Biblis for RODOS scenario 2.

For Cesium-137, dose rate conversion factors are  $1,4 \cdot 10^{-4} \mu\text{Sv/h}$  per  $\text{Bq/m}^3$  and  $2 \cdot 10^{-3} \mu\text{Sv/h}$  per  $\text{kBq/m}^2$  (cf. Table B.1 and B.2 of IRCU report 53, for Barium-137m using emission probability 85% and  $1.21 \text{ Sv/Gy}$ ). Thus, the proposed warning level of  $0.2 \mu\text{Sv/h}$  corresponds with Cesium-137 air activity concentration of  $1400 \text{ Bq/m}^3$  and deposited concentration on ground of  $100 \text{ kBq/m}^2$ .

Fig 13 shows the time evolution of simulated net dose rate at real monitoring sites. 3 hours after the start of the release, dose rate would be exceeded at 3 sites. However, the simulated dose rate is below the warning level. The maximum dose rate is  $0.1 \mu\text{Sv/h}$ . After the cloud passage, net dose rate would decrease to a maximum level of about  $0.01 \mu\text{Sv/h}$ .

From this scenario data, the following conclusions could be derived:

- In case of dry deposition conditions, the warning level of  $0.2 \mu\text{Sv/h}$  would be exceeded in an area in the order of  $100 \text{ km}^2$ . Thus the detection probability for European monitoring systems would be less than some 10%. Under similar conditions, a  $10^{15} \text{ Bq}$  Cesium-137 release would be detectable by dense central European monitoring networks.
- In case of rainy weather, the deposition of radioactivity is much more efficient than under dry conditions. For wash-out, the deposition rate is by a factor of 100 or even more higher than under dry conditions. Thus, in case of wet deposition conditions, a  $10^{13} \text{ Bq}$  Cesium-137 release would be detectable by dense central European monitoring networks.

## 7. Conclusion

A simple procedure is proposed to detect abnormal situations for dose rate monitoring network on European level (EURDEP). False negative alerts due to technical perturbation events as well as to radiological events (enhanced natural radioactivity, rain events) are filtered effectively.

It is demonstrated, that the filtering algorithm is appropriate for the German monitoring system with more than 2000 probes. For the German monitoring network, less than 50 alerts per year are to be expected. In most cases, additional technical information available within the national system could be used to avoid false alerts within 1 hour.

The proposed early warning method should be appropriate for other European monitoring system as well.

The simple procedure will allow detecting abnormal situations for all dose rate monitoring networks on European level (EURDEP). False negative alerts due to technical perturbation events as well as to radiological events (enhanced natural radioactivity, rain events) are filtered effectively. Based on such an algorithm the expected incidence rate of false negative alerts in EURDEP would be less than 100 cases per year.

The proposed warning level would allow the detection of releases of about  $10^{13}$  to  $10^{15}$  Bq for gamma emitting nuclides by dense central European monitoring networks and corresponds with air activity concentrations in the order of  $1000 \text{ Bq/m}^3$  and activity deposited on ground in the order of  $100 \text{ kBq/m}^2$ .

At the moment, reduction of the proposed warning level would rise the incidence of false alerts by rain events. In principle, this problem could be solved by using detector types providing spectroscopic information or allowing natural rejection algorithms.

## References

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