

**A**  
**Report**  
**On**  
**Chernobyl**  
**Reports**

**W. Verschuur**  
**14 - 01 - 2013**  
**Bachelor Thesis**  
**Psychology**  
**University of Twente**

**Prof. Dr. J.M.C. Schraagen**

1st Supervisor

**Dr. M. Noordzij**

2nd Supervisor

## **Abstract**

Not many of us have ever read, or will ever read, an entire official report about the 1986 Chernobyl disaster. Yet, many of us will be able to mention, for instance, that the disaster took place at a nuclear power plant in the Ukraine, which at that time was part of the Soviet Union. It is very likely that some of us will be able to recall consequences of the catastrophe, or even mention which causes ultimately led to a dangerous exposure to radiation in a wide area. Somehow, we have been informed about what happened on and around that unfortunate day in April 1986. Since the disaster, many different media have reported about 'Chernobyl': newspapers, television, journals, magazines and (more recently) the internet. The forms these media use to provide us with information are not nearly as extensive as an official report. Thus, what we know about the Chernobyl accident is based on information that is by definition a reduction of what really happened. This study was aimed at finding out more about this reduction. What does it look like? Does the reduction follow a certain pattern? Reports about the Chernobyl disaster were studied to answer these questions. A total of 62 articles (31 scientific and 31 non-scientific) were analysed, using a coding scheme. Some interesting results were found: (1) basic elements of a simple story (Story Grammar Theory (Thorndyke, 1977)) appeared in most of the articles, especially in non-scientific texts. (2) Non-scientific descriptions of the Chernobyl disaster were longer and more detailed. (3) The number of words, used to describe the disaster, diminished over time. (4) 'Human error' appeared more often in non-scientific literature. (5) In both scientific and non-scientific articles, the focus on 'sharp end' elements of the accident was seen, although more often in non-scientific work. (6) The existence of a certain 'gist' (Bartlett, 1932), appears to be likely. Elements that were mentioned in almost any text about the disaster were: 'Chernobyl', 'nuclear power plant', 'April 26, 1986', 'explosion' and a 'release of radiation'.

<b>1. Introduction</b>	4
<b>1.1 Articles about Chernobyl as data</b>	4
<b>1.2 Information reduction in general</b>	5
<b>1.3 Information reduction on Chernobyl disaster</b>	8
<b>1.4 Variables</b>	11
<b>1.5 Research questions</b>	13
<b>2. Method</b>	15
<b>2.1 Materials</b>	15
<b>2.2 Coding scheme</b>	15
<b>2.3 Procedure</b>	16
<b>3. Results</b>	
<b>3.1 General information about the articles</b>	17
<b>3.2 Results on research questions</b>	17
<b>4. Conclusions and discussion</b>	30
<b>References</b>	34
<b>Appendix A</b>	35
<b>Appendix B</b>	44

## 1. INTRODUCTION

Not many of us have ever read, or will ever read, an entire official report about the 1986 Chernobyl disaster. Yet, many of us will be able to mention, for instance, that the disaster took place at a nuclear power plant in the Ukraine, which at that time was part of the Soviet Union. It is very likely that some of us will be able to recall consequences of the catastrophe, or even mention which causes ultimately led to a dangerous exposure to radiation in a wide area.

Somehow, we have been informed about what happened on and around that unfortunate day in April 1986. Since the disaster, many different media have reported about 'Chernobyl': newspapers, television, journals, magazines and (more recently) the internet. The forms these media use to provide us with information are not nearly as extensive as an official report. Thus, what we know about the Chernobyl accident is based on information that is by definition a reduction of what really happened. What is said in thousands of words cannot be said in a few words without losing some information. (Ignoring the fact that the reduction already started when the actual disaster was translated into language). Thus, a certain reduction is inherent to the practical world of spreading information. This study is aimed at finding out more about this reduction. What does it look like? Does the reduction follow a certain pattern? Reports about the Chernobyl disaster will be studied to answer these questions.

### 1. 1 Articles about Chernobyl as data

To detect a certain reductive pattern in reports on disasters, a thorough description of information reduction, as it reaches us through various media, is crucial. Therefore, what type of media to conduct research on, is of the utmost importance. Not all forms of media report seem to be equally suitable for our research purposes. In the first place, the media reports should be accessible to others and preserved completely unchanged, in order to facilitate replication of our research. Secondly, the reports should have some similarities, so that they can be compared to one another: one author may report on the Chernobyl disaster, only mentioning the aftermath, while another author is trying to explain some of the causes of the accident. The content of these two reports lay so far apart, that comparing them with one another makes no sense, given the purpose of this study, i.e. finding and describing a certain pattern of information reduction, within the reports. For example, comparing the number of goals scored in a football match, to the number of points made in a tennis play, is

meaningless. Third, there should be many of these reports, since a thorough picture of the reduction is desired. Fourth and last, the reports should be relatively easy to examine, given the large number required for analysis. Influenced by these four constraints, written material, scientific and non-scientific, within a range of 100 to 500 words, to be found via scientific and non-scientific internet search engines, seems to be most useful.

## 1.2 Information reduction in general

The ease with which information is reduced as it passes on between people is very well represented, using a well-known game as a metaphor: the Whisper Game, or as Bartlett (1932) names it: 'Chinese Whisper' or 'Broken Telephone' (Mesoudi, 2006). A number of people are sitting in a circle. One person starts the game with writing down a short story: the source. Then he or she whispers this exact story into the neighbour's ear. The neighbour passes the story on to his or her neighbour, again whispering. This continues until the message has reached the person who started the game. At that point, the final version is compared with the original story. A schematic representation of the Whisper Game would look like figure 1.

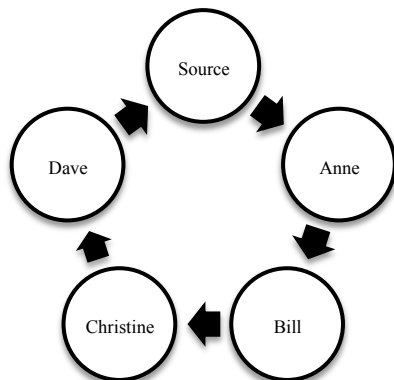


Figure 1: The Whisper Game. Source = original story, written down. Anne, Bill, Christine, Dave = people that pass information. Black arrow = whispering information.

Anyone who has ever played this game knows that an adequate recall of the original story is very rare. Bartlett made use of the Chinese Whisper game in several experiments. In a typical form of such an experiment, the first participant reads a text and tries to recall it. This recalled text is passed on to the second participant, who reads it and also attempts to recall the information. In a similar way the third, fourth, fifth, etc. person in the chain is being informed and asked to recall. Bartlett measured the changes that occurred between the recalls, as information passed along the chain. From these experiments, Bartlett deduced the existence of two mechanisms in information passing. The first is that participants tend to make the

received information shorter in length, less detailed, with only an overall gist remaining. Secondly, participants tend to twist information, in order to make it more coherent and consistent with what they already know (Mesoudi & Whiten, 2008). "These two processes," as Mesoudi and Whiten (2008, p. 3491) state, "loss of detail and assimilation to prior knowledge, led Bartlett (1932) to propose that remembering is primarily a reconstructive process, and seldom a process of exact replication. Only the gist or overall impression of the material is preserved and rebuilt around pre-existing knowledge structures or schemas."

Imagine that in the Whisper Game as presented in figure 1, Dave is not able to mention the original story accurately. Where, how, and why did it go wrong? According to Bartlett, Dave would probably have shortened, changed, 'un-detailed', 'gisted' and fit the information he received into pre-existing schemas. Most likely, Anne, Bill and Christine did the same, in earlier stages. Thus, the text that finally reaches the game starter (Source) is the result of a mix of incorrect information streams (the black arrows) and false cognitive processing (within Anne's, Bill's, Christine's and Dave's minds).

This typical mix has been confirmed by Vicente and Brewer (1993). They conducted research in which they investigated the role of reconstructive memory in citation errors that occur in the scientific literature. For their study, they made use of research done by De Groot, concerning memory of chess players. In one of the experiments that Vicente and Brewer conducted, members of Psychology faculties at two major Universities were given an open-ended question asking them to describe what they remembered about the details of De Groot's work, without consulting any references. Fifteen members of the faculty answered the question. Vicente and Brewer ascertained that all data were "consistent with three different positions: (a) the sources these scientists read were distorted, but the memories of the scientists were accurate representations of these texts; (b) these scientists had read one of the correct sources and this information became distorted in the recall process; and (c) there were distortions in both the original texts and in the memory of the scientists." Translating these three options to Dave in the Whisper Game would lead to the following conclusion: given the fact that Dave does not recall the original story properly, he must have (1) received the wrong information from Christine and passed this information on accurately, or (2) he received the correct information from Christine, but something went wrong in the recall process, or (3) he received the wrong information from Christine and made a mistake in the process of recalling.

In the Whisper Game example, the source is perceived by only one person. In the real world a source is, usually, perceived by many people. Think of it as a rippling in the water, after a stone was thrown in.

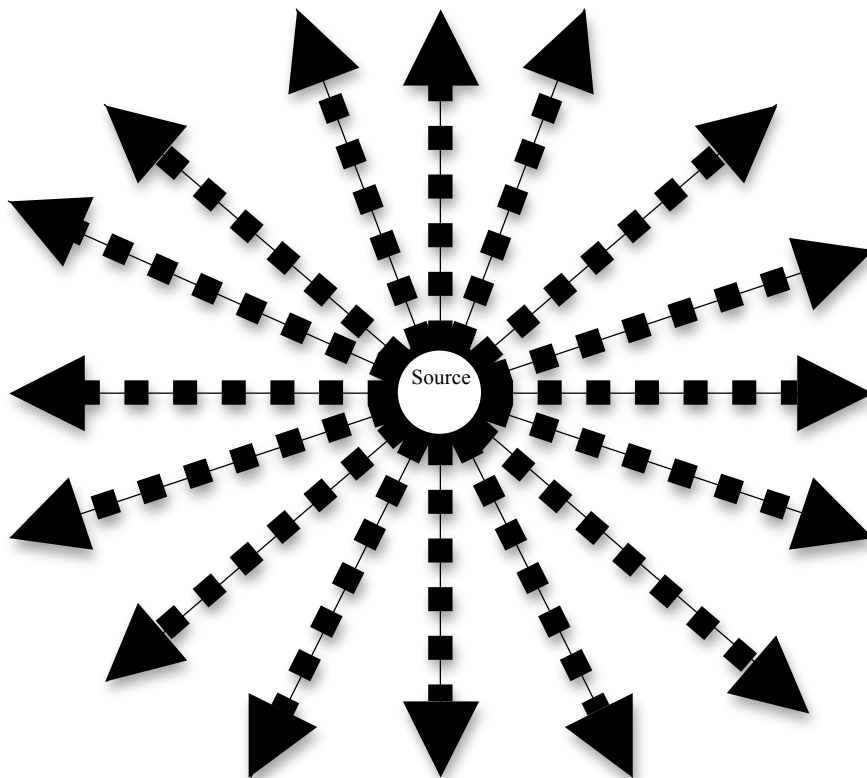


Figure 2: Information spreading as 'rippling water'. Source = the original source, i.e. an official report about the Chernobyl disaster. Black boxes = people who spread information by publishing or speaking, e.g., a journalist. Arrowed lines = the information streams, e.g., an article in the newspaper.

The spreading of information could be imagined as an endless number of water ripples (figure 2), with an endless number of links, related to each other in an endless number of ways. As demonstrated by Bartlett (1932), this spreading of information is prone to reduction. Other research concerning information reduction has been carried out by Feltovich et al. (1994; 2004). They argue that information reduction follows a certain pattern. Feltovich et al. (2004) state that, in order to learn, people tend to simplify, or even oversimplify, information into better retrievable and understandable knowledge. They call this simplification the Reductive Tendency. A total of eleven dimensions, by which a certain Reductive Tendency takes place, are distinguished. Each of the eleven dimensions represents a general difficulty in learning. Examples of these dimensions are *static versus dynamic*, *sequential versus simultaneous*, *universal versus conditional*, *regular versus irregular* and *surface versus deep*. In all dimensions, the second option is considered to be more difficult, in the sense that these options require more mental effort. Feltovich et al. (2004) state that people have a tendency to

lean towards the first option of each dimension, even when the truth is more consistent with the second option.

In what manner would these reduction tendencies, as described by Bartlett (shortening, changing, 'un-detailing', 'gisting' and fitting the information into pre-existing schemas) and Feltovich (simplifying complexity), appear in reports about an accident, such as the Chernobyl nuclear disaster? To answer that question, one should start with another question: what kind of schema could be the basis of a description of the Chernobyl disaster?

### **1.3 Information reduction on Chernobyl disaster**

First, before formulating a theoretical framework, it is interesting to take a closer look at the Chernobyl disaster itself. Below, a short version of what happened is presented.

*April 25, 1986. At a nuclear power plant (NPP) in Chernobyl, Ukraine (former Soviet Union) a maintenance shutdown of reactor 4 was scheduled. The plant management decided to take advantage of this situation, by conducting a safety test which (after earlier unsuccessful attempts) still had to be done. The test was meant to check whether the cooling pumps would be able to cool enough, driven by an energy buffer, during a power gap between a total shut down and the emergency diesel generators running full speed. The test was planned to take place at daytime, during the shift of more experienced operators. But, due to problems at another power plant in Ukraine, Chernobyl received the request to keep running. The daytime shift had to wait until late in the evening before they could start to prepare for the test. As a requirement for the test to begin, the reactor had to run at a lower output than normal, ideally between 700 and 1000 MWth. The operator in charge tried to lower the (thermal) output (which was now probably around a normal 2000 MWth) by inserting control rods into the reactor. He succeeded, and by the time the power output reached the desired 700 MWth, the nightshift took over. Not much later, things went wrong. Probably the system was not working properly, due to which power dropped too much. As a result the so called 'xenon poisoning effect' caused the power output to drop even further, to about 30 MWth. That was way too low. In order to restore the power output, the operator removed many control rods. Too many, according the safety rules, which prescribe a specific Operation Reactivity Margin (ORM). It is very likely that the operator in charge did not know he violated rules. The computer (SKALA) that should have calculated the number of control rods to be left in and out, was probably not working properly. The automatic shutdown function was disabled, which was according to protocol for the test preparation. The thermal power output*



increased as desired and expected. Finally, the operators established a somewhat stable situation around a power output of 200 MWth. 26 April, 01:23:04 AM: The test was started. The steam supply to the generators was cut off, as planned. At this time the diesel generators had to start up. This would take about 1 minute, in which the energy buffer should have been sufficient to supply the cooling pumps. This appeared to be not the case. Too much steam was formed in the reactor core, causing a 'positive void effect' (one of the design flaws of the RBMK-1000 reactors that were used in Chernobyl), due to which the thermal output increased rapidly and the nuclear chain reaction went out of control. A steam explosion occurred. One of the operators pushed the emergency shutdown button (also named AZ-5 or SCRAM button), which immediately inserts all control rods into the reactor core. Due to design flaws of the control rods, instead of stopping the nuclear chain reaction, there was an initial power surge. At 01:24 AM this surge led to an even bigger explosion. The protecting shield was blown off. Radiation was released and the graphite core burned for almost ten days. More than 30 people died in the first few weeks. (INSAG-7, 1992).

What kind of schema could be the basis of a description of the Chernobyl disaster, such as the one above? Descriptions of a disaster can be seen of as a story. Therefore, theory on story grammar, as formulated by Thorndyke (1977), may be useful as a blueprint. In his story grammar theory, Thorndyke proposes the existence of 4 basic elements in a simple story: *Setting*, *Theme*, *Plot* and *Resolution*. The *Setting* consists of *Location*, *Characters* and *Time*. The *Theme* consists of the *Goal* of a story. The *Plot* consists of the *Episode*, and the *Resolution* consists of an *Event* or *State*. This structure, applied to the Chernobyl case, is shown in Table 1 below.

1 Setting:	1.1 Characters:	1.1a NPP Operators
		1.1b NPP Management
	1.2 Location:	1.2a Ukraine
		1.2b Chernobyl
		1.2c Nuclear Power Plant (NPP)
		1.2d Reactor 4
		1.2e Control Room

	1.3 Time:	1.3a April 25/26
		1.3b At night (01:24 AM)
2 Theme:	2.1 Goal:	2.1a Reactor design flaws
		2.1b Operators' human error 2.1c Operators' lack of knowledge 2.1d Management pressure 2.1e Time pressure 2.1f Poor safety culture
3 Plot:	3.1 Episode:	3.1a (Bad) design RBMK reactor
		3.1b Poor safety culture 3.1c Experiment was postponed to the nightshift 3.1d Operators (or engineers) did not have enough knowledge 3.1e Xenon poisoning 3.1f (Thermal) power output dropped enormously 3.1g Pressure from management to go on with experiment 3.1h Operators (or engineers) turned off automatic shutdown system 3.1i Operators (or engineers) made mistakes 3.1j Violation of safety rules (e.g. such as the Reactor 4 running below the Operating Reactivity Margin (ORM)) 3.1k Conduction of an experiment/test (incompletely and incorrectly prepared) 3.1l Positive void coefficient (positive feedback loop of increasing nuclear (and thermal) power output) 3.1m Tips of safety rods were made of a moderator, namely graphite 3.1n Activating the emergency shut-down (SCRAM, AZ(-5) button, Panic Button) 3.1o Massive power surge (e.g. when safety rods were led down into the reactor)
4 Resolution:	4.1 Event/state:	4.1a Explosion

	4.1b Radiation release 4.1c (Number of) deadly victims
--	---

Table 1: story grammar schema applied on Chernobyl case.

## 1.4 Variables

The structure, as presented in Table 1, may act as a schema (Bartlett, 1932) by which people tend to order an event, such as the Chernobyl disaster ("material is preserved and rebuilt around pre-existing knowledge structures or schemas" (Mesoudi & Whiten, 2008, p. 3491)). Therefore, the aspects of Thorndyke's story grammar (1977) are likely to appear in reports on the Chernobyl catastrophe. Assuming that the scheme in figure 3 is applicable to Chernobyl descriptions in media reports: in what way can the schema contribute to the measurement of a certain information reduction? Bartlett found that people tend to shorten texts in length, with less detail and only an overall gist remaining (Mesoudi & Whiten, 2008). Structuring these three elements along the schema in figure 3, the following patterns are likely to occur: (1) authors reduce the number of Setting-elements, Theme-elements, Plot-elements and Resolution-elements, (2) authors reduce the number of words, used to describe certain elements of the disaster and (3) authors do not reduce an essence, the 'gist'. In order to find a certain tendency, independent variables are needed. Three independent variables are probably useful: the factor time (older to newer), the factor expertise of the author (scientific or non-scientific) and the factor of precision (author mentioning, or not mentioning references).

Another interesting phenomenon, in the context of information reduction, is the distinction between *latent conditions* and *active errors* (Reason, 1997). "In health care, active errors are committed by those providers (e.g., nurses, physicians, technicians) who are in the middle of the action, responding to patient needs at the *sharp end*. (Cook & Woods, 1994) Latent conditions are the potential contributing factors that are hidden and lie dormant in the health care delivery system, occurring upstream at the more remote tiers, far removed from the active end" (Henriksen et al., 2008, p. 74). Translated to the Chernobyl case, the operators in the NPP control room, during the catastrophic test, were at the sharp end, making the active errors (inserting too many control rods, pushing the emergency button, etc.). Whereas latent conditions had been established in earlier stages, as a result of general shortcomings, such as a poor safety culture and bad reactor design; the *blunt end*. The relation between these endpoints is described by Reason (1990) as follows: "Rather than being the main instigators of an accident, operators tend to be inheritors of system defects created by poor design, incorrect installation, faulty maintenance and bad management decisions. Their part is usually

that of adding a final garnish to a lethal brew whose ingredients have already been long in the cooking." (Henriksen et al., 2008, p. 74).

Do authors have a tendency to point out either the blunt end of the disaster, or the sharp end? And if they do so, are the independent variables (year, expertise and precision) having any influence? According to Wears and Leape (1999, pg. 371): "Error investigations, when they occur at all in the traditional model, concentrate on the 'sharp end' of the system, where patients and care givers interact. They generally ignore the many contributing factors and latent errors that originate in the 'blunt end', where the organizational policies, procedures, and resource allocation decisions are made that drive the 'sharp end'."

When taking a closer look at the Plot-elements in the story grammar schema (Table 1), point 3.1a to point 3.1o (causes of the Chernobyl accident) can be ordered chronologically. This ranking following a timeline, results in a list of 15 causes: from 'blundest end' to sharpest end'. Figure 3 shows this list, with three categories: *blunt end*, *sharp end* and *sharpest end*.

#### Blunt end

- 3.1a (Bad) design RBMK reactor
- 3.1m Tips of safety rods were made of a moderator, namely graphite
- 3.1b Poor safety culture
- 3.1d Operators (or engineers) did not have enough knowledge
- 3.1c Experiment was postponed to the nightshift

#### Sharp end

- 3.1e Xenon poisoning
- 3.1f (Thermal) power output dropped enormously
- 3.1g Pressure from management to go on with experiment
- 3.1h Operators (or engineers) turned off automatic shutdown system
- 3.1i Operators (or engineers) made mistakes

#### Sharpest end

- 3.1j Violation of safety rules (e.g. such as the Reactor 4 running below the Operating Reactivity Margin (ORM))
- 3.1k Conduction of an experiment/test (incompletely and incorrectly prepared)
- 3.1l Positive void coefficient (positive feedback loop of increasing nuclear (and thermal) power output)
- 3.1n Activating the emergency shut-down (SCRAM, AZ(-5) button, Panic Button)
- 3.1o Massive power surge (e.g. when safety rods were led down into the reactor)

Figure 3: blunt end to sharp end.

The sharp and sharpest end factors are, in almost any case, examples of human error. Thus, when authors emphasize sharp end causes over blunt end factors, they accept human error as a fair argument. Dekker and Nyce (2011) discussed the issue of cultural acceptance of human error and the individual responsibility in their publication *Cognitive Engineering and the moral theology and witchcraft of cause*. They state that: "In the Western intellectual tradition, it has seemed self-evident to see ourselves and evaluate ourselves as individuals ... It also seemed self-evident that we should be evaluated in terms of our personal achievements (or failures to achieve)." This cultural background might be a basis for a reduction of information towards a focus on the sharp end, and in specific human error (figure 3, 3.1i). Is there a focus on human error? And if there is, do any of the independent variables relate to this focus?

### **1.5 Research questions**

The following research questions are formulated:

#### Question 1

*Does the number of*

*Q1.1 Setting-elements,*

*Q1.2 Theme-elements,*

*Q1.3 Plot-elements, and*

*Q1.4 Resolution-elements, diminish*

*a) over time (year: old to new)?*

*b) with lack of expertise (genre: scientific/non-scientific)?*

*c) with lack of precision (source: source mentioned/no source mentioned)?*

#### Question 2

*Q2) Does the number of words describing the causes, diminish*

*a) over time (year: old to new)?*

*b) with lack of expertise (genre: scientific/non-scientific)?*

*c) with lack of precision (source: source mentioned/no source mentioned)?*

#### Question 3

*Q3) Does the number of mentioned causes diminish*

*a) over time (year: old to new)?*

*b) with lack of expertise (genre: scientific/non-scientific)?*

*c) with lack of precision (source: source mentioned/no source mentioned)?*

Question 4

*Q4) Do authors tend to focus on sharp end causes?*

Question 5

*Q5) Is the human error theme mentioned most often?*

Question 6

*Q6) Are the story grammar elements (setting, theme, plot and resolution) useful as a schema for reports on the Chernobyl disaster?*

Question 7

*Q7) Do the independent variables (time, lack of expertise and lack of precision) influence hypothesis the focus on sharp end and human error?*

Question 8

*Q8) Does a certain gist appear, a story that is always mentioned, regardless of any factor?*

## 2. METHOD

### 2.1 Materials

Articles, in which a description was given about the 1986 Chernobyl disaster, were targeted as materials for answering the exploratory research questions. Initially, the search for useful articles was done via Google Scholar. Not each search result was suitable. Some constraints defined the eventual search string and the selection of articles that were returned. Constraints that influenced the search query were: (1) articles had to be written in English. (2) The number of words with which the Chernobyl disaster was described had to be within a certain range, between a minimum of 100 and a maximum of 500. (3) Also, the description had to consist of an explanation of what led to the fatal explosion. Using merely the word "Chernobyl" or even "Chernobyl disaster" resulted in 100 pages with results. Nearly none of the results fulfilled constraints (2) and (3). Descriptions on the accident were too long, or the causes of the fatal explosion were not mentioned, because, from the viewpoint of the authors, the released radiation (and the exposure to it) was the disaster, not the power plant explosion that caused it. Therefore, a more specific search query was needed. Finally, "Chernobyl causes explosion" appeared to be a suitable string. Again, a total of 100 pages with search results were returned. Further selection had to be done, rejecting articles because of constraints (2) and (3), added with (4): the date of publication had to be mentioned. From the total of 100 pages with results, 34 articles satisfied all constraints. 31 were scientific publications, 3 were non-scientific (scientific articles are defined as those, that are published under the flag of a University or any other scientific organisation; all other articles are labeled as non-scientific). In order to compare scientific and non-scientific material optimally, 28 more non-scientific articles had to be found, resulting in a total of 62 articles: 31 scientific and 31 non-scientific articles. The 28 non-scientific articles were collected using the regular Google search engine, restricted to the same search query and constraints as mentioned earlier.

### 2.2 Coding scheme

To analyze the 62 articles, they had to be coded. A coding scheme was developed (see Appendix A). The coding scheme consisted of 103 variables, representing all the facets as mentioned in the introduction. Setting, theme, plot, resolution (schema), sharpest, sharp, and blunt end, the causes, independent variables (year of publication, genre scientific or non-scientific, reference use or no reference use), general descriptions such as: article reference,

internet-link, number of words article, number of words about the accident, year of publication, etc.. The final coding scheme was tested for its inter-rater reliability, using Cohen's Kappa. Via earlier versions, which scored successively 0.50, 0.58 , 0.65, the final coding scheme scored 0.77, which may be considered a high level of inter-rater reliability.

### **2.3 Procedure**

The articles were collected via the internet, as mentioned earlier. All texts were saved. Then, the articles were coded, using the coding scheme. The filled in coding schemes were labeled and coupled to the underlying article. The coded texts from the articles are presented in Appendix B.



### 3. RESULTS

#### 3.1 General information about the articles

A total of 62 articles were coded, 31 of which were scientific; 31 were non-scientific. Table 2 presents general characteristics of the articles, such as average number of words, lowest and highest number of words and distribution over publication dates.

	<i>average number of words article</i>	<i>lowest number of words article</i>	<i>highest number of words article</i>	<i>average number of words Chernobyl</i>	<i>lowest number of words Chernobyl</i>	<i>highst number of words Chrenobyl</i>
<i>all articles</i>	7.456,34	472	121.547	259,94	101	498
<i>scientific</i>	12.947,32	2.011	121.547	230,19	101	484
<i>non-scientific</i>	1.967,35	472	8.776	289,69	105	498

	<i>1986-1994</i>	<i>1995-2003</i>	<i>2004-2012</i>	<i>reference: yes</i>
<i>all articles</i>	7 (11,3%)	11 (17,7%)	44 (71%)	35 (56,5%)
<i>scientific</i>	4 (12,9%)	6 (19,4%)	21 (67,7%)	26 (83,9%)
<i>non-scientific</i>	3 (9,7%)	5 (16,1%)	23 (74,2)	9 (29%)

Table 2: general numeric information articles

#### 3.2 Results on research questions

Data analysis was done, using SPSS. Performed are the one-way ANOVA and Chi-square test. For all results on the performed statistical tests, a significance level of .05 was used. Levels between .05 and .1 are marginally significant.

##### Question 1

*Q1.1a) Does the number of setting-elements diminish over time (publication date, old to new)?*

Neither the data, nor the analysis suggest the existence of such a tendency. The figure below (Figure 4) shows the average number of setting-elements per time unit. The mean number of setting-elements slightly increased from  $M = 5$  within the first 8 years, to  $M = 5,27$  in the last 8 years.

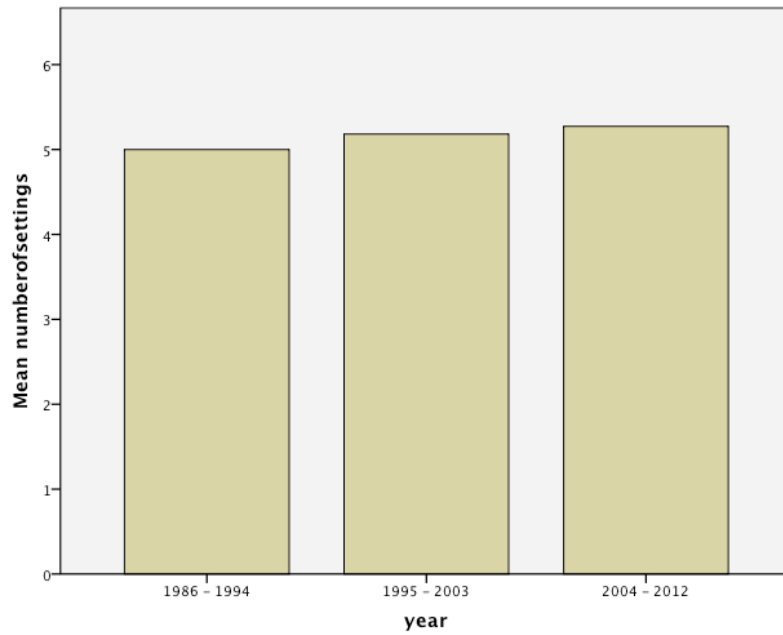


Figure 4: mean number of setting-elements to year of publication.

Performing a one-way ANOVA (year, number of settings), resulted in a  $F(2,59) = 0.132$ ,  $p = .88$ .

*Q1.1b) Does the number of setting-elements diminish with lack of expertise (scientific - non-scientific)?* Analysis gives rise to confirm the opposite tendency. There is a significant difference between the scientific and non-scientific articles, concerning the number of setting-elements that are mentioned. The chart below (Figure 5) shows the average number of setting-elements for each genre, which is higher within the group of non-scientific articles ( $M = 5,61$ ) than it is within the group of scientific articles ( $M = 4,84$ ).

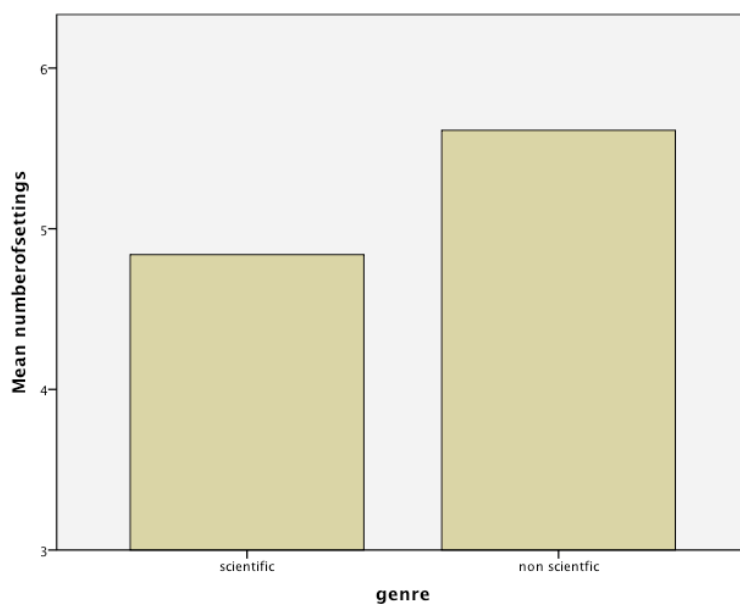


Figure 5: mean number of setting-elements to genre.

A one-way ANOVA (dependent: number of setting-elements, factor: scientific or non-scientific), showed a significant difference between genres,  $F(1,60) = 5.71, p = .02$ .

*Q1.1c) Does the number of setting-elements diminish with lack of precision (source mentioned or no source mentioned)?* A marginally significant difference is found, after conducting a one-way ANOVA (dependent: number of setting-elements, factor: scientific or non-scientific):  $F(1,60) = 3.85, p = .06$ . Another one-way ANOVA was run (dependent: number of setting-elements, factor: source or no source), testing only the 31 non-scientific articles, which resulted in:  $F(1,29) = 0.03, p = .88$ . One more one-way ANOVA was performed (dependent: number of setting-elements, factor: source or no source, testing only the 31 scientific articles). Result:  $F(1,29) = 1.98, p = .17$ .

*Q1.2a) Does the number of theme-elements diminish over time (publication date, old to new)?*

*Q1.2b) Does the number of theme-elements diminish with lack of expertise (scientific - non-scientific)?*

*Q1.2c) Does the number of theme-elements diminish with lack of precision (source mentioned - no source mentioned)?* Neither 1.2a, nor 1.2b and 1.2c appeared to show any significant tendencies. In respective, using the associated one-way ANOVA's, the following results were delivered:  $F(2,59) = 1.02, p = .37$ ;  $F(1,60) = 0.99, p = .32$ ;  $F(1,60) = 1.04, p = .31$ . Performing the same ANOVA's on 'scientific' and 'non-scientific' separately (for 1.2a and 1.2c), also delivered no significant values.

*Q1.3a) Does the number of plot-elements diminish over time (publication date, old to new)?*

No significant difference, using a one-way ANOVA (dependent variable: number of causes on plot; factor: year) appeared:  $F(2,59)=0.88, p=.42$ . Again, performing the same ANOVA's on 'scientific' and 'non-scientific' separately, delivered no significant values, namely  $F(2,28) = 1.65, p = .21$  and  $F(2,28) = 0.63, p = .54$ .

*Q1.3b) Does the number of plot-elements diminish with a lack of expertise (scientific - non-scientific)?* The opposite tendency is suggested, using a one-way ANOVA (dependent variable: number of causes on plot; factor: scientific or non-scientific):  $F(1,60) = 4.04, p = .05$ . The figure below (Figure 6) shows the mean number of plot-elements to genre: 'scientific' ( $M = 1.87$ ) and 'non-scientific' ( $M = 2.61$ ).

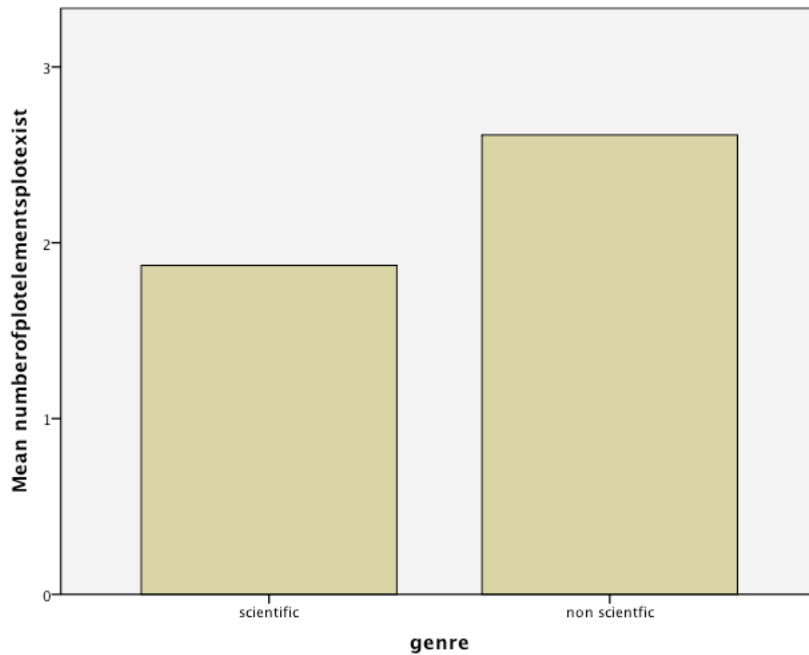


Figure 6: mean number of plot elements to genre.

*Q1.3c) Does the number of plot-elements diminish with lack of precision (source mentioned - no source mentioned)?* Conducting a one-way ANOVA (dependent variable: number of causes on plot; factor: scientific or non-scientific) returned  $F(1,60) = 3.37, p = .07$ , which suggests marginally significance. Again, after performing the same ANOVA's on 'scientific' and 'non-scientific' separately (for 1.3a and 1.3c) there were no significanies found.

*Q1.4a) Does the number of resolution-elements diminish over time (publication date, old to new)?*

*Q1.4b) Does the number of resolution-elements diminish with lack of expertise (scientific - non-scientific)?*

*Q1.4c) Does the number of resolution-elements diminish with lack of precision (source mentioned - no source mentioned)?* Neither 1.4a, nor 1.4b and 1.4c showed any significant tendencies. In respective, using the associated one-way ANOVA's, they had a significancy value of  $p = .74, p = .33$ , and  $p = .91$ . Performing the same ANOVA's on 'scientific' and 'non-scientific' separately (for 1.4a and 1.4c) , also delivered no significant differences.

## Question 2

*Q2a) Does the number of words describing the causes diminish over time (publication date, old to new)?* Analysis on the data, using a one-way ANOVA (dependent variable: total number of words on causes; factor: year) suggests the existence of such a tendency.  $F(2,59) =$

3.65,  $p = .03$ . Figure 7 shows the direction of the tendency; from  $M = 155.86$  (1986-1994), via  $M = 72.73$  (1995-2003), to  $M = 102.87$  (2004-2012).

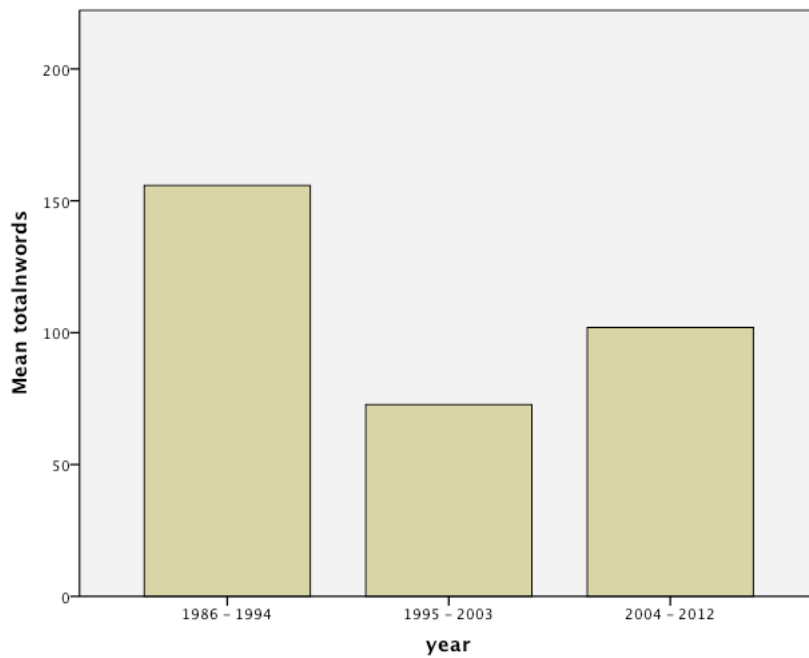


Figure 7: mean number of words on causes to year.

Interestingly, running the same ANOVA on the scientific group only, delivered no significance:  $F(2,28) = 0.98$ ,  $p = .39$ . In Figure 8 one can see the average number of words, concerning causes of the Chernobyl accident, to decrease over time (from  $M = 131$ , via  $M = 73.5$ , to  $M = 81.1$ ). Nevertheless, apparently the tendency is not significant.

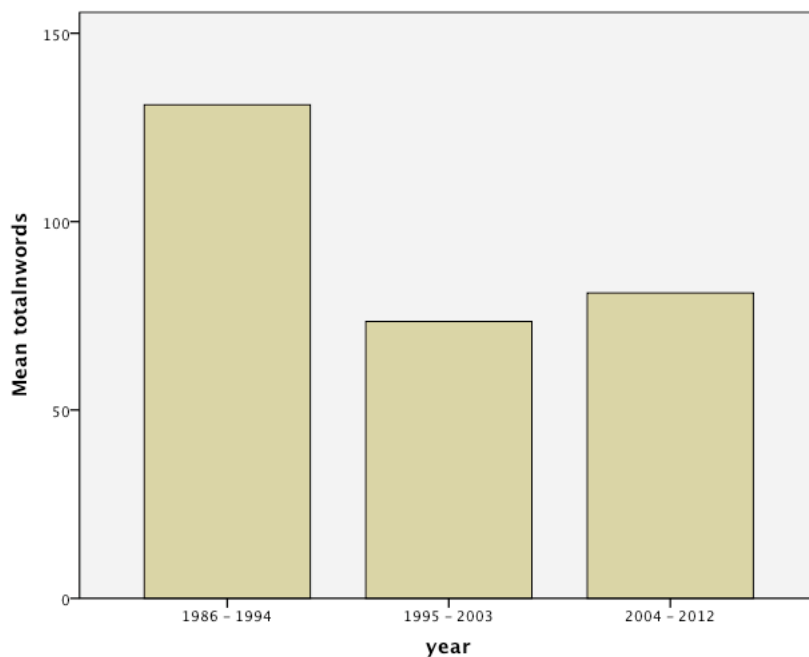


Figure 8: mean number of words on causes to year, only scientific articles.

Thus, running the same ANOVA on the non-scientific group had to result in a significant value. It did:  $F(2,28) = 4.48, p = .02$ . This suggests that the expected tendency (the decrease in number of words, concerning the chernobyl disaster's causes) is only seen in non-scientific articles. The mean number of words on causes of the Chernobyl disaster decreased from  $M = 189$  (1986-1994), via  $M = 71.8$  (1995-2003), to  $M = 121.04$  (2004-2012). In Figure 9, the differences within the non-scientific data are presented.

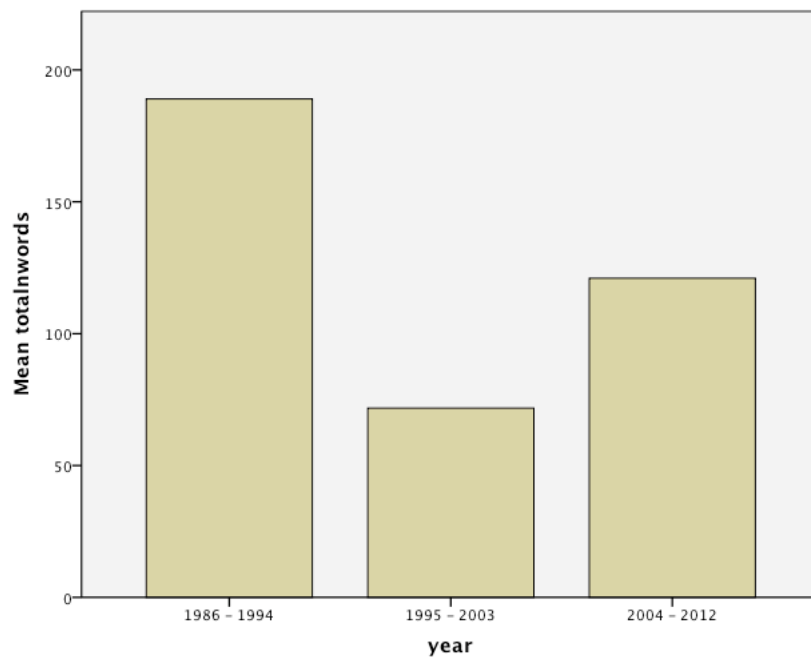


Figure 9: mean number of words on causes to year, only non-scientific articles.

*Q2b) Does the number of words describing the causes diminish with lack of expertise (scientific - non-scientific)?* The figure below (Figure 10) shows an opposite tendency. The average 'number of causes that are mentioned' was higher in non-scientific articles:  $M = 86.06$  opposed to  $M = 119.68$ .

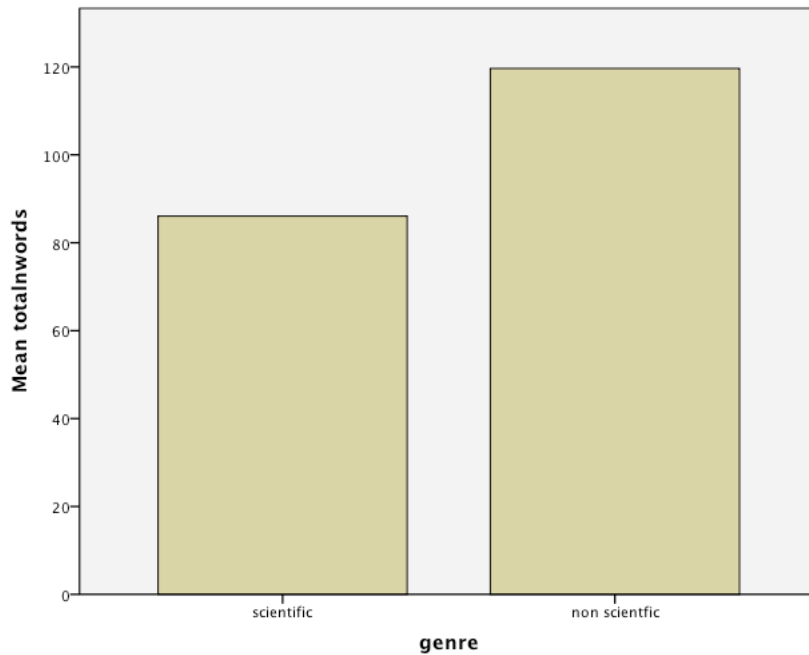


Figure 10: mean number of words on causes to genre.

The difference between scientific and non-scientific texts appeared to be significant, after having performed a one-way ANOVA (dependent: number of words on causes; factor: scientific or non-scientific):  $F(1,60) = 4.61, p = 0.05$ .

*Q2c) Does the number of words describing the causes diminish with lack of precision (source mentioned - no source mentioned)?* The source-element appeared to be not a significant factor in determining the 'number of words describing causes' of the Chernobyl accident. Performed was a one-way ANOVA (dependent: source or no source; factor: number of words on causes):  $F(1,60) = 2.24, p = .14$ . The results, using the same ANOVA's, for non-scientific only and scientific only were not significant either; successively  $F(1,29) = 0.06, p = .81$  and  $F(1,29) = 0.18, p = .67$ .

### Question 3

*Q3a) Does the number of causes that are mentioned, diminish over time?* Another interesting variable to add, besides the 'number of words on causes', may be the 'mentioned number of causes' itself. Conducting a one-way ANOVA(year; number of causes) resulted in:  $F(2,59) = 1.03, p = .36$ . The averages, as presented in Figure 11 were  $M = 4.14$  (1986-1994),  $M = 3.36$  (1995-2003) and  $M = 4.18$  (2004-2012).

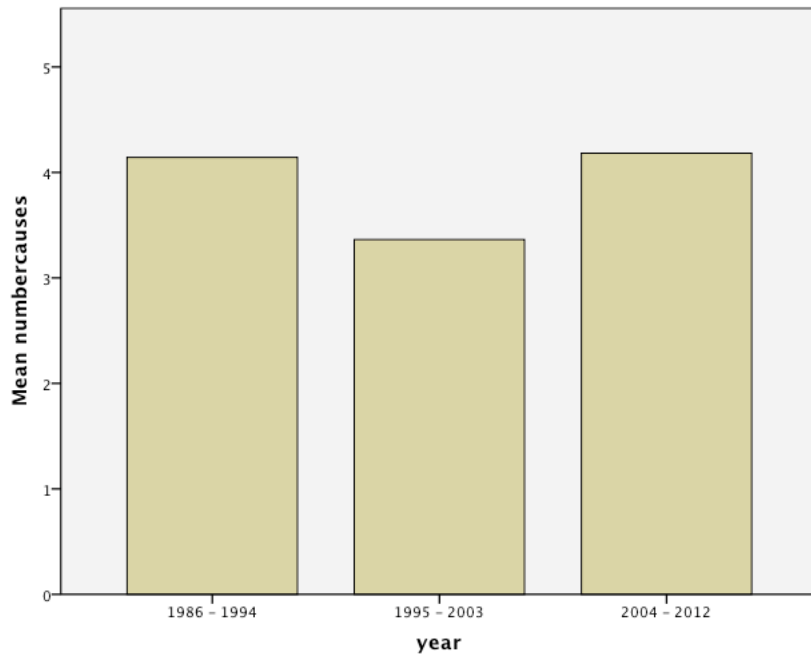


Figure 11: mean number of causes to year.

Then the ANOVA was performed with only scientific articles and only non-scientific articles; both tests did not deliver a significant outcome, successively  $F(2,28) = 0.32, p = .73$  and  $F(2,28) = 0.72, p = .50$ .

*Q3b) Does the number of causes that are mentioned, diminish with genre (scientific or non-scientific)?* A one-way ANOVA (dependent: number of causes; factor: scientific or non-scientific) was run through all data to find out whether the 'number of causes that are mentioned' show any tendency. Figure 12 gave rise to such a conclusion, and the results on the one-way ANOVA confirmed the difference between scientific ( $M = 3.45$ ) and non-scientific ( $M = 4.61$ ):  $F(1,60) = 7.99, p = .006$ .



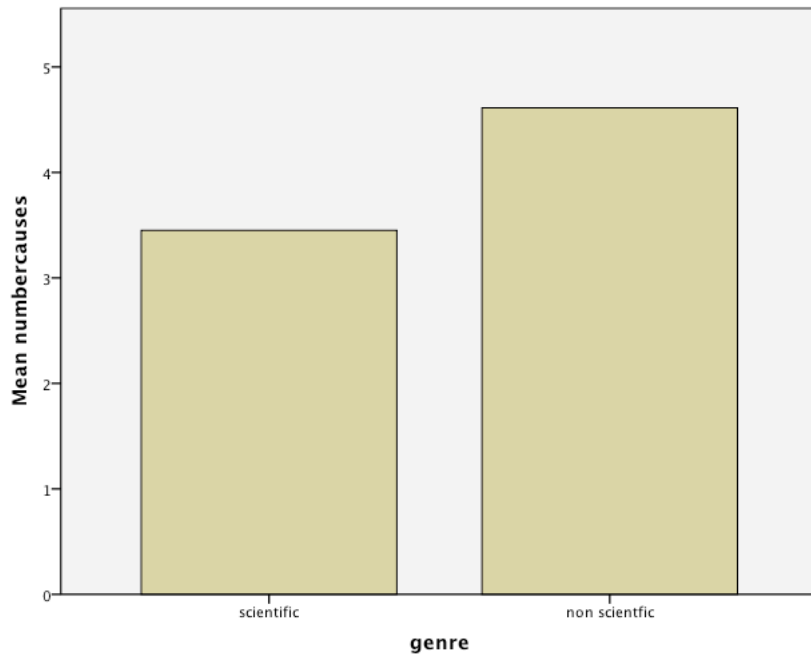


Figure 12: mean number of causes to genre.

*Q3c) Does the number of causes that are mentioned, diminish with lack of precision?* When the one-way ANOVA was run for the number of causes that were mentioned, a significancy value of  $p = .014$  was delivered:  $F(1,60) = 6.37$ . Figure 13 shows the direction of the relation. In articles without any reference, there were more causes mentioned ( $M = 3.57$  opposed to  $M = 4.63$ ).

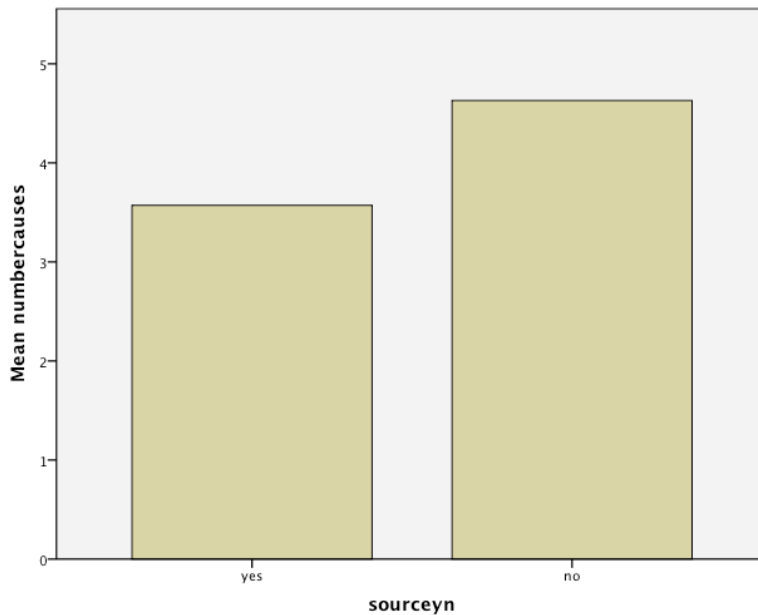


Figure 13: mean number of causes to source.

A part of the explanation for the differences between scientific and non-scientific articles, concerning the 'number of words on causes' and the 'number of causes mentioned' might lay in a difference in the 'total number of words on Chernobyl' as a whole. A one-way ANOVA (dependent: words on chernobyl; factor: scientific or non-scientific) confirms such an expectation:  $F(1,60) = 4.16, p = .05$ . Figure 14 presents the mean number of words on the Chernobyl disaster in scientific ( $M = 230.19$ ) and non-scientific articles ( $M = 289.68$ ).

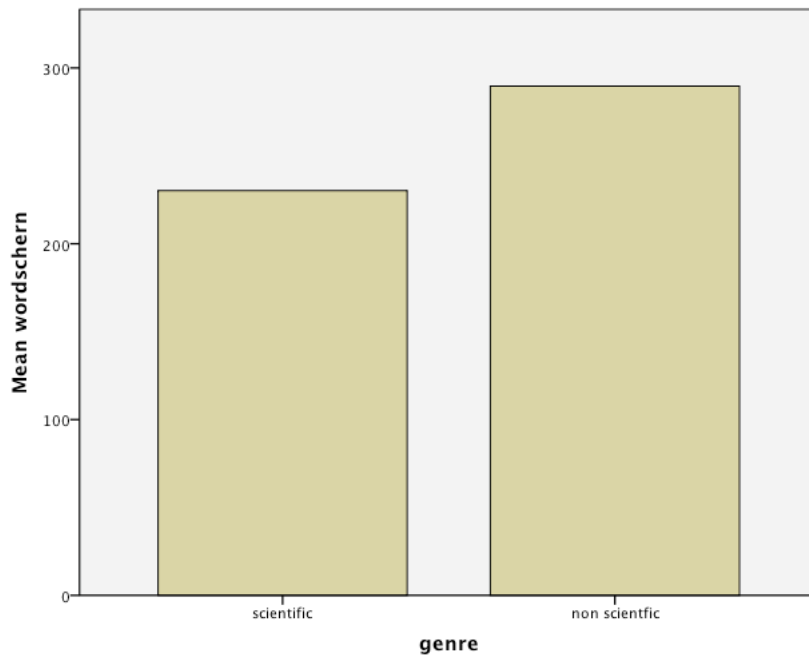


Figure 14: mean number of words on Chernobyl to genre.

#### Question 4

*Q4) Do authors tend to focus on sharp end causes?* All causes were distributed over the 3 'sharp end / blunt end' categories (Figure 3): 'blunt end', 'sharp end' and 'sharpest end'. Then, the appearance of a certain emphasis has been determined by counting the number of elements per category: each time that one of the categories appeared more than in both other categories, there was an emphasis detected. For example, with a distribution of '2, 3, 0' on categories 'blunt, sharp, sharpest' end, an emphasis was detected on the category 'sharp'. With distributions such as '2, 2, 0' or '3, 3, 3', no emphasis was ascribed. Following this system, there was an emphasis in 41 out of 62 cases. In 12 of these cases the accent was on the 'blunt end' (29,3%), in 8 of these cases on the 'sharp end' (19,5%), and in 21 of these cases on the 'sharpest end' (51,2%). In 21 articles (33,9%), none of the 3 categories was emphasized.

Running a Pearson's Chi-square test ('emphasis on sharpest end, yes or no' opposed to 'emphasis on sharp end, yes or no' and 'emphasis on blunt end, yes or no') delivered

significant results; successively:  $\chi^2(1,62) = 4.71, p = .03$  and  $\chi^2(1,62) = 7.62, p = .006$ .

### Question 5

*Q5) Is the human error theme mentioned most often?* No, in 33 out of 62 articles, human error is mentioned (53,2%). The design features of the Chernobyl number 4 reactor are mentioned more often as a reason for the (size of the) disaster, with an appearance of 39 out of 62 articles (62,9%). The other themes appeared less often: lack of knowledge (13 times; 21%), time pressure (3 times; 4,8%), management pressure (2 times, 3,2%), and poor safety culture (2 times, 3,2%)

### Question 6

*Q6) Are the story grammar elements (setting, theme, plot and resolution) useful as a schema for reports on the Chernobyl disaster?* In most of the articles all the parts of the schema appeared. The setting-element appeared in all cases (62 times, 100%), the theme-element appeared 51 times (82,3%), the plot-element was present in 56 articles (90,3%), and the resolution-theme in 60 out of 62 cases (96,8%). The story grammar schema as a whole (setting, theme, plot and resolution) appeared in 71% of the articles (44 out of 62). One may conclude that the absence of elements was spread over the cases. In other words, in (most of) the 18 articles in which no complete story grammar schema appeared, just a single element was missing.

An interesting difference was detected between the scientific and non-scientific articles, when it comes to the appearance of the story grammar schema. Much more non-scientific articles consisted of the story grammar schema than scientific articles. The table below (Table 3) shows the 'appearance of the story grammar schema' against the genre. Although the difference is eye-catching, it was only marginally significant  $\chi^2(1, N = 62) = 2.82, p = .09$ . Differences in story grammar appearance over 'time' or with 'lack of precision' (source mentioned, or not) were not found  $\chi^2(2, N = 62) = 3.05, p = 0.22$  and  $\chi^2(1, N = 62) = 2.57, p = .11$ .

	story grammar mentioned		total
	yes	no	
scientific articles	19	12	31
non-scientific articles	25	6	31
total	44	18	62

Table 3: frequencies 'appearance of the story grammar schema' to genre.

Question 7

Q7) Do the independent variables (time, lack of expertise and lack of precision) influence the focus on sharp end and human error? Table 4 shows the frequencies of 'genre' to the 'emphasis on sharpest end'. Clearly, in the non-scientific articles, as compared to the scientific articles, there was a tendency towards the sharpest end, while in scientific articles, an emphasis on 'sharpest end' factors appeared not more often than an emphasis on 'sharp end' and 'blunt end' factors. A Pearson's Chi-square produced  $\chi^2(1, N = 62) = 5.83, p = .02$ , which means that there has been more focus on sharp end elements, within the group of non-scientific articles (Table 4). Out of the 16 non-scientific articles in which the sharpest end was not emphasized, 2 had an emphasis on 'sharp end' and 5 on 'blunt end'. Thus, a total of 7 focuses appeared in the 16 remaining articles.

	emphasis on sharpest end		total
	yes	no	
scientific articles	6	25	31
non-scientific articles	15	16	31
total	21	41	62

Table 4: emphasis on sharpest end to genre.

Not surprisingly, this tendency (in a weaker strength) appeared after running a Pearson's Chi Square on 'emphasis on sharpest end' to 'source mentioned, yes or no':  $\chi^2(1, N = 62) = 4.35, p = .04$ . The same Chi-square with 'year' in stead of 'source mentioned' did not detect a significant difference:  $\chi^2(2, N = 62) = 0.42, p = .81$ .

Whether the factors time, genre and source played a role in the focus on human error, was tested, again using Pearson's Chi-square (human error to genre, source, year). Genre (see Table 5) appeared to be a significant factor:  $\chi^2(1, N = 62) = 5.25, p = .02$ . 'Source' and 'year' were not; in respective:  $\chi^2(1, N = 62) = 1.82, p = .18$  and  $\chi^2(2, N = 62) = 0.80, p = .67$ .

	human error mentioned		total
	yes	no	
scientific articles	12	19	31
non-scientific articles	21	10	31
total	33	29	62

Table 5: crosstabulation of human error to genre.

### Question 8

*Q8) Does a certain gist appear, a story that is always mentioned, regardless of any factor? In order to deliver a complete view of elements that were mentioned often, a ranking was made. This ranking consists of all elements that were mentioned more often than they were not (i.e. more than 50% appearance). They are presented in Table 6 , in order of occurrence, from most to least mentioned.*

element	number of articles in which it was mentioned	percentage of articles in which it was mentioned
Chernobyl	62	100%
explosion	60	96,8%
radiation release	60	96,8%
nuclear power plant	58	93,5%
date	58	93,5%
test conducted	48	77,4%
operators	46	74,2%
reactor design features	45	72,6%
design flaws	39	62,9%
reactor 4	39	62,9%
human error	33	53,2%

Table 6: frequently mentioned elements.

Although a certain gist should generally appear in all articles, regardless of its genre, some interesting differences between the scientific and non-scientific cases are worth mentioning. Two causes were mentioned in more than 50% of the non-scientific articles, but were much less seen in scientific texts. The mentioning of a 'power surge', to begin with. This cause appeared in almost 55% of the non-scientific cases, whereas in the scientific articles it was mentioned even less than 23% of the times. Another cause, human error, was also much more common in non-scientific literature: it was detected in almost 52% of the articles; in scientific articles the presence was around 39%. Also the time at which the explosion occurred was mentioned more often in non-scientific articles, namely in 58,1% of the cases. This same setting-element was seen in 38,7% of the scientific texts.

#### 4. CONCLUSIONS & DISCUSSION

The results suggest that the story grammar schema (figure 3) is, in most cases, an adequate tool to order the elements of the Chernobyl disaster descriptions. In 71% of the articles (44 out of 62) all elements of the schema appeared. The average presence of each separate element (setting, theme, plot and resolution) was even higher (respectively 100%, 82,3%, 90,3% and 96,8%). Therefore, one may conclude that the absence of story grammar elements within the articles, was scattered. Whether a story grammar schema, such as in figure 3, was 'used' to order and recall information, or whether the schema is just a useful tool to describe the descriptions, cannot be answered on the basis of the current dataset.

An interesting finding is the higher story grammar appearance within the non-scientific articles. An explanation for this difference may be a 'looser' approach of non-scientific writers, when it comes to precise reporting. It seems imaginable that scientific authors feel more obligated to 'stick to the facts', as a result of which they might be more alert on overruling or outruling their own interpretations. Writers without a scientific background or ambition, would therefore be more likely to 'reproduce' via a story schema.

The largest differences in the Chernobyl disaster descriptions are found between scientific and non-scientific literature. Nevertheless, a finding worth mentioning is a reduction over time, within the non-scientific articles. The number of words that were used to describe the causes of the accident have decreased, while neither the total number of words of the description, nor the number of causes show the same tendency. This reduction tendency might confirm the idea that a shortening of texts appears, without the necessity of a reduction in essence, or 'gist' (Bartlett, 1932).

As mentioned, the most eye-catching differences are found between scientific and non-scientific articles. One is that the number of setting-elements and plot-elements is higher in non-scientific articles. These elements have in common that they represent detailed information. Thus, scientific articles about the Chernobyl disaster tend to be less detailed. Partly, this might be a result of the scientific author's ambition to publish without mistakes. The more one states, the more risk one takes to be incorrect. Especially when it comes to details, which usually do not represent the essence, one might choose to leave them out. Another explanation would be that details are the elements that 'juice-up' a story, as a result of which non-scientific authors (more often story grammar users) are likely to add more details in their writings.

An extra finding may change the view on this tendency. The non-scientific descriptions of Chernobyl were significantly longer, which creates the space for more detail. One might state that this explains the higher number of details. However, the 'extra space' was claimed by the non-scientific authors and not by the scientific writers, which still suggests that there is a certain 'reason' behind the larger and more detailed non-scientific literature. Another explanation for the difference in number of mentioned details might be, that the goal of a scientific author differs from that of a non-scientific writer. Perhaps, scientific authors are more likely to condemn with a less detailed text, since their use of the Chernobyl case was no more than a tool, with which a theory was confirmed.

Further analysis on the data partly confirms the idea that a focus on sharp end elements exists. In 41 out of 62 cases, one of the three sharp-blunt categories (blunt end, sharp end, sharpest end) was emphasized. In 21 of these 41 cases, sharpest end elements are accentuated the most. However, the difference between scientific and non-scientific articles is striking. Half of the non-scientific texts has an emphasis on the 'sharpest end'. In scientific articles this accent appears in one-fifth of the cases. The focus on sharp end elements in non-scientific cases is significantly higher than in scientific articles. Even stronger, in scientific articles the emphasis is almost evenly divided over the three categories, whereas in non-scientific articles the attention is mainly on sharpest end elements. Another interesting finding is that the number of articles in which an emphasis appears, is about equal for scientific and non-scientific publications. An explanation for the sharp end focus in non-scientific writings may be the story-like construction, in which the final actions before the catastrophe are essential: a story without concrete actions is not very exciting, or not even a story at all. Another relation might lay in the human focus of sharp end elements.

Human error is very often mentioned in the articles. Explicitly as 'mistakes by operators' or more in general terms, such as 'failure of operators', 'human failure' or even 'human error'. In 33 out of 62 cases it was mentioned as a theme-element. The non-scientific articles were responsible for 21 out of 33 mentionings, which means that there is more attention for human error in non-scientific articles than there is in scientific writings. The difference proved to be significant. In general, a focus on human error is common in Western culture: there is a tendency to see ourselves as individuals and expect to be evaluated as such; with a personal responsibility in achievement and failure (Dekker & Nyce, 2011). The earlier mentioned 'stick to the facts'-argument might explain the difference between scientific and non-scientific texts, in respect of a focus on human error. Scientific writings might be less influenced by the consequences of a cultural background and features of the Western society,

since their authors pay more attention to a correct reproduction, protected from any value judgement.

The data are consistent with the idea that some sort of 'gist' exists (Hirst, 1980; Bartlett, 1932; Wynn & Logie, 1998). In all articles, 'Chernobyl' was mentioned (which is not a surprise, since it was one of the words in the search query). In almost all texts the explosion and released radiation were mentioned. Also the date (April 26, 1986) was mentioned in nearly all cases, as well as the location of the disaster. Using a stringent definition of a gist, the elements: 'Chernobyl', 'explosion', 'release of radiation', 'April 26, 1986', and 'nuclear power plant' remain. Applying these elements to the story grammar schema, would deliver the following gist (figure 15):

Setting:	location:	Chernobyl, nuclear power plant
	time:	April 26, 1986
	characters:	-
Theme:		-
Plot:		-
Resolution:		Explosion, release of radiation.

Figure 15: most stringent gist.

Using a wider definition, for instance with elements that were mentioned in more than half of the cases, the gist would look like this (figure 16):

Setting:	location:	Chernobyl, nuclear power plant
	time:	April 26, 1986
	characters:	Plant operators
Theme:		Reactor design flaws, human error
Plot:		Certain design of reactor, experiment conducted
Resolution:		Explosion, release of radiation.

Figure 16: gist composed of factors which were mentioned more often than they were not (>50%).

One of the constraints in this study is that it is impossible, with the specific research design, to determine on which information the authors based their writings. Even when references are mentioned, one can never be sure about the sources that were used. Were those sources the spoken word? Were those sources written? And if the authors based their texts on earlier written material, how did they reproduce it? Did they read a source, put it aside, and then write their description? Or did they read a source, then write a few words, then read the source again, then write a few words, etc. reproducing the text like 'synonym machines'?



These kinds of differences may have implications for the extent to which memory played a role in reproduction. Bartlett's and Feltovich's work are highly memory based. Thus, for their views on information reduction to be applicable, memory mechanisms are required. An argument in advantage of memory as a part of the studied reconstructions, is that the articles were no 'copy-paste' of existing sources, neither they were exact quotations. Thus, some form of cognitive processing must have occurred. This processing could have ranged from merely acting as a 'synonyms machine' by authors (if that is possible at all) to the type of 'scheme using', 'un-detailing' and 'gisting' as Bartlett mentioned.

Another constraint of this research is the distribution of the articles over publication dates. Most of the articles were published in the last 9 years. Only a few articles are from the first 18 years after the accident. Therefore, certain tendencies over time may not have been detected, due to a lack of old articles. An inescapable shortcoming is the use of a coding scheme. On one hand, it structures data, which is necessary. On the other hand, it closes doors to the gathering of those data, that are not a part of the coding scheme.

All findings considered, the major conclusions are that (1) the differences between scientific and non-scientific articles are the most striking, (2) in the sense that many of the expected tendencies were only seen in non-scientific literature. (3) In non-scientific articles, tendencies towards a focus on human error and (4) an emphasis on sharp end elements appeared. (5) The 'number of words on causes' diminished over time in non-scientific articles. (6) The level of detail was higher in non-scientific writings. (7) The story grammar scheme has proved to be a useful tool to structure the elements of a disaster report, especially in non-scientific texts. (8) The existence of a certain 'gist' is very likely. In its most stringent form it consists of the setting-elements: Chernobyl, nuclear power plant, April 26, 1986, and the resolution-elements: explosion and release of radiation.

## References

- Bartlett, F.C. (1932). *Remembering: A Study in Experimental and Social Psychology*. Cambridge University Press.
- Cook, R. & Woods, D. Operating at the sharp end: the complexity of human error. Bogner M, ed. *Human error in medicine*. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.; 1994. p. 255-310.
- Dekker, S.W.A. & Nyce, J.M.C. (2011). *Cognitive engineering and the moral theology and witchcraft of cause*. Springer-Verlag London Limited, 2011.
- Feltovich, P.J. & Spiro, R.J. & Coulson, R.L. & Adami, J.F. (1994). *Conceptual Understanding and Stability, and Knowledge Shields for Fending Off Conceptual Change*. CVJ, 31 December 1994. (Technical Report No. 7).
- Feltovich, P.J. & Hoffman, R.R. & Woods, D. & Roesler, A. (2004). Keeping it too simple: How the reductive tendency affects cognitive engineering. *Human centered computing*, may/jun 2004.
- Henriksen, K. & Dayton, E. & Keyes, M.A. & Carayon, R. & Hughes, R. (2008). *Understanding Adverse Events: A Human Factors Framework*. Patient Safety and Quality: An Evidence-Based Handbook for Nurses: Vol. 1.
- Hirst, W. (1980) The Locus of Constructive Activity in Memory for Mathematical Proofs. *Journal of Experimental Psychology: Human Learning and Memory* 1980, (Vol. 6, No. 2, 119-126).
- INSAG-7 (1992) *The Chernobyl Accident: Updating of INSAG-1*. International Nuclear Safety Advisory Group. International Atomic Energy Agency, Vienna, 1992.
- Mesoudi, A. & Whiten, A. & Dunbar, R. (2006). A bias for social information in human cultural transmission. *British Journal of Psychology*. Volume 97, August 2006, Issue 3, pages 405–423.
- Mesoudi, A. & Whiten, A. (2008) Roles of cultural transmission experiments in understanding human cultural evolution. *Phil. Trans. R. Soc. B* (2008). 363, 3489–3501 doi:10.1098/rstb.2008.0129.
- Reason, J. (1990). *Human error*. Cambridge. Cambridge University Press.
- Reason, J. (1997). Managing the risks of organizational accidents. *Appl Ergon* 2000; 31(6):649-61.7.
- Thorndyke, P.W. (1977). Cognitive Structures in Comprehension and Memory of Narrative Discourse. *Cognitive Psychology* (9, 1977). 77- 110.
- Vicente, K.J. & Brewer, W.F. (1993). Reconstructive remembering of the scientific literature. *Cognition* 46 (1993). 101-128.
- Wears, R.L. & Leape, L.L. (1999). Human error in emergency medicine. *Ann Emerg Med*, 1999 (September; 34:370-372). p. 373.
- Wynn, V.E. & Logie, R.H. (1998). The Veracity of Long-Term Memories. Did Bartlett get it Right? *Applied Cognitive Psychology* (1998). VOL. 12, 1±20.

## Appendix A

### Coding Schema

#### Analysis of publications concerning descriptions of disasters

**Unit of Data Collection:** Each publication which a) contains a description of the particular disaster with a minimum of 100 words and a maximum of 500 words, b) was searched by particular search terms c) has an author mentioned, d) is retrievable by a third-party.

1) **Coder ID:** Indicate the number of the person who coded that sheet.

2) **Publication ID:** Give each publication a unique 3-digit number, beginning with 001 and proceeding upward without duplication across all episodes.

3) **Reference and brief description:** Give a short description of the publication by mentioning the context in which the disaster is described.

84) **Year of publication**

4) **Internet-link and date:** Give the internet link with which you can retrieve the publication and the date of finding it.

5) **Total number of words publication:** Give the total number of words of the whole publication.

6) **Total number of words disaster:** Give the total number of words concerning the description of the disaster.

7) **Source:** Is the author mentioning a source of information concerning the disaster?

0    Yes                    1    No

8) **If yes, which source?**

---

9) **Publication:**

10) **1. Genre:** Say to what genre the publication belongs.

- 0 scientific
- 1 non - scientific

**2. Number of causes and their proportions**

*Instruction:*

*-All words within a sentence in which a cause is mentioned, should be counted.*

*Example: 'The KLM aircraft had to take-off (with destination Amsterdam Schiphol), through a wall of dense fog'. Coding should be: cause number 11; 16 words.*

*-Each space between letters marks a new word.*

*Example: 'Las Palmas' are 2 words.*

*'Take-off' is 1 word*

*-If one sentence contains more than one cause, the words should be divided evenly over those causes.*

*Example: 'The Pan Am crew confusion about which taxi lane to take, was partly due to unclear communication with the Tenerife traffic tower and partly due to the low visibility'.*

*This sentence should be coded as cause 4; 9 2/3 words*

*cause 11; 9 2/3 words*

*cause 14 9 2/3 words*

<u>Causes</u>	<u>Number of words mentioning a specific cause</u>	<u>Percentage of words mentioning a specific cause, related to the total number of words concerning causes</u> <i>(round the number</i>	<u>Is the cause mentioned in the text?</u> <i>0 = Yes</i>

		<i>behind the comma up or down to get an even number)</i>	
1. (Thermal) power output dropped enormously	41)	26)	11)
2. Violation of safety rules (e.g. such as the Reactor 4 running below the Operating Reactivity Margin (ORM))	42)	27)	12)
3. Conduction of an experiment/test (incompletely and incorrectly prepared)	43)	28)	13)
4. Operators (or engineers) did not have enough knowledge	44)	29)	14)
5. (Bad) design RBMK reactor	45)	30)	15)
6. Activating the emergency shut-down (SCRAM, AZ(-5) button, Panic Button)	46)	31)	16)
7. Positive void coefficient (positive feedback loop of increasing nuclear (and thermal) power output)	47)	32)	17)
8. Tips of safety rods were made of a moderator, namely graphite	48)	33)	18)
9. Massive power surge (e.g. when safety rods were led down into the reactor)	49)	34)	19)
10. Experiment was postponed to the nightshift	50)	35)	20)
11. Pressure from management to go on with experiment	51)	36)	21)
12. Xenon poisoning	52)	37)	22)
13. Operators (or engineers) made mistakes	53)	38)	23)
14. Operators (or engineers) turned off automatic shutdown system	53)	39)	24)
15. Poor safety culture	55)	40)	25)
Total	78) ... words	100%	
<u>Factors that are mentioned in the publication but not in the accident reports (just write them down, do not rank them among the total word above):</u>			
17. 79)			
18. 80)			
19. 81)			
20. 82)			
21. 83)			

### 3. Setting

#### 3 a) Location:

56)Is Ukraine mentioned?	0	Yes	1	No
57)Is Chernobyl mentioned?	0	Yes	1	No
58)Is the Nuclear Power Plant (NPP) mentioned?	0	Yes	1	No
59)Is Reactor 4 mentioned?	0	Yes	1	No
60)Is the Control Room mentioned	0	Yes	1	No

#### 3 b) Characters:

61)Are the NPP operators mentioned?	0	Yes	1	No
62)Is the NPP management mentioned?	0	Yes	1	No

#### 3 c) Time:

63)Is the date mentioned (April 25/26, 1986)?	0	Yes	1	No
64)Is the time mentioned (around 02:00 AM, or midnight)?	0	Yes	1	No

### 4. Theme

65)Is the bad design of the RBMK reactor mentioned?	0	Yes	1	No
66)Is the pressure from management mentioned?	0	Yes	1	No
67)Is the operator's lack of knowledge mentioned?	0	Yes	1	No
68)Is the poor safety culture mentioned?	0	Yes	1	No
85)Is time pressure mentioned?	0	Yes	1	No
86)Are the human errors by operators mentioned?				

0 Yes 1 No

## 5. Resolution

69)Is the fatal explosion of the reactor mentioned?	0	Yes	1	No
70)Is the number of deadly victims mentioned?	0	Yes	1	No
71)Is the released radiation mentioned?	0	Yes	1	No

## 6. Plot

72)Is mentioned that one of the operators pushed the Emergency Button, which was the direct cause for the fatal explosion in reactor 4, which caused the lid to be blown off?

0 Yes 1 No

## 7 Gist / story grammar

73)7. a) Is the gist/ story grammar mentioned by the author(s)? *The gist/story grammar consists of the parts*

*1. Setting:*

*location: Ukraine AND/OR Chernobyl AND/OR Nuclear Power Plant AND/OR Reactor 4 AND/OR Control Room*

*AND*

*Characters: NPP Operators AND/OR NPP Management*

*AND, not necessarily*

*Time: (April 26,) 1986 AND/OR 02:00 AM*

*AND 2. Theme: Bad design of the RBMK reactor*

*AND 3. Plot: operator pushed the Emergency Button, which was the direct cause for reactor 4 to explode.*

*AND 4. Resolution: Explosion of reactor and radiation leak.*

0    Yes                    1    No

If the last question was answered with 'No' go on with item 7. b). If the last question was answered with 'Yes' go on with item 5.

<sup>74</sup>**7. b)** What part(s) from the story grammar is (are) missing? (Setting, Theme, Plot, Resolution)?

### **5. Relation between causes**

Strings of causes. Xa led to Xb led to Xc etc.

*Instruction:*

*- Find mentioned relations between the different causes. Be alert for cues such as:*

*- .... led to ...*

*- ... leads to ....*

*- due to ....*

*- .... resulted in ....*

*- ..... results in ...*



- as a result .....

- ..... because .....

- etc.

- Strings of causes should be filled out as follows:

Example:

Cause Xa	Cause Xb	Cause Xc	Cause Xd	Cause Xe	Cause Xf	Effect	Number of X's per string	Highest number of causes per X
3	6, 8,11	1	7			14.	4	3
2, 5, 13, 14						15.	1	4

Meaning:

- Cause 3 led to causes 6, 8 & 11. Causes 6, 8 & 11 led to cause 1. Cause 1 led to cause 7. Cause 7 led to cause 14. In schema:

$Xa(3) > Xb(6,8,11) > Xc(1) > Xd(7) > Effect(14)$

- Causes 2, 5, 13 & 14 together led to causes 15. In Schema:

$Xa(2,5,13,14) > Effect(15)$

- Only fill out the longest option of a particular string.

Example: when  $Xa(1) > Xb(4) > Xc(5) > Effect(12)$ , only fill out that string.

So do not note:  $Xa(1) > Xb(4) > Effect(5)$ , or

$Xa(4) > Xb(5) > Effect(12)$ , or

any other possible separation

Cause Xa	Cause Xb	Cause Xc	Cause Xd	Cause Xe	Cause Xf	Effect	Number of X's per string	Highest number of causes per X
						1.		
						2.		
						3.		
						4.		
						5.		
						6.		
						7.		
						8.		
						9.		
						10.		
						11.		
						12.		
						13.		
						14.		
						15.		
						16.		
						17.		
						18.		
						19.		

						20.		
						21.		
						22.		
						23.		
Total number of strings: 75)						Highest:	<sup>76)</sup>	<sup>77)</sup>

## Appendix B

### Coded texts of articles

**Publication ID:** 001

**Reference:** The costs of failure: A preliminary assessment of major energy accidents, 1907–2007  
Benjamin K. Sovacool Energy Governance Program, Centre on Asia and Globalisation, Lee Kuan Yew School of Public Policy, National University of Singapore, Singapore Received 6 October 2007; accepted 24 January 2008 Available online 14 March 2008

**Internet-link:** <http://www.sciencedirect.com/science/article/pii/S0301421508000529>

**Date:** 19-11-2012

**Total number of words publication:** 13 725

**Total number of words disaster:** 230

**Publication:**

Chernobyl nuclear reactor, Kiev, Ukraine Perhaps the most well-known accident in global history, a mishandled safety test at the Chernobyl nuclear plant in Kiev, Ukraine, killed at least 4056 people and damaged almost \$7 billion of property. On the evening of April 25, 1986, engineers on the evening shift at Chernobyl's number four reactor began an experiment to see whether the cooling pump system could still function if auxiliary electricity supplies malfunctioned. Close to midnight, the operators turned off the automatic shutdown system so that the test could proceed, and then mistakenly lowered too many control rods into the reactor core. The control rods displaced coolant and concentrated reactivity in the lower core, causing fuel pellets to rupture and explode, destroying the reactor roof and sweeping the eruption outwards into the surrounding atmosphere. As air raced into the shattered reactor, it ignited flammable carbon monoxide gas and resulted in a radioactive fire that burned for 9 days. The accident at Chernobyl released more than 100 times the radiation than the atom bombs dropped on Nagasaki and Hiroshima, and most of the fallout concentrated near Belarus, Ukraine and Russia. At least 350,000 people were forcibly resettled away from these areas, and cesium and strontium severely contaminated agricultural products, livestock, and soil. After the accident, traces of radioactive deposits unique to Chernobyl were found in nearly every country in the northern hemisphere.

**Publication ID:** 002

**Reference:** 'The star called Wormwood': the cause and effect of the Chernobyl catastrophe  
DOI: 10.1088/0963-6625/1/3/001 1992 1: 241 Public Understanding of Science, Helene Knorre

**Internet-link:** <http://pus.sagepub.com/content/1/3/241.short>

**Date:** 19-11-2012

**Total number of words publication:** 5 246

**Total number of words disaster:** 484

**Publication:**

At 1.23 am on 26 April 1986 Alexander Akimov, a reactor operator on duty at Unit IV of the Chernobyl nuclear power station, noticed that there was something out of order at the turbine generator. He pressed the emergency reactor shielding button. Akimov and his shift supervisor Leonid Toptunov must have thought that this would solve the problem. Perhaps they hoped that it would stop the reactor just as a brake stops a car. In the event, however, there was a massive explosion. Later it was claimed by many sources that the two men were clearly to blame for the explosion, as they had pressed the 'wrong' button. But actually it was the right button. The men were killed instantly: they never even realized what had happened. They had never been properly informed about the RBMK reactor's special features- peculiarities of its emergency shielding system, drawbacks in its control system design, even errors in its technical specifications (RBMK are high capacity boiling water reactors, designed and used in the USSR). The two men had no idea that the emergency button was made not to block the reactor but, on the contrary, to start it in certain circumstances. But at first none of the personnel grasped the situation that fatal night, especially after the risky experiment which had taken place at the station on the eve of the catastrophe. During the experiment neither the design features nor the drawbacks of the reactor had been taken into account. So that night, the safety rods which were lowered in response to the emergency accelerated the nuclear reaction instead of shutting it down. Had the operator not pressed the button, the reactor would have stalled by itself in minutes, as its operational reserve was by that time coming to an end. But the catastrophe did happen, and nothing can be done about it now. When the control and safety rods were lowered into the fissile core, water columns above them, which absorb neutrons and decelerate the fission, were displaced, and the fission accelerated. In two and a half seconds it increased tenfold. All the devices for nuclear power control were broken and there was an explosion. For two or three seconds the power decreased a little, but then it started accelerating again and increased several hundred times more. Seven seconds later there was another explosion. One-metre thick concrete blocks cracked like thin glass; ceiling panels were scattered all about; and the concrete reactor cover was blown upwards. The dark night was suddenly lit by a huge

fire, and red-hot pieces of graphite debris from the fissile core were scattered kilometres away from the devastated reactor. And then came the turn of the most dangerous fallout: the invisible, inaudible and intangible radiation which, spread by the wind, swiftly covered forests and fields, cities and villages, and sleeping people unaware of the great disaster that had befallen them.

**Publication ID:** 003

**Reference:** Chernobyl accident: Causes, consequences and problems of radiation measurements

V. Kortov, Yu. Ustyantsev Physical & Engineering Institute, Ural Federal University, 19 Mira Str., 620002 Ekaterinburg, Russia, 2012

**Internet-link:** <http://www.sciencedirect.com/science/article/pii/S1350448712001680#>

**Date:** 19-11-2012

**Total number of words publication:** 3 504

**Total number of words disaster:** 312

**Publication:**

Causes of Chernobyl nuclear accident

The reactor explosion in the 4th Unit of Chernobyl NPS was caused by design flaws and staff operation errors. The main drawbacks of RBMK-1000 reactor were reactivity increase resulting from insertion of control and protection rods into the reactor core and low speed of reactor protection system operation. Emergency protection rods were inserted into the reactor within 18 s (instead of 2e3 s) which prevented the control and protection system from effective control over fast processes in the reactor. The accident occurred during the scheduled tests of power supply mode in case of external sources loss. This mode was conceived in the test program and was to be launched if the reactor capacity dropped by 30% accompanied by emergency cooling system shut down. In this term there is some similarity with Fukushima accident, when the emergency cooling systems were destroyed by the earthquake and tsunami. The Fukushima reactors, however, were shut down immediately after the first shock of the earthquake. The Chernobyl staff in absence of the emergency cooling lowered the reactor capacity down to inadmissible low level (20% from the nominal capacity). Constructional and physical characteristics of RBMK-1000 reactor did not allow the staff to effectively control its work at such low capacity. However, (Summary Report, 1986) the scheduled tests were completed and the staff received the command to shut down the reactor. It was this scheduled procedure that appeared to be the accident cause. The insertion of the protection rods into the reactor core at low reactivity level did not bring the reactor to a halt. On the contrary, it led to sharp increase in reactivity, reactor power growth and fast heating of the reactor active zone which caused the explosion. The photo picture of the explosion destroyed part of the reactor core and reactor building at Chernobyl is shown in Fig. 1.

**Publication ID:** 004

**Reference:** Twenty years' experience with post-Chernobyl thyroid cancer

Dillwyn Williams \* MD, F Med Sci Professor Strangeways Research Laboratory, Worts Causeway, Cambridge CB1 8RN, UK, Best Practice & Research Clinical Endocrinology & Metabolism Vol. 22, No. 6, pp. 1061–1073, 2008 doi:10.1016/j.beem.2008.09.020 available online at <http://www.sciencedirect.com>

**Internet-link:** <http://www.sciencedirect.com/science/article/pii/S1521690X08001176>

**Date:** 24-12-2012

**Total number of words publication:** 6 857

**Total number of words disaster:** 179

**Publication:**

The accident at Chernobyl happened on April 26th 1986, it was the result of a combination of an ill-judged experiment, poor reactor design, and human error. The reactor overheated, the graphite core caught fire, there was a steam explosion that blew off the reactor lid, scattered fragments of radioactive fuel and burning graphite in the immediate vicinity, and 'boiled off' the volatile isotopes present, releasing in total about 1019 Becquerel into the atmosphere. The main isotopes released were xenon-133, iodine-131, tellurium-132, and neptunium-239, with smaller amounts of caesium-134 and -137, strontium-89 and -90, and a range of others. Iodine-133 and -135 were also released, but the half-lives of these isotopes are extremely short and they are unlikely to be important for health consequences, apart from to those living close to the reactor. Chernobyl is located in the far north of Ukraine, close to the border with Belarus. The radioactive cloud was at first carried to the north, and the heaviest fallout occurred in the south of Belarus, particularly in the district (Oblast) of Gomel.

**Publication ID:** 005

**Reference:** Consequences and Countermeasures in a Nuclear Power

Accident: Chernobyl Experience Vladimir A. Kirichenko, Alexander V. Kirichenko, and Day E. Werts, Biosecurity and Bioterrorism: Biodefense Strategy, Practice, and Science Volume 10, Number 3, 2012<sup>a</sup> Mary Ann Liebert, Inc. DOI: 10.1089/bsp.2012.0019

**Internet-link:** <http://online.liebertpub.com/doi/abs/10.1089/bsp.2012.0019>

**Date:** 26-12-2012

**Total number of words publication:** 5 207

**Total number of words disaster:** 325

**Publication:**

The accident occurred at 1:24 a.m. on Saturday April 26, 1986, during a safety test operation to check whether the inertia of the station turbine was sufficient to start up the emergency diesel generator in the event of a central electricity blackout. The test was conducted by electrical engineers without a nuclear physicist in charge. There was unexpected and substantial delay during the test at the request of the district dispatcher, who ordered that the reactor remain running at 50% power in order to meet electrical demand. This created a time pressure during the test. In order to conduct the test and decrease the reactor power, the operators disconnected a chain of safety systems, including the emergency core coolant system and the automatic control rod shutdown mechanism, which were not designed to be actuated while the reactor was being operated at low power.<sup>1</sup> During manual operation, the reactor control rods were mispositioned, and an uncontrolled power surge triggered a steam explosion, rupturing the reactor containment vessel. Shortly afterward, a second large hydrogen explosion blew apart the reactor core and destroyed most of the building, causing a major release of radioactive material into the atmosphere and igniting several tons of graphite blocks serving as the neutron moderator in Chernobyl (RBMK) type reactors. This persistent graphite fire, not a nuclear reaction, was responsible for 10 successive days of continuous release of large amounts of radioactive material into the environment. An attempt to stop the fire by bombarding the damaged reactor with thousands of tons of sand, boron, dolomite, clay, and lead from helicopters failed. In fact, these attempts clogged the reactor several times, resulting in more spikes of explosions containing radioactive material. About 2 weeks after the accident, on May 10, the reactor fire was extinguished when coal miners tunneling beneath the site introduced pipes with liquid nitrogen and other coolants into the reactor vault to the burning graphite core.

**Publication ID:** 006

**Reference:** A Reader in Uncomfortable Heritage and Dark Tourism. Jose Ramon Perez, 2009.

**Internet-link:** [www.urbain-trop-urbain.fr/wp-content/uploads/2011/04/UHDT\\_Reader\\_allege.pdf#page=32](http://www.urbain-trop-urbain.fr/wp-content/uploads/2011/04/UHDT_Reader_allege.pdf#page=32)

**Date:** 26-12-2012

**Total number of words publication:** 75 792

**Total number of words disaster:** 303

**Publication:**

On April 25, 1986, Reactor Number 4 was programmed to have its annual maintenance shutdown. It was an ideal opportunity to carry out the long over due safety test, given that the conditions needed for it were 20 to 30 percent of the normal output level. A first obstacle came with a phone call: the Kiev grid controller demanded an increase in the output of Chernobyl, to compensate for a regional power station that had gone down. Complying with the request meant that the test had to be rescheduled during the night shift. A smaller crew at this time meant less hands and less expertise for the test, but the plant director and the plant's chief engineer agreed to do so. After midnight, ten hours behind schedule, while power was being reduced in preparation for the test, a mistake at the control room caused the output of the reactor to drop to 7 percent, a level too low for the test (Imanaka, 2008). The three operators now needed to raise the power quickly, and to do so they had to go beyond the safety regulations, they had to disable the automatic shutdown mechanism, designed to prevent the reactor from going meltdown. After a brief argument on abandoning the test, the situation being too dangerous, the engineer in charge said that they had their orders and assumed responsibility for switching off the override. The test was begun, but in only a few seconds the power increase was dramatic, and when the second engineer pressed the emergency button, it was too late to stop the chain reaction. At 01:23 hours on 26th April, a first steam explosion blew off the roof of the reactor, while subsequent hydrogen and graphite explosions set parts of the building on fire and scattered nuclear fuel and debris kilometres away.

**Publication ID:** 007

**Reference:** Technological catastrophes: their causes and

prevention<sup>1</sup> M. Manion a,\*, W.M. Evan ba Drexel University, Department of English and Philosophy, Philadelphia, PA 19104, USA b University of Pennsylvania, The Wharton School, Philadelphia, PA, USA , Technology in Society 24 (2002) 207–224

**Internet-link:** <http://www.sciencedirect.com/science/article/pii/S0160791X02000052>

**Date:** 26-12-2012

**Total number of words publication:** 8 609

**Total number of words disaster:** 233

**Publication:**

However, just seven years later, on April 26, 1986, the world got its answer when Unit 4 at Chernobyl, a nuclear power plant in the Ukraine, exploded, causing the reactor's 1,661 fuel rods to blast masses of radioactive material into the air. To date, the human toll of the disaster has been approximately 6000 deaths and 30,000 injured. The accident occurred during a test to determine how long the turbines would continue to produce electricity when cut off from the steam supply produced from the nuclear reactions in the core. A comprehensive Soviet report of the disaster concluded that operator error was the root cause of the disaster. Operator error led to "violations of the established order in the preparation of tests," "violations of the testing program itself," and "inadequate understanding on the part of personnel of the operating processes in a nuclear reactor" [29]. The failure at Chernobyl also demonstrates the complex interaction between operator error and other factors. In addition to obvious operator errors, three principal design defects of the RBMK (Russian Graphite-moderated Reactor) greatly exacerbated the problem. They are: (1) the fact that the reactor tends to gain power rather than slow down as water is lost or turned to steam; (2) inadequate containment surrounding the reactor core; and (3) the design of the system does not provide protection against operator interference with the safety systems.

**Publication ID:** 008

**Reference:** Chernobyl Retrospective, 9 1988 by Grune & Stratton. I Frederick J. Bonte, From the Nuclear Medicine Center, The University of Texas Health Science Center at Dallas. Address reprint requests to Frederick J. Bonte, MD, Professor of Radiology and Director, The University of Texas Health Science Center at Dallas, Nuclear Medicine Center, 5323 Harry Hines Blvd, Dallas, TX 75235.

**Internet-link:** <http://www.sciencedirect.com/science/article/pii/S0001299888800163#>

**Date:** 26-12-2012

**Total number of words publication:** 5 771

**Total number of words disaster:** 408

**Publication:**

On April 25, the reactor staff began to reduce power for a previously scheduled service shutdown. It was during this period that they had planned to conduct their experiment. Their objective was to determine how long the decelerating electric generators could power some of the reactor's emergency systems. For the purposes of the experiment, operators shut off the emergency cooling system and withdrew most of the control rods. At this point there was evidently a buildup within the reactor of isotopes of xenon and iodine, fission byproducts: These nuclides slowed the nuclear chain reaction and caused reactor power output to drop. In compensation for this the operators withdrew even more of the control rods. Inherent in the design of the unit IV reactor is a feature known as a "positive void coefficient," which can produce a power surge if cooling water is lost. In virtually all modern reactors, loss of cooling water has the opposite effect of producing an emergency reactor shutdown. Just as the test began, the Chernobyl operators reduced the flow of coolant to stabilize steam pressure, and at the same time, the decelerating generator powering the coolant pumps further reduced the amount of cooling water flowing through the reactor. Because of the positive void coefficient a huge power surge resulted. A reactor designed to operate at 3,200 megawatts may have reached more than 1 million megawatts. In an effort to control the power surge the operators activated emergency circuits which dropped the withdrawn control rods into the reactor, but the response time was too slow. The uncontrolled nuclear reaction was now causing increasing steam generation in the coolant water, and the temperature of the reactor core rose sharply. Fuel rods began to disintegrate and fell into the cooling water, generating more steam, and causing a massive increase in pressure. The result was a steam explosion that destroyed the reactor core and its housing. Hydrogen and carbon monoxide were formed when the steam reacted with the graphite core, and with the zirconium fuel rod cladding. These gases were expelled into the air atmosphere within the reactor building and, as a result, a second explosion occurred, blowing the roof off the unit IV building. A huge amount of radioactive debris was hurled into the atmosphere following the second explosion, and the emission was increased when a stubborn fire began to consume the graphite reactor core.

**Publication ID:** 009

**Reference:** Biological consequences of Chernobyl: 20 years on Anders Pape Møller<sup>1</sup> and Timothy A. Mousseau<sup>2</sup> <sup>1</sup>Laboratoire de Parasitologie Evolutive, CNRS UMR 7103, Université Pierre et Marie Curie, Bât. A, 7e` me` tage, 7 quai St. Bernard, Case 237, F-75252 Paris Cedex 05, France 2, TRENDS in Ecology and Evolution Vol.21 No.4 April 2006

**Internet-link:** <http://www.sciencedirect.com/science/article/pii/S0169534706000292>

**Date:** 26-12-2012

**Total number of words publication:** 6 763

**Total number of words disaster:** 153

**Publication:**

A brief history of the Chernobyl event

On 26 April 1986, during a test of the ability of the Chernobyl nuclear power plant to generate power while

undergoing an unplanned shutdown, safety systems were turned off, leading to an explosion and nuclear fire that burned for ten days, releasing between 9.35!103 peta- becquerel (PBq) and 1.25!104 PBq of radionuclides into the atmosphere (by contrast, the Three Mile accident in Pennsylvania, USA on 27 March 1979 released just 0.5 terabecquerel). Although many of these radionuclides either dissipated or decayed within days (e.g. 131Iodine), 137 Caesium (137Cs) still persists in the environment even hundreds of kilometres from Chernobyl. Likewise, 90 Strontium (90Sr) and 239Plutonium (239Pu) isotopes are common within the exclusion zone. Given the 30, 29 and 24 000 yr half-lives of 137Cs, 90Sr and 239Pu, respectively, these contaminants are likely to be of significance for many years to come.

**Publication ID:** 010

**Reference:** School and Health 21, 2010, Health Education: Contexts and Inspiration  
The Chernobyl Disaster And Human Health, Vladislav NAVRÁTIL

**Internet-link:** [www.ped.muni.cz/z21/knihy/2010/26/26/texty/eng/navratil\\_e.pdf](http://www.ped.muni.cz/z21/knihy/2010/26/26/texty/eng/navratil_e.pdf)

**Date:** 26-12-2012

**Total number of words publication:** 2 210

**Total number of words disaster:** 451

**Publication:**

On the April 26, 1986, the reactor crew at Chernobyl – 4 nuclear power plant was been preparing for a test to determine how long turbines would spin and supply power following a loss of main electrical power supply. Such experiment was proposed to test a safety emergency core cooling feature during the shut down procedure. The reactor RBMK (Fig.2) is consisted of about 1600 individual fuel channels and each operational channel required huge amount of cooling water (at about 28 tons per hour). There was concern that in case of an external power failure the power station would overload, leading to an automated safety shut down in which case there would be no external power to run the plant's cooling water pumps. For this purpose there were three backup diesel generators, required 15 seconds to start up and at 60–75 seconds to attain full speed and required power (together 90 seconds so called "power blackout"). This more than one minute power gap was considered to be unacceptable and it was suggested that the mechanical energy of the steam turbine could be used to generate electricity to run water pumps, while they were spinning down. Because generator voltage decreases with this spinning down, a special device (voltage regulating system) was to be tested during the simulated blackout. Every nuclear reactor is designed in such a way that in case of an failure, the reactor would be automatically scram. For this purpose control rods would be inserted and stop the nuclear fission process and other generators. According to detail analysis, the Chernobyl experiment was performed at the most dangerous point in the reactor cycle. For the experiment the reactor was set at a low power setting (50 %) and the steam turbine run up to full speed. At this low power output a phenomenon called xenon poisoning by which high levels of <sup>135</sup>Xe absorb neutrons and thus inhibit nuclear reaction, become predominant. To increase power, control rods were pulled out of the reactor core, automatically control system was switched out and staff had to use manual control. The result of these very unstable conditions was the first steam explosion. It blew the 2000 ton heavy cover damaged the top of the reactor hall. Second, more powerful explosion occurred about two second after the first. It was caused by the hydrogen which had been produced by steam – zirconium or hot graphite – steam reaction. Very hot parts of ejected material caused a fire and the smoke arising from the burning radioactive graphite blocks contaminated great areas (Fig.4). In order of high irradiation most of the staff of the reactor died within three weeks.

**Publication ID:** 011

**Reference:** Consequences of the Nuclear Power Plant Accident at Chernobyl

Harold M.Ginzburg, MD, JD, MPH Eric Reis, Public Health Reports, January-February 1991, Vol. 106, No. 1

**Internet-link:** <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1580196/>

**Date:** 26-12-2012

**Total number of words publication:** 6 779

**Total number of words disaster:** 120

**Publication:**

On April 26, 1986, in Chernobyl, Ukrainian Soviet Socialist Republic (SSR), an accident occurred at Reactor 4 of the Chernobyl Nuclear Power Plant (NPP). There was an initial explosion and fire in the core containment facility, a subsequent fire in the reactor's graphite moderators, and a 10-day long (April 26-May 6) release of gases and aerosols containing great amounts of radioactive material that resulted in the widespread dispersion of clouds of radioactive nuclides. Reactors 1 and 2, which are physically separate from the damaged reactor, were not immediately threatened; the nearby Reactor 3 was structurally endangered by the fires. The graphite-moderated, boiling-water-cooled design of the Chernobyl reactors contributed to both the start and the severity of the accident.



**Publication ID:** 012**Reference:**

Nuclear power and the environment: comparative assessment of environmental and health impacts of electricity-generating systems S.M. Rashad\*, F.H. Hammad National Centre for Nuclear Safety and Radiation Control, Atomic Energy Authority, 3, Ahmed El Zomer, El Zohoor Dist., Nasr City, Cairo, Egypt Applied Energy 65 (2000) 211±229 [www.elsevier.com/locate/apenergy](http://www.elsevier.com/locate/apenergy)

**Internet-link:** <http://www.sciencedirect.com/science/article/pii/S0306261999000690>

**Date:** 26-12-2012

**Total number of words publication:** 6 938

**Total number of words disaster:** 101

**Publication:**

About 7 years after TMI occurred, the catastrophe in the graphite moderated, light-water cooled reactor Chernobyl 4 happened. Important contributing causes to the accident were major deficiencies in the reactor construction (unstable physical properties in combination with ineffective shut-down procedure) and in the safety philosophy (lack of tight and strong containment). Soviet officials confirmed, in April 1991, in Paris that the total death toll was 31 (these persons died within 2 months after the accident); 145 people show signs of radiation-induced illness (later illness can be expected for these); and 135 000 persons were evacuated within 6 days after the accident.

**Publication ID:** 013

**Reference:** Nuclear Engineering and Design 105 (1988) 157-172 157

North-Holland, Amsterdam Simulation Of The Chernobyl Accident, C.D. Fletcher, R. Chambers, M.A. Bolander, and R.J. Dallman, Idaho National Engineering Laboratory, EG&G Idaho Inc., Idaho Falls, Idaho 83415, USA, Received July 1987

**Internet-link:** <http://www.sciencedirect.com/science/article/pii/0029549388903378>

**Date:** 26-12-2012

**Total number of words publication:** 9 960

**Total number of words disaster:** 267

**Publication:**

Chernobyl, Unit 4, was a 3140 MW t (1000 MWe), RBMK-1000 class reactor operated in the USSR prior to a severe accident on April 26, 1986. The reactor was a boiling-light-water-cooled, graphite-moderated type, and contained 1661 vertical zirconium pressure tubes within the graphite stack. Each tube contained 18 fuel rods with a 7-m heated length. The reactor coolant system consisted of an intricate arrangement of pressure tube inlet and outlet connectors, horizontal drum-type steam separators, condensate inlet and outlet headers, and recirculation pumps. The following description of the accident sequence is a condensation of information provided in the Soviet report on the accident [1]. The accident occurred during the performance of a plant test designed to investigate pumped recirculation flow response following isolation of steam from a turbogenerator. Under the procedures for the plant test, half of the recirculation pumps were powered by the affected turbogenerator. At the initiation of the test, the shutdown control valves of the affected turbine were closed, causing the turbine to coast down. As a result, electrical output of the associated generator declined. Since half of the recirculation pumps were powered by this generator, the output of the pump motors, and hence the core flow, declined accordingly. As the core flow declined, the core average void fraction increased. An increase in core power resulted because the coolant void reactivity coefficient is positive in the RBMK-1000 reactor design. Sufficient and timely control rod negative reactivity was not available to compensate for the increase in core power because of a series of operator actions. This caused a runaway power excursion that destroyed the plant.

**Publication ID:** 014

**Reference:** The threat of radioactive substances in its civilizational context Radioactivity Around Us

Jerzy W. Mietelski No 3 (15) 2007, Focus on Nuclear Physics Academia

**Internet-link:** [academia.pan.pl/pdfen/changes\\_str.%2020-23\\_mietelski.pdf](http://academia.pan.pl/pdfen/changes_str.%2020-23_mietelski.pdf)

**Date:** 26-12-2012

**Total number of words publication:** 2 283

**Total number of words disaster:** 325

**Publication:**

The immediate cause of the Chernobyl catastrophe was a special test carried out at the power plant, paradoxically meant to improve safety. The experiment required the reactor to operate at low power, and all five automatic safeguard systems had to be turned off. The test was meant to be carried out on the afternoon of 25 April, and the staff for that shift was trained for it. But after the daytime experiment was started the local grid controller demanded that the full power supply be reinstated and that the planned shutdown be post-

poned until nighttime. The abortion of the test initiated problems with the reactor's stability. In the meantime, another shift came on duty. The operator's inept attempts to stabilize the reactor, operating at low power, led to a situation that was unacceptable under the reactor's safety regulations, reducing the number of control rods to three times less than required. The reactor demonstrated its inherent design flaw, instability at low power, when power suddenly increased more than 100-fold. The resulting heat changed all the water in the cooling system into steam, rupturing it. Once reaching the graphite moderator, heated to a temperature of more than 1500°C, the steam broke down into hydrogen and oxygen, which immediately began to react with one another and boosted the strength of the explosion. That explosion started a fire that lasted 10 days. It is estimated that 100% of gasses, some 30% of volatile substances, and 3% of non-volatile substances, such as plutonium, were released from the reactor during that time. According to CLOR estimates, residents of Poland received an average dose of 0.32 mSv in 1986. Over their lifetimes, the dose they receive as a consequence of the Chernobyl disaster is in the worst case less than 10% of the dose that they receive from natural substances present in our environment, and on average it is not quite 1% of that dose.

**Publication ID:** 015

**Reference:** Business, Economics and Public Policy Working Papers, The 25th Anniversary of the Chernobyl Accident Phil Simmons, School of Business, Economics and Public Policy Faculty of the Professions, University of New England, 2012 Number: 2012 - 1

**Internet-link:** [www.une.edu.au/business-school/working-papers/economics/econwp12-1.pdf](http://www.une.edu.au/business-school/working-papers/economics/econwp12-1.pdf)

**Date:** 26-12-2012

**Total number of words publication:** 8 189

**Total number of words disaster:** 156

**Publication:**

The Chernobyl accident began on the 26th of April 1986 as a result of an ill-judged experiment disabling safety devices when the plant was shut down. A steam explosion blew a reactor apart releasing radioactive gases. Graphite in the exposed core caught fire and burned for ten days despite efforts to extinguish the blaze (Anspaugh, 2008). This fire released radio-nuclides as aerosols and fuel particles into the atmosphere. The reactor was an older style RBMK type that did not have a protective shield to capture escaped gases and particles as modern reactors do. Due to bureaucratic secrecy, firemen were not informed of the dangers and some of those on duty who initially dealt with the fire suffered severe radiation burns. As the days went by, stories of individual heroism and self sacrifice emerged while the number of deaths increased. By the time the fire was extinguished, there were 30 deaths, 28 from radiation sickness (WHO 2006).

**Publication ID:** 016

**Reference:** Ecological lessons from the Chernobyl accident

J.N.B. Bell, G. Shaw b,1 Department of Biological Sciences/Department of Environmental Science and Technology, Imperial College London, Silwood Park Campus, Ascot, Berkshire SL5 7PY, UK  
Department of Environmental Science and Technology, Imperial College London, Silwood Park Campus, Ascot, Berkshire SL5 7PY, UK Available online 11 July 2005 Environment International 31 (2005) 771 – 777  
[www.elsevier.com/locate/envint](http://www.elsevier.com/locate/envint)

**Internet-link:** <http://www.sciencedirect.com/science/article/pii/S0160412005000966>

**Date:** 26-12-2012

**Total number of words publication:** 5 215

**Total number of words disaster:** 105

**Publication:**

The Chernobyl nuclear power complex, which is now closed down and being decommissioned, is located 100 km north-west of Kiev, close to the border of Belarus. The accident occurred at 01:23 on 26 April 1986, resulting from a fatal combination of design fault and operation of an illegal and unauthorised experiment. There were two explosions in one of the reactors, which blew off the 1000 tonnes of cover plate and the roof of the building. This was followed by influx of air into the reactor's graphite core, which started to burn, discharging noble gases, fission products, and uranium fuel into the atmosphere (Savchenko, 1995).

**Publication ID:** 017

**Reference:** Nuclear Innovation In Risk Society, Andrea De Mauro  
Alta Scuola Politecnica, Milano, Torino Italy, 2006

**Internet-link:** [www.geocities.ws/scannapuerci/demauroinnovation.pdf](http://www.geocities.ws/scannapuerci/demauroinnovation.pdf)

**Date:** 26-12-2012

**Total number of words publication:** 2 063

**Total number of words disaster:** 244

**Publication:**

On the Friday evening of April 25, 1986, the scientists at Chernobyl-4 reactor prepared to run a test to see how long the turbines would keep spinning and producing power in a critical situation due to the shutdown of the electrical power supply. In order to do that, they disabled some important control systems, including the automatic shutdown safety mechanisms. At 1:00 AM on April 26, the flow of coolant water dropped and the temperature of the reactor core began to increase. The moderator of that Soviet designed reactor was constructed of graphite. Nowadays this models are outlaw because very dangerous: the graphite is likely to burn out when temperature is too high. That day in Chernobyl, once graphite started to burn, it was almost impossible to extinguish. These facts show that the causes of the accident were a fool combination of human errors and imperfect technologies. In fact, that kind of experiment is clearly dangerous and should not be done in a real plant. Today's computing power lets the scientists use computer-based simulations rather than tests on effective plants, so this trial seems today even more foolish than in the past. In the immediate aftermath of the explosion and fire, 187 people felt ill from acute radiation sickness; 31 of these died. In Italy, the exposure to radiation was similar to that given by a radiograph but less dangerous because diluted in a week.

**Publication ID:** 018

**Reference:** Linköping University Medical Dissertations

No. 1001 Malignancies in Sweden after the Chernobyl accident in 1986, Martin Tondel

Division of Occupational and Environmental Medicine, Department of Molecular and Clinical Medicine  
SE-581 85 Linköping, Sweden, Linköping 2007

**Internet-link:** <http://liu.diva-portal.org/smash/record.jsf?pid=diva2:23612>

**Date:** 26-12-2012

**Total number of words publication:** 21 631

**Total number of words disaster:** 222

**Publication:**

The accident at the Chernobyl nuclear power plant in Ukraine, USSR occurred on 26 April, 1986 and was the most serious accident in the history of nuclear power industry. In short, due to basic engineering deficiency of the reactor model as such, and due to faulty actions by the operators, including switching off the emergency safety system, the steam pressure in reactor 4 built up, until a steam explosion occurred at 01.23:49. The reactor lid went off and the reactor core was exposed together with the graphite moderator. In the resulting fire the release of 5,300 PBq of radioactive material (excluding noble gases) continued until it could be stopped after 10 days. Within a few days to weeks 30 power plant employees and firemen died including 28 persons with acute radiation syndrome who had received a whole body dose of 2-16 Gy<sup>137</sup>, which equals a dose at 1,000 metres from the hypocentre in Hiroshima<sup>149</sup>. During 1986 approximately 116,000 people were evacuated from areas surrounding the Chernobyl nuclear power plant i.e. areas with a ground contamination of >1,480 kBq caesium-137/m<sup>2</sup>. Approximately, 600,000 persons took part in the recovery work (liquidators) until 1990<sup>137</sup>. The total amount of released radioactive substances has been calculated to be 200 times more than the combined release from the atomic bombs dropped on Hiroshima and Nagasaki<sup>145</sup>.

**Publication ID:** 019

**Reference:** Update of Impacts of the Chernobyl Accident: Assessments of the Chernobyl Forum (2003-2005)

and UNSCEAR (2005-2008) Balonov, Mikhail<sup>1</sup>; Crick, Malcolm<sup>2</sup>; Louvat, Didier Institute of Radiation Hygiene, St. Petersburg, RUSSIA United Nations Scientific Committee on the Effects of Atomic Radiation, Vienna, AUSTRIA, International Atomic Energy Agency, Vienna, AUSTRIA, Balonov et al. Update of Impacts of the Chernobyl Accident: Assessments of the Chernobyl Forum (2003-2005) and UNSCEAR (2005-2008) Proceedings of Third European IRPA Congress 2010 June 14<sup>116</sup>, Helsinki, Finland

**Internet-link:** [citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.176.254&rep=rep1&type=pdf](http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.176.254&rep=rep1&type=pdf)

**Date:** 26-12-2012

**Total number of words publication:** 6 585

**Total number of words disaster:** 128

**Publication:**

The Chernobyl accident was the most severe in the history of the world nuclear industry. At night of 26 April 1986, Unit 4 of the Chernobyl nuclear power plant, located 130 km to the north-east of Kiev, the capital of Ukraine<sup>1</sup>, was destroyed by two powerful explosions in the reactor core. The Chernobyl NPP was equipped with four RBMK reactors with a graphite moderator, a thermal power of 3200 MW and an electrical power of 1000 MW each. The explosions were caused by gross breaches of the operating procedures by staff and technical inadequacies in the safety systems (INSAG 1993). As a result of the explosions, highly radioactive core fragments were ejected onto the site. The hot graphite exposed to air caught fire and burned for 10 days.

**Publication ID:** 020

**Reference:** Nuclear, Biological and Chemical Weapons: What the Surgeon Needs To Know, Scandanavian Journal of Surgery 94: 293-299, 2005, Schecter, W.P., Department of Surgery, University of California, San Francisco CA, USA

**Internet-link:** [www.fimnet.fi/sjs/articles/SJS42005-293.pdf](http://www.fimnet.fi/sjs/articles/SJS42005-293.pdf)

**Date:** 26-12-2012

**Total number of words publication:** 11 213

**Total number of words disaster:** 117

**Publication:**

The accident at the Chernobyl nuclear reactor in the Ukraine on April 26, 1986 demonstrated the possible sequelae of sabotage or accident at a nuclear power plant. A chain of human errors and technology mal-functions brought about a series of explosions lifting the 1,000 ton upper reactor cover and allowing water cooling the reactor core to escape. In addition, the roof of the reactor ruptured expelling 25 % of the core. Thirty one acute deaths occurred: 2 from blast injury, 1 from myocardial infarction and 28 from massive radiation exposure. 238 survivors had acute radiation sickness. Cutaneous burns were common. Thousands throughout Northern Europe were exposed to radioactive fallout with long-term health consequences (11).

**Publication ID:** 021

**Reference:** Hard Lessons, Engineering Disasters, Engineering & Technology 25 April - 8 May 2009  
[www.theiet.org/magazine](http://www.theiet.org/magazine) Nick Spurrier

**Internet-link:** [http://ieeexplore.ieee.org/xpls/abs\\_all.jsp?arnumber=5136882&tag=1](http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5136882&tag=1)

**Date:** 26-12-2012

**Total number of words publication:** 3 364

**Total number of words disaster:** 246

**Publication:**

There is good reason to describe the explosion at Chernobyl nuclear power plant in the Ukraine on 26 April 1986 as the most catastrophic engineering disaster in history, as the consequent release of radioactivity led to the enforced and lasting evacuation of the surrounding area. A highly radioactive plume drifted over large areas of Europe as well as affecting millions of people. The causes of the disaster have been analysed extensively. The reactor at Chernobyl, the RBMK (high Power Channel Type Reactor) was – and is – flawed in a number of ways, some of which cannot be rectified. As Hans Meyer of the international Atomic Energy Agency said in 1996, “the great danger of the RBMK reactors is that they can catch fire in a way other reactors cannot”. On top of this, there were administrative failings at the plant. The immediate cause was the conducting of a test, which had been postponed and then restarted with the result that many operators were exhausted. Also, with a change of shift, some of those who arrived for work either did not know what was happening or were inexperienced. Greenpeace concludes that there has been a failure to learn lessons with regard to the continued operation of dangerous reactors. However, in other areas lessons have been learnt. Countries reorganised their emergency responses to such accidents, a stimulus was provided to get international agreements on food contamination. The awareness of radiation effects and their treatment was increased dramatically.

**Publication ID:** 022

**Reference:** The John and Frieda Arak Anthology 2009 - 2010 A Student’s Guide to Writing at the University of Delaware, 2010, Scientific Issues, Going Nuclear, David Denlinger

**Internet-link:** [supriortfolio.com/docs/print/arak.pdf#page=65](http://supriortfolio.com/docs/print/arak.pdf#page=65)

**Date:** 26-12-2012

**Total number of words publication:** 4 783

**Total number of words disaster:** 259

**Publication:**

Just like at any fossil-fuel burning plant, there is always the possibility of unexpected dilemmas and disasters. This was no better illustrated than at the nuclear reactor at Chernobyl, located in present day Ukraine. In April of 1986, the number four reactor at Chernobyl suddenly exploded spewing radioactive material over thousands of square kilometers throughout the Soviet Union. While there were few immediate repercussions of the explosion, today there is plenty of evidence of the impact that the nuclear radiation has had. In the 22 years that have passed since the explosion, the effects are still seen today in the forms of malignant cancer, deformed children (Park 30), and suffering agrarian economies (Park 118). But while the effects of the Chernobyl disaster are devastating, there have been many positive results in the aftermath; the explosion has allowed the nuclear industry to learn through its error. Put simply, the most probable failure of reactor four was a result of the loss of coolant. As excess heat began to spread through the reactor, there was “a violent chemical explosion which would rupture the shielding around the reactor core and tore apart the reactor building” allowing for the release of radioactive steam and gases (Park 34). There are several causes of Chernobyl’s failure: lack of a double-

walled facility, reactors running unstably at low power, and revelations of hasty efforts to reach target dates for construction (Park 35-37). By understanding Chernobyl's faults, scientists and builders of the Nuclear Regulatory Commission have been able to further improve safety during reactor construction and design.

**Publication ID:** 023

**Reference:** Health effects of the Chernobyl accident: fears, rumours and the truth§

Mati Rahu, Department of Epidemiology and Biostatistics, Institute of Experimental and Clinical Medicine, Hiiumäe 42, 11619 Tallinn, Estonia; Estonian Centre of Excellence in Behavioural and Health Sciences, Tallinn, Estonia  
Received 29 October 2002; received in revised form 13 November 2002; accepted 19 November 2002  
European Journal of Cancer 39 (2003) 295–299, www.ejconline.com

**Internet-link:** <http://www.sciencedirect.com/science/article/pii/S0959804902007645>

**Date:** 26-12-2012

**Total number of words publication:** 3 539

**Total number of words disaster:** 132

**Publication:**

The impact of the world's worst nuclear disaster at Chernobyl in 1986 is reviewed within a framework of a triad of fear, rumour and truth. The accident stemmed from an experiment to test a safety procedure, specifically, whether it was possible to shut down reactions in the core in the event of a main power loss. The reactor's emergency core cooling system was intentionally switched off. Unfortunately, later, out of control, the reactor overheated, and was followed by the intense generation of steam and two explosions that destroyed the reactor core [2]. The explosions resulted in a fire, confusion, chaos, fear and the release of radioactivity into the environment. Intensive research was initiated. One investigator remarked that "Chernobyl research very soon became a fast growing international industry"[3].

**Publication ID:** 024

**Reference:** Asia's Emerging Nuclear Era: Climate Strategies and Implications for U.S. Policy, 2011

Henry M. Jackson

**Internet-link:**

<https://dlib.lib.washington.edu/dspace/bitstream/handle/1773/16489/Task%20Force%20N%202011.pdf?sequence=1#page=233>

**Date:** 26-12-2012

**Total number of words publication:** 121 547

**Total number of words disaster:** 130

**Publication:**

The cause of the Chernobyl accident is also significant. Contrary to popular belief that the accident at Chernobyl was a nuclear explosion, the accident was actually caused by steam. More importantly, the root causes of the accident lie in a combination of a flawed reactor design with inadequate containment safeguards operated by poorly trained personnel. Both the maintenance and the design of the plant failed to meet international safety guidelines, making Chernobyl an isolated incident. Studies of the incident have proven that public perception and the media were incorrect in terms of total damage, lingering health effects, and the cause of accident. Ultimately, the Chernobyl incident functions more as testament of how little understood the nuclear field is, rather than as an example of the dangers of nuclear power generation.

**Publication ID:** 025

**Reference:** T. Matsunaga et al. : Environmental behavior of plutonium isotopes studied in the area affected by the Chernobyl accident, Environmental behavior of plutonium isotopes studied in the area affected by the Chernobyl accident Humic Substances Research Vol.5/6 (2009) Takeshi Matsunagaa and Seiya Nagaob, Nuclear Science and Engineering Directorate, Japan Atomic Energy Agency, Tokai-mura, Naka-gun, Ibaraki-ken 319-1195, Japan, Graduate School of Environmental Earth Science, Hokkaido University, Sapporo 060-0810, Japan

**Internet-link:** <http://www.sciencedirect.com/science/article/pii/S0168583X12004053>

**Date:** 26-12-2012

**Total number of words publication:** 9 783

**Total number of words disaster:** 253

**Publication:**

The Chernobyl accident occurred during a test of emergency preparedness for a loss of offsite power, in the early morning of April 26, 1986. Detailed descriptions of the accident are typically given by IAEA(1991, 2006a), UNSCEAR(2000), Vargo (2000), OECD/NEA (2002), Andoh and Hirano (2002), and Smith and Beresford (2005). Briefly, nuclear reactions in the reactor increased markedly as a combined result of improper operation and technical deficiencies of the reactor itself. The resultant thermal energy overheated the coolant water, pro-

ducing water vapor which further increased the reactor power due to the nature of nuclear reaction and the design of this reactor. This sequence of events occurred within 3 minutes (Smith and Beresford, 2005), and resulted in a steam pressure induced-explosion. Hydrogen may have been also involved in the explosion (Andoh and Hirano, 2002). A part of the nuclear fuel contained in zirconium metal tubes was broken down into fine particles of several hundred microns in diameter, or was melted into super-heated hot debris. Because the explosion damaged the reactor building, radionuclides liberated from the nuclear fuel were released into the open environment (Tables 1 and 2). About 3.5% of the total nuclear fuel was also released. This number has been still in discussion. High temperatures due to both fire and nuclear decay heat contributed to the release of radioactive materials over several days after the explosion. A major release of radionuclides continued for about 10 days, and a small-scale release continued for more than 1 month.

**Publication ID:** 026

**Reference:** European Journal of Radiology 63 (2007) 167–177, Rays as weapons

H. Vogel, Asklepios Klinik St. Georg, Röntgenabteilung, Lohmühlenstrasse 5, 20099 Hamburg, Germany

Received 25 April 2007; received in revised form 25 April 2007; accepted 26 April 2007

**Internet-link:** <http://www.sciencedirect.com/science/article/pii/S0720048X07002707>

**Date:** 26-12-2012

**Total number of words publication:** 7 681

**Total number of words disaster:** 171

**Publication:**

In the Chernobyl reactor, April 26th 1986, the control system failed during a test. The graphite inflamed (ignition point: 480 °C), the control rods were deformed in the heat. The chain reaction went out of control. An explosion, most probable of oxyhydrogen gas, destroyed the building and its roof; the reactor's core came into direct contact with the atmosphere. The temperature may have been between 1000 and 3000 °C, core melting may have occurred. Radioactive isotopes reached the environment (Table 4.1) mainly the atmosphere [4] (See Table 4.2). Radioactive isotopes had been released for 10 days and scattered in different directions with the wind. Fallout in the form of dust and rain was scattered on earth. In 1986, 28 persons from the clean up personal (240,000 "liquidators") died out of 134, who became sick of acute radiation disease (ARS); a total of 31 people were said to be killed by the accident. The estimates of the number of exposed individuals differ between 1.6 and 9 Mio [3,21,28].

**Publication ID:** 027

**Reference:** The Chernobyl Accident, Radiation and Health concerns, G.J. Vargo, august 2000. International Nuclear Safety Program PNNL, prepared for the U.S. Department of Energy

**Internet-link:** [www.pnl.gov/main/publications/external/technical\\_reports/pnnl-13294.pdf](http://www.pnl.gov/main/publications/external/technical_reports/pnnl-13294.pdf)

**Date:** 26-12-2012

**Total number of words publication:** 8 939

**Total number of words disaster:** 372

**Publication:**

At 1:23 a.m. on April 26, 1986, an accident at Chernobyl Unit 4, a 1000 MWe RBMK(a)nuclear power plant located in Ukraine, Soviet Union, resulted in destruction of the reactor core and part of the building in which the reactor was housed. In the initial steam explosion and subsequent fires, large amounts of radioactive material were released in the form of gases and dust particles. The energy released in the explosion was equivalent to 40 tons of TNT and resulted in discharge of about 4% of the reactor's nuclear fuel to the environment. As a result of the initial explosion and subsequent fires, which continued for about 10 days after the accident, it is estimated that approximately 350 megacuries (MCi)(b)of radioactive material were released to the environment (NEA 1996). Most of this radioactivity was in the form of short-lived(c) noble gases such as krypton and xenon, which were quickly dispersed. Radioactive iodine, mainly 131I, was deposited on vegetation such as grass or was inhaled by emergency workers or members of the public near the site. The radioactive iodine also was concentrated in the milk of cows that grazed on the contaminated vegetation. In humans, iodine is concentrated in the thyroid gland. This iodine-cow-milk-human pathway was responsible for large doses to many children and accounts for one of the subsequent major health effects, as described below. Some of the radioactive particles released from the accident were lifted as high as 10 km (6 miles) by the hot gases of the fire. Upper level winds carried these particles throughout portions of Ukraine, Belarus, and Russia, and smaller amounts were transported to portions of northern and western Europe. Fallout from this accident was detected in the United States, although the levels detected were very low. The principal environmental contaminants transported from the site were radioactive isotopes of iodine (mainly 131I) and cesium (primarily 137Cs). Smaller amounts of strontium (primarily 90Sr) were also released and detected. The root causes of the Chernobyl accident were 1) deficiencies in the plant design and 2) excessive reliance on administrative controls to fulfill critical safety

functions. The design deficiencies combined with inadequate safety evaluation and multiple operator errors during a test of the turbine-generator system placed the reactor in an unstable operating condition.

**Publication ID:** 028

**Reference:** Environmental Disasters in History, Renu Bhargava, Indira School of Business Studies, Pune, India, Bhatler College Journal of Multidisciplinary Studies, Vol. 1, No. 1, 2010

**Internet-link:** [bcjms.bhatlercollege.ac.in/V1/9.pdf](http://bcjms.bhatlercollege.ac.in/V1/9.pdf)

**Date:** 26-12-2012

**Total number of words publication:** 5 975

**Total number of words disaster:** 223

**Publication:**

On April 26, 1986 tests were conducted in nuclear reactor 4 of the Chernobyl nuclear power plant in Ukraine, located 80 miles from Kiev. These tests required part of the security system to be shut down. Errors in the reactor design and errors in judgment of the personnel of the power plant caused cooling water to start boiling. This caused reactor stress, resulting in energy production increases to ten times the normal level. Temperatures reached more than 2000 °C, causing fuel rod melting and further cooling water boiling. Extreme pressures in cooling water pipes resulted in cracks, which caused steam to escape. At 1:23h in the middle of the night the escaped steam caused an explosion slamming off the roof of the building, starting a major fire and simultaneously forming an atmospheric cloud containing approximately 185 to 250 million curies of radioactive material. Fire and explosion instantly killed 31 people. Two days after the explosion, the Swedish national radio reported that 10.000 times the normal amount of cesium-137 existed in the atmosphere, prompting Moscow to officially respond. The following day over 135.000 people were evacuated from within a 30 km radius of the accident. This area was labeled the 'special zone'. The evacuation of the special zone was permanent, as the high levels of radioactivity have been predicted to exist for several centuries.

**Publication ID:** 029

**Reference:** Notes on the Economic Valuation of Nuclear Disasters, Alistair Munro, National Graduate Institute for Policy Studies, 7-22-1 Roppongi, Minato-ku, Tokyo 106-8677, Japan, prepared for the Environmental course on the Masters in Public Policy at the National Graduate Institute of Policy Studies, Tokyo, 2011.

**Internet-link:** [www3.grips.ac.jp/~munro/notes%20nuclear%20valuation%20a.pdf](http://www3.grips.ac.jp/~munro/notes%20nuclear%20valuation%20a.pdf)

**Date:** 26-12-2012

**Total number of words publication:** 7 460

**Total number of words disaster:** 109

**Publication:**

The largest civilian accident to-date occurred at the Chernobyl plant in what is now Ukraine in 25th April 1986. During a planned experiment on the reactor, there was a sudden and unanticipated power surge. In response workers attempted an emergency shut-down of the plant, but this led to a further sharp rise in power output and sequence of violent explosions which released a large amount of radioactive material into the atmosphere. Once exposed to the air, the graphite in the reactor vessel caught fire and over several days fire released plumes of smoke which drifted over much of the local area and then across large parts of northern Europe.

**Publication ID:** 030

**Reference:** Potent Portables: A Miniature Future Fop Nuclear Reactors, Haseeb Shahid, 2011

**Internet-link:** <http://www.pitt.edu/~has83/paper.htm>

**Date:** 28-12-2012

**Total number of words publication:** 4 179

**Total number of words disaster:** 148

**Publication:**

The Soviet Union also experienced a catastrophe at the Chernobyl Nuclear Power Plant on April 26, 1986. An accidental power surge at reactor number four led to an emergency situation at the reactor. The containment vessel for the reactor was already poorly designed, and further human error and inability compounded the situation. Explosions had led to further damage of the building and reactor, and also exposed a graphite moderator to the air. The graphite subsequently ignited and sent nuclear fallout, a collection of radioactive dust that spreads around an explosion, throughout the area. The fallout alone was responsible for the development of cancer and ultimately death in people that were subject to it. These events showed just how catastrophic even an accident could be. Coupled with the atomic bombs, these events frightened people around the world and hindered the spread of nuclear technology, such as the nuclear reactor.

**Publication ID:** 031

**Reference:** Threat Convergence Briefing Nuclear Meltdowns ,Ryan Costello, the Fund for Peace Publication FFP: TTCVR1103 (Version 11e), April 2011

**Internet-link:** [www.fundforpeace.org/global/library/ttcvr1103-threatconvergence-meltdowns-11e.pdf](http://www.fundforpeace.org/global/library/ttcvr1103-threatconvergence-meltdowns-11e.pdf)

**Date:** 26-12-2012

**Total number of words publication:** 3 004

**Total number of words disaster:** 413

**Publication:**

The Chernobyl disaster began on April 26, 1986, during a safety test prior to a routine maintenance shutdown of the Chernobyl plant's Unit 4 reactor. The test sought to determine if enough energy could be generated to continue the cooling of the reactor if the station lost power. Inadequate safety protocol, operator error, and a poor system design precipitated the disaster that followed. The test was largely deemed an electrical operation without nuclear implications. Thus, the operators did not understand that the test could jeopardize the safety of the reactor.<sup>10</sup> The shutdown of the reactor commenced while the reactor was in an extremely unstable state. Protocol called for the reactor to be stabilized at approximately 700-1000 MWt prior to the test, but power had fallen to 30 MWt before stabilizing at 200 MWt. To compensate, the operators withdrew the number of control rods to eight, although the minimum Operating Reactivity Margin mandated fifteen rods.<sup>11</sup> When the test commenced, a massive energy surge caused fuel fragmentation and rapid steam production, which damaged fuel channels, jammed control rods, and quickly led to a steam explosion that released fissile materials. A second explosion followed seconds later, ejecting graphite and fuel that caught fire, contributing to the main release of radioactivity.<sup>12</sup> The Unit 4 reactor had no containment shell, so once the explosions occurred radioactive materials were immediately released into the surrounding environment.<sup>13</sup> Two workers were killed in the explosions. Over the next day and a half, 200-300 tons of water per hour was injected into what remained of the reactor core, although this was discontinued to prevent the flooding of other reactors. Over the next eight to nine days, helicopters dumped approximately 5,000 tons of sand, lead, clay, boron and dolomite onto the burning core to put out the fire and limit the release of radioactive materials.<sup>14</sup>

**Publication ID:** 032

**Reference:** Radiation Protection ISBN 92-64-02163-9, Evolution of the System of Radiological Protection Asian Regional Conference, Tokyo, Japan, 24-25 October 2002, Nuclear Energy Agency Organisation For Economic Co-operation and Development, European Region Case Study The Ethos Project For Post-Accident Rehabilitation In The Area Of Belarus Contaminated By The Chernobyl Disaster, J. Paterson, United Kingdom

**Internet-link:** [citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.76.4138&rep=rep1&type=pdf#page=29](http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.76.4138&rep=rep1&type=pdf#page=29)

**Date:** 26-12-2012

**Total number of words publication:** 4 012

**Total number of words disaster:** 204

**Publication:**

The context for this case study surely needs little introduction. On 25 April 1986 an explosion and fire in the number 4 reactor at the Chernobyl nuclear power plant in what is now Ukraine released a significant amount of radiation to the atmosphere. The bulk of the material expelled during the accident fell out in the immediate vicinity of the plant, but lighter material was carried by the wind causing significant contamination across a wider area of Ukraine, Belarus and Russia. Contamination was also evident to a lesser extent in other parts of Europe and the effects of the accident could be measured throughout the entire Northern Hemisphere. The causes of the accident are now accepted to be a combination of flaws in the reactor design and a poor safety culture within the plant that led operators to take risks that a better degree of co-ordination would have revealed and prevented. As the worst civilian nuclear accident in history, the Chernobyl disaster presented the authorities with an unprecedented problem. The immediate containment and more prolonged clean-up operations eventually involved as many as 600 000 people (known as liquidators) and some hundreds of thousands of residents were evacuated from their homes and relocated to uncontaminated areas.

**Publication ID:** 033

**Reference:** Soviet-Built Nuclear Plants and Their Safety, Yasuo Onishi, Oleg V. Votsekhovich, Mark J. Zheleznyak, Chernobyl - What have we learned? 1-7. 2007.

**Internet-link:** [http://link.springer.com/chapter/10.1007%2F1-4020-5349-5\\_1?LI=true#page-1](http://link.springer.com/chapter/10.1007%2F1-4020-5349-5_1?LI=true#page-1)

**Date:** 26-12-2012

**Total number of words publication:** 2011

**Total number of words disaster:** 168

**Publication:**

Twenty years ago, on April 26, 1986, Unit 4 of the Chernobyl Nuclear Power Plant suffered a core meltdown. Human error was a direct cause of this accident. Plant operators had dismantled automatic emergency shutdown devices to test safety equipment, and then made a mistake on plant shutdown with poorly designed safety rods, causing a steam explosion and graphite fire (DOE 1987, Marples and Young 1997). The accident released sic



times more radionuclides into the atmosphere than were released by the Hiroshima atomic bomb. This was the most devastating nuclear accident in history (IAEA 1991, Dreicer et al. 1996). The largest amounts of radionuclides released from the Chernobyl plant were the short-lived (with half-lives of just hours to several days) xenon ( $^{133}\text{Xe}$ ), iodine ( $^{131}\text{I}$  and  $^{131}\text{I}$ ), technetium ( $^{132}\text{Tc}$ ), and neptunium ( $^{239}\text{Np}$ ). The main radionuclides affecting human health are the longer-lived cesium ( $^{137}\text{Cs}$ ), strontium ( $^{90}\text{Sr}$ ), plutonium ( $^{238}\text{Pu}$ ,  $^{239}\text{Pu}$ ,  $^{240}\text{Pu}$ ), and americium ( $^{241}\text{Am}$ ), in addition to iodine ( $^{131}\text{I}$ ). About 120,000 people were evacuated from the area within 30 km of the plant.

**Publication ID:** 034

**Reference:** George L. Voelz as told to Ileana G. Buican How great is the risk? Plutonium and Health, Los Alamos Science Number 26, 2000

**Internet-link:** <https://www.fas.org/sgp/othergov/doe/lanl/pubs/00818013.pdf>

**Date:** 26-12-2012

**Total number of words publication:** 11 097

**Total number of words disaster:** 234

**Publication:**

On April 26, 1986, one of the four reactors at the Chernobyl nuclear power station in the Ukraine (formerly part of the Soviet Union) melted down and exposed millions of people to the single largest radiation event in world history. The facts leading up to the explosion are well known. Reactor 4 produced steam that drove generators to make electricity. On the night of the accident, operators were testing the generators to determine how long they could run without power. To this end, they reduced the power produced in reactor 4 and stopped the steam flow to the generators. But the RBMK-1000 design of reactor 4 has a flaw that makes its operation at low power unstable. Moreover, in violation of existing rules, the operators withdrew most control and safety rods from the core and switched off some important safety systems so that those should not interfere with test results. Ironically, the safety systems could have averted the destruction of the reactor's core. Power production in the reactor's core surged to 100 times the maximum permissible level, temperature increased in a couple of seconds, and two explosions blew off the metal plate sealing the reactor's top and destroyed the building housing the reactor. Within seconds, the explosions showered the environment with hot and highly radioactive gases. The gases contained aerosolized fuel and fission products, the radioactive nuclei created when uranium atoms split.

**Publication ID:** 035

**Reference:** The Chernobyl Catastrophe, by Vessela Daskalova, May 5, 1996

**Internet-link:** <http://oii.org/html/story.html>

**Date:** 26-12-2012

**Total number of words publication:** 727

**Total number of words disaster:** 266

**Publication:**

On April 26, 1986 the worst catastrophe in nuclear history occurred in the station at Chernobyl, Ukraine. The failure of the system was caused by the attempt of technicians to install a security system (two years after the plant started working). Technically, the failure of reactor No. 4 was described as follows: "The technicians shut down the reactor's emergency water-cooling system, its emergency shut-down system, its power regulating system, and they withdrew almost all of the control rods from its core, while allowing the reactor to run at seven percent power. These mistakes were compounded by some others, and at 1:23 a.m. on April 26 the chain reaction in the core went out of control. Several explosions and a large fireball that followed blew off the heavy steel and concrete lid of the reactor. This and an ensuing fire in the graphite reactor core released large amounts of radioactive materials into the atmosphere where it was carried great distances by air currents." Briefly the direct cause of the accident was that the technicians let the reactor run on very low power which was dangerous. Two people died immediately from the explosion and 29 from radiation. About 200 others became seriously ill from the radiation; some of them later died. It was estimated that eight years after the accident 8,000 people had died from diseases due to radiation (about 7,000 of them from the Chernobyl cleanup crew). Doctors think that about 10,000 others will die from cancer. the most frightening fact is that children who were not born when the catastrophe occurred inherited diseases from their parents.

**Publication ID:** 036

**Reference:** The Parable of the Boiled System Safety Professional: Drift to Failure C. Herbert Shivers, NASA Marshall Space Flight Center, Huntsville, Alabama, USA, Keywords: failure, resiliency, vigilance 2011

**Internet-link:** <http://ntrs.nasa.gov/search.jsp?R=20110015770>

**Date:** 1-1-2013

**Total number of words publication:** 8 776

**Total number of words disaster:** 343

**Publication:**

On April 26, 1986, two huge explosions blew apart Unit 4 of the Chernobyl Nuclear Power Plant in the Ukrainian SSR. At least 31 workers and emergency personnel were killed immediately or died from radiation sickness soon after the accident. The nearby village of Pripyat, where most Chernobyl plant workers lived, some 200,000 residents, was evacuated and sealed. Radioactive debris was carried by clouds over most of northern Europe. Long term effects still being debated, but increased childhood thyroid cancer in Belarus and Ukraine is tied to the accident. RBMK reactors ("High Power Channel-type Reactor") possess a number of design features that are considered by Western engineers to be too risky for operation as commercial power plants: Kinetic instability features (can develop local hot spots, and are more difficult to control), old technology instrumentation and control functions inferior to Western equivalents, the RBMK design does not provide for a reactor containment, Aluminum fuel channels were used for cost reasons instead of safer, but more expensive Zirconium alloy (used in US), all U.S. and Western reactors have containment as a critical risk mitigation design feature. But all these design weaknesses did not initiate the Chernobyl accident; they exacerbated its consequences. Against the advice of the Chief Reactor Operator, the political leader of the plant ordered an unauthorized experiment. The purpose of the experiment was to determine if, in case of a power outage, the kinetic energy of the spinning turbines could maintain the cooling pumps until the emergency diesel generators turned on. Inadequate prior planning and training (for the experiment), combined with poor operational hazard controls resulted in a botched experiment, and an unsafe outcome. The reactor core heated to over 5000 C and parts of the core melted. Molten core metal in contact with water produced hydrogen and the ensuing explosion blew the top off the reactor. A second explosion followed. The Chernobyl accident was the result of two cause factors: 1) RBMK reactor design weaknesses, and 2) deficient safety culture: the deliberate violation of safety rules, combined with lack of proper planning.

**Publication ID:** 037

**Reference:** Chernobyl: Ten Years After, Causes, Consequences, Solutions. no.nukes, 3rd version - April 1996

**Internet-link:** <http://archive.greenpeace.org/comms/nukes/chernob/lead25.html>

**Date:** 1-1-2013

**Total number of words publication:** 2 325

**Total number of words disaster:** 357

**Publication:**

Causes, Design Problems

The RBMK's had a number of design flaws, the main four of which are:- 1) the sensitivity of the neutron field to reactivity perturbations leading to control difficulties and requiring complicated control systems. 2) No functioning containment. 3) a positive void co-efficient of reactivity that increases as power is decreased. 4) a control rod follower design fault that actually increases reactivity at the bottom of the core upon insertion from a completely withdrawn position. In addition, owing to the control rods being fitted too closely in the guide channels, their movement was slowed by the surrounding water, giving an extremely slow insertion time of 20 seconds. The control rod follower did not match the full height of the reactor core, leaving a water gap at the top and bottom and exacerbating the effect. To date the reactors have not been made sufficiently safe and it is impossible for them to do so. The danger was graphically expressed by Hans Meyer, spokesman for the IAEA who told Reuters, on the opening day of the IAEA's Conference on RBMK reactors in Vienna on April 1st-3rd 1996 "The great danger of the RBMK reactors is that they can catch fire in a way other reactors cannot."

Despite this, the IAEA's Conference concluded with Viktor Siderenko, deputy minister at the Russian Ministry of Atomic Energy, calling for increased technical assistance for the reactors costing between \$100-150 million per reactor, compared to the present level of about \$20 million.

Consequences

It has been estimated that, although different radionuclides were released, the total radioactivity of the material from Chernobyl was 200 times that of the combined releases from the atomic bombs dropped on Hiroshima and Nagasaki. However, there is still ongoing discussion about the quantity of radioactive material released in 1986. Many of the official estimates at the time claimed that 50 million curies (excluding noble gases) were released. However, in 1995, the Committee on the Safety of Nuclear Installations from the Nuclear Energy Agency released the results of further research on the source term which shows that, the release was about 140 million curies, three times the original estimate.

**Publication ID:** 038

**Reference:** Chernobyl Children's Project International [www.chernobyl-international.org](http://www.chernobyl-international.org)

1-888-CCP-8080, Chernobyl: The Facts

What You Need to Know Almost 20 Years After the Disaster, 2004

**Internet-link:**

<http://www.google.nl/url?sa=t&rct=j&q=&esrc=s&source=web&cd=11&ved=0CDEQFjAAOAO&url=http%3A>

%2F%2Fwww.chernobylinternational.org%2Fdocuments%2Fchernobylfacts2.pdf&ei=LQ3jULe4GtSM0wXfi4BI&usg=AFQjCNEDmXdBmP2fL6LicUrsWPU4F6H58w&bvm=bv.1355534169,d.d2k&cad=rja

**Date:** 1-1-2013

**Total number of words publication:** 1 611

**Total number of words disaster:** 123

**Publication:**

In the early morning hours of 26 April 1986, a testing error caused an explosion at the Chernobyl nuclear power station in northern Ukraine. During a radioactive fire that burned for 10 days, 190 tons of toxic materials were expelled into the atmosphere. The wind blew 70% of the radioactive material into the neighboring country of Belarus. Almost 20 years later, the people of Belarus continue to suffer medically, economically, environmentally and socially from the effects of the disaster. These are the facts: The Accident  
The Chernobyl power plant is located on the border area between Ukraine and Belarus. The explosion of the reactor at Chernobyl released 100 times more radiation than the atom bombs dropped on Hiroshima and Nagasaki.

**Publication ID:** 039

**Reference:** IAEA.org International Atomic Agency, Frequently Asked Chernobyl Questions, 2012

**Internet-link:**

<http://www.iaea.org/newscenter/features/chernobyl-15/cherno-faq.shtml>

**Date:** 1-1-2013

**Total number of words publication:** 1 789

**Total number of words disaster:** 147

**Publication:**

On April 26, 1986, the Number Four RBMK reactor at the nuclear power plant at Chernobyl, Ukraine, went out of control during a test at low-power, leading to an explosion and fire that demolished the reactor building and released large amounts of radiation into the atmosphere. Safety measures were ignored, the uranium fuel in the reactor overheated and melted through the protective barriers. RBMK reactors do not have what is known as a containment structure, a concrete and steel dome over the reactor itself designed to keep radiation inside the plant in the event of such an accident. Consequently, radioactive elements including plutonium, iodine, strontium and caesium were scattered over a wide area. In addition, the graphite blocks used as a moderating material in the RBMK caught fire at high temperature as air entered the reactor core, which contributed to emission of radioactive materials into the environment.

**Publication ID:** 040

**Reference:** BBC News, The Chernobyl Disaster, Chernobyl: 20 Years On, 2009.

**Internet-link:** <http://news.bbc.co.uk/2/shared/spl/hi/guides/456900/456957/html/n1page1.st>

**Date:** 1-1-2013

**Total number of words publication:** 842

**Total number of words disaster:** 373

**Publication:**

25-26 April 1986

Engineers on the evening shift at Chernobyl's number four reactor began an experiment to see whether the cooling pump system could still function using power generated from the reactor under low power should the auxiliary electricity supply fail. At 2300 control rods, which regulate the fission process in a nuclear reactor by absorbing neutrons and slowing the chain reaction, were lowered to reduce output to about 20% of normal output required for the test. However, too many rods were lowered and output dropped too quickly, resulting in an almost complete shutdown.

Safety systems disabled

Concerned by possible instability, engineers began to raise the rods to increase output. At 0030 the decision was taken to carry on. By 0100 power was still only at about 7%, so more rods were raised. The automatic shutdown system was disabled to allow the reactor to continue working under low power conditions. The engineers continued to raise rods. By 0123, power had reached 12% and the test began. But seconds later, power levels suddenly surged to dangerous levels.

Overheating

The reactor began to overheat and its water coolant started to turn to steam. At this point it is thought that all but six control rods had been removed from the reactor core - the minimum safe operating number was considered to be 30. The emergency shutdown button was pressed. Control rods started to enter the core, but their reinsertion from the top displaced coolant and concentrated reactivity in the lower core.

Explosions

With power at roughly 100 times normal, fuel pellets in the core began to explode, rupturing the fuel channels.

At about 0124, two explosions occurred, causing the reactor's dome-shaped roof to be blown off and the contents to erupt outwards. As air was sucked in to the shattered reactor, it ignited flammable carbon monoxide gas causing a reactor fire which burned for nine days. Because the reactor was not housed in a reinforced concrete shell, as is standard practice in most countries, the building sustained severe damage and large amounts of radioactive debris escaped into the atmosphere. Firefighters crawled onto the roof of the reactor building to fight the blaze while helicopters dropped sand and lead in an effort to quell the radiation.

**Publication ID:** 041

**Reference:** Written By: S.E. Smith, Edited By: Bronwyn Harris, Last Modified Date: 17 December 2012

**Internet-link:** <http://www.wisegeek.org/what-happened-at-chernobyl.htm>

**Date:** 1-1-2013

**Total number of words publication:** 524

**Total number of words disaster:** 438

**Publication:**

On 26 April 1986, one of the worst nuclear accidents in history occurred at the Chernobyl reactor in the Ukraine. The fourth reactor exploded in the early hours of the 26th and released radiation and particulate material, devastating a 20 mile (32 kilometer) radius and affecting to the rest of the world as well. The cause of the disaster was readily identified, and it was deemed by some nations to be gross negligence on the part of plant operators. There were 30 deaths at the site of the explosion, and many more people suffered illness as a result of radiation exposure. The site of the Chernobyl reactor was cordoned off, and the reactor was capped with a large concrete pad. In the 21st century, it became evident that the pad was not effectively sealing off the radiation and that additional steps would need to be taken to prevent additional leakage of contaminated material. The area around the reactor is still restricted to humans, and in the slang of the region is known as the “dead zone,” despite the plant and animal life that has begun to take over the abandoned plant. The accident was caused by a routine shutdown at the power plant. The shutdown was designed to test the ability of the plant to function at low power, although other tests of similar plants and other reactors had suggested that powering down the plant was unsafe. The reactor became unstable as the flow of cooling water slowed, and because automatic shutoff had been disabled, the plant could not turn itself off. A worker realized the situation and attempted to turn off the reactor, but a power surge resulted instead, blowing the cover plate of the reactor off and showering radioactive material and particulates in a wide radius.

Graphite from the core caught fire and burned for nine days, releasing a large amount of radioactivity into the atmosphere. Effects of the Chernobyl disaster could be felt all over the world, with many nations reporting a rise in radioactivity as a result. The area surrounding the plant was quickly evacuated, although personnel at the site, such as firefighters and medical staff, suffered from intense radiation exposure. The events at Chernobyl were a sobering lesson for the rest of the world, which realized that poorly maintained nuclear power plants could affect the rest of the planet and not merely the regions they were in. Citizens around the site continue to suffer the effects of radiation poisoning, requiring extensive public health monitoring and treatment. More stringent safety procedures at nuclear plants were instituted, with the aim of preventing similar catastrophic accidents.

**Publication ID:** 042

**Reference:** Environmental Issues, From Larry West, former About.com Guide  
Chernobyl Nuclear Accident, 2005 or later

**Internet-link:** <http://environment.about.com/od/chernobyl/p/chernobyl.htm>

**Date:** 1-1-2013

**Total number of words publication:** 1 089

**Total number of words disaster:** 131

**Publication:**

The Chernobyl Nuclear Accident:

On April 26, 1986, the operating crew planned to test whether the Reactor No. 4 turbines could produce enough energy to keep the coolant pumps running until the emergency diesel generator was activated in case of an external power loss. During the test, power surged unexpectedly, causing an explosion and driving temperatures in the reactor to more than 2,000 degrees Celsius—melting the fuel rods, igniting the reactor’s graphite covering, and releasing a cloud of radiation into the atmosphere.

Causes of the Chernobyl Nuclear Accident:

The precise causes of the accident are still uncertain, but it is generally believed that the series of incidents that led to the explosion, fire and nuclear meltdown at Chernobyl was caused by a combination of reactor design flaws and operator error.

**Publication ID:** 043

**Reference:** The Chernobyl accident, Health Protection Agency 2012

**Internet-link:**

<http://www.hpa.org.uk/Topics/Radiation/UnderstandingRadiation/UnderstandingRadiationTopics/RadiationIncidents/Chernobyl/>

**Date:** 1-1-2013

**Total number of words publication:** 1 475

**Total number of words disaster:** 333

**Publication:**

Chernobyl is 100 km north of Kiev in the Ukraine, close to borders with Russia and Belarus. Ukraine was part of the Soviet Union up to 1989 and at Chernobyl there was a major nuclear power station with four graphite-moderated boiling water (Soviet RMBK-type) reactors. In the early hours of Saturday 26 April, 1986, an accident occurred in reactor 4 at the power station. It remains the most serious accident to occur at a nuclear power station anywhere in the world. The accident happened during a turbine test prior to the reactor being shutdown for re-fuelling. The test was started early on Friday 25 April 1986 but was interrupted for operational reasons during the afternoon. Because of this delay, staff had to operate the reactor outside its design parameters for an extended time, which included switching off basic safety systems and withdrawing nearly all the control rods from the reactor. When the turbine test was actually carried out in the very early hours of the following morning, the operators feared the reactor had become unstable and tried to insert all the control rods at once. Unfortunately, a design flaw in the control rods meant the reactor became even more unstable and it suddenly surged to full power and beyond. This caused the fuel to melt and a pressure explosion followed by a hydrogen explosion blew the 1000 tonne lid off the reactor. There was substantial damage to the reactor building and large amounts of radioactive fission products were released into the environment. A subsequent fire in the open reactor continued for more than a week and dispersed radioactive material until an improvised seal was constructed using sand, clay, lead and boron dropped from military helicopters. Two workers at the power station died from physical injuries on 26 April and over 200 workers and firemen who tackled the blaze after the explosion were hospitalised with radiation burns. Twenty-eight people from this group died from acute radiation exposure syndrome during the following days and weeks.

**Publication ID:** 044

**Reference:** A Look at Chernobyl Before and After the Worst Nuclear Disaster in History, More than 25 years after the nuclear disaster, the word Chernobyl still incites fear and concern. Before 1986, Chernobyl was a city. Since 1986, it has become a difficult lesson learned.

By Jennie Wood, Information Please® Database, © 2007 Pearson Education, Inc..

**Internet-link:** <http://www.infoplease.com/world/disasters/chernobyl-25th-anniversary.html>

**Date:** 1-1-2013

**Total number of words publication:** 1 349

**Total number of words disaster:** 158

**Publication:**

The Disaster

On April 26, 1986, a power output surged during a systems test. An emergency shutdown was attempted, but the power output spiked even more, which led to an explosion at reactor No. 4 at 1:23am. Two workers died instantly. Further explosions and a fire released highly radioactive material into the atmosphere. The release of nuclear fallout at Chernobyl was 400 hundred times higher than that of the atomic bombing of Hiroshima. Both mechanical malfunction and human error were cited as the causes of the disaster. At the time of the disaster, 49,400 people lived in Pripyat. More than 24 hours after the first explosion, residents were ordered to evacuate, but by this time, many had already suffered varying degrees of radiation poisoning. They were told that the evacuation wouldn't last long and to leave their personal belongings. Most of those residents, however, never returned and their belongings are still there today, reminders of lives interrupted and forever altered.

**Publication ID:** 045

**Reference:** Nuclear Safety and Security in Russia and the World  
Melissa English International Studies, Nazareth College, Last Updated: April 20, 2005

**Internet-link:** <http://www-pub.naz.edu/~menglis6/Chernobyl.htm>

**Date:** 1-1-2013

**Total number of words publication:** 1 421

**Total number of words disaster:** 438

**Publication:**

In the middle of a shutdown test that took place at 1:21 AM in the morning on 26 April, 1986, there was an electrical surge and reactor number four responded in kind. It exploded, releasing radioactive poisons into the

atmosphere.<sup>1</sup>[4] The power surge was created by a huge flaw in the RBMK reactor. The design allowed the nuclear materials to overheat if any of the coolant water was lost. When the test was performed, the team cut down on the power which resulted in a loss of water. As a result, the uranium rods quickly overheated, caused too much steam, and sent the 1,000 metric ton reactor ceiling into the air. This put too much stress on the pressurized water tubes (used in light water reactors such as the RBMK) causing all 1,600 of them to explode leaving a gaping hole open for the radiation emitting from the reactor to leak out into the atmosphere. The test that was conducted was actually against the power plant's official policies; it was done by a small group that wanted to test out the ability of the reactor to create electrical power without its source of energy being connected. Without the approval of the safety commission for the plant, the team that led the test attempted to run the plant on low-power, ignoring many safety regulations.<sup>2</sup>[5] Along with the fact that proper safety precautions were not being followed, the RBMK reactor itself had other major flaws that allowed for massive amounts of radiation to escape. Unlike the Three Mile Island accident in 1979, during which the radiation was contained within the facility, Chernobyl was not constructed to withstand such a large blast of radiation. The building at Three Mile Island was constructed with a final layer of concrete on the outside specifically put there to contain radiation. The RBMK facility did not have this containment layer to protect the environment from radiation.<sup>3</sup>[6] Even so, most officials maintain that even with the extra layer, the amount of radiation released after the accident was enough to have penetrated and contaminated the area surrounding the power plant.<sup>4</sup>[7] The immediate results of the explosion, which killed 31 people immediately from heat and radiation poisoning, spread across Ukraine, Belarus, and Russia.<sup>5</sup>[8] The explosion released radioactive materials in the form of cesium-137 and strontium-90, both of which have about 30 year half lives. Radioactive poisons had been released into a radius larger than 100 miles, but, furthermore, they became airborne and are known to have affected areas in Sweden, northern Russia, and even Alaska.<sup>6</sup>[9]

**Publication ID:** 046

**Reference:** Expensive Mistakes and Cheap Thrills: explorations in human stupidity after 2011

**Internet-link:** <http://www.expensivemistakescheapthrills.co.za/chernobyl>

**Date:** 1-1-2013

**Total number of words publication:** 706

**Total number of words disaster:** 378

**Publication:**

Although this disaster has had an extreme impact on thousands of people exposed to high levels of radiation, and should therefore be treated as a tragedy (and with respect owed to the victims), it cannot be said that human fault (at least somewhere along the line) isn't to be found at the bottom of the radioactive "lava" found in the basement of the Chernobyl power plant. This is not to say that the operators on duty during the terrible sequence of events that took place on the 26th of April, 1986, are to be blamed: instead, as a 1993 INSAG report established, the direct cause of the tragedy has to be attributed to several factors, not least of which were the reactor control rods that were 1.3m shorter than they were supposed to be. Mixed in with a physical flaw were the facts of ill-communication between the different shift operators/engineers, a lack of information/training provided to those engineers, and the attempt to conduct a reactor safety test (ironically) at an inopportune time. It is almost as if the reactor explosions (the first explosion was followed by another after only 3 seconds) were the final results of a series of errors which, in combination, acted to cause the disaster. The human cost of the Chernobyl meltdown cannot be measured, and the fallout from the event still has an impact on the environment of countries like Germany, many hundreds of kilometres away: for example, in 2010, 1 000 wild boars that were hunted were found to be unsuitable for human consumption due to radioactivity (probably ingested through radioactive mushrooms). In the Scandinavian countries, livestock are often fed with very high quality feed for

---

several months before slaughter to ensure their appropriateness for human consumption. The worst effects of the accident, however, are felt by those closest to the site. During the attempts to bring the fire raging after the explosion under control, many fire-fighters lost their lives to radiation poisoning either immediately following after the event or several months down the line. Animals within a relatively close proximity experienced thyroid cancer, were stunted in their growth, and stopped being able to reproduce due to nuclear fallout. Additionally, and morbidly, the incidence of the birthing of deformed fetuses also dramatically increased.

**Publication ID:** 047

**Reference:** WiseDude.com, Chernobyl Nuclear Disaster, Copyright 2006 WiseDude.com.

**Internet-link:** <http://www.wisedude.com/history/chernobyl.htm>

**Date:** 1-1-2013

**Total number of words publication:** 679

**Total number of words disaster:** 345

**Publication:**

The fateful day

April 25<sup>th</sup>-26<sup>th</sup> 1986 saw the world's worst nuclear power disaster at Chernobyl in the former USSR (now Ukraine). Clouds of radioactive isotopes spread as far as Ireland and Greece. It left untold human misery in its wake, not only for those exposed to it but for their next generation too. The amount of radioactive material released into the atmosphere was about 90 times the radiation produced by the bomb dropped in Hiroshima. The number of people exposed to the resultant radiation has been estimated to be around five million. Hindsight has shown human folly to be the root cause of the disaster. We always do learn from our mistakes, only this mistake proved too costly. The nuclear power plant at Chernobyl is located 80 miles north of Kiev. The plant had four nuclear reactors and the accident occurred while reactor number four was being tested. The accident that occurred at 1.23 AM manifested itself in the form of a fireball so forceful that it blew off the reactor's steel and concrete lid. The immediate toll on human lives was 30. But the resultant radiation caused permanent health problems to several thousands. Besides this, the environmental damage due to the high levels of radiation was also very high.

The causes

Several safety regulations had been flouted at the nuclear power plant and several weaknesses of the plant had been disregarded despite the shortcomings being common knowledge. The reactor that blew up had certain design faults like being unstable when the power supply was low. The accident occurred during a test of the reactor and several safety violations occurred. For example, although it was known and stipulated that a minimum of 30 control rods were required only 6-8 of them were used. The cooling system of the reactor had been disabled. The purpose of the test, during which the explosion took place, was to see how the reactor would function in the event of a power shutdown. Several operational errors added to the instability created by low power supply and there occurred disastrous results.

**Publication ID:** 048

**Reference:** Chernobyl disaster, chernobylwel.COMe 2012

**Internet-link:** <http://chernobylwel.com/index.php?language=en&content=accident>

**Date:** 1-1-2013

**Total number of words publication:** 788

**Total number of words disaster:** 306

**Publication:**

The Chernobyl nuclear power plant accident occurred on April 26, 1986. It was the largest nuclear energy disaster in history. The explosion took place in the fourth block of the Chernobyl power plant, located only 120 km from the capital of Ukraine – Kiev, close to the border with Belarus. Chernobyl power plant was at that time one of the largest in the world. It was dedicated to a strategic military program for the Soviet army. The actual crash happened due to a coincidence of several factors. Beside the fact that the reactor did not have an updated security system, it had a low level of automation. On the fatal night of April 26, there was an experiment going on, which should have tested the inertial range of the turbo-generator unit. Overheating fuel caused the destruction of the generator's surface. At 1:24 AM local time, 40-60 seconds after beginning of the experiment, two large explosions took place. According to some experts, the process missed to start the automatic safety system by only two seconds. This would have stopped the turbo-generator's overheating. The steam released by the first explosion removed concrete roof of the reactor weighing 1000 ton. The second explosion followed only two to five seconds after the first one. Air from outside entered the reactor and caused water vapor to mix with molten graphite. The personnel of the power plant did not follow the necessary safety regulations. The nuclear disaster was also a coincidence. The reactor should have been shut down before the experiment. However, this was postponed by nine hours because of the forthcoming May 1 celebrations and the electricity needed to fulfill

the production plan. This delay caused that the experiment was run by other worker shift than the one that prepared it. The night shift comprised fewer experienced operators to conduct the experience.

**Publication ID:** 049

**Reference:** Chernobyl Nuclear Power Plant Accident CIA, Department of Defense, Department of Energy, Congressional, GAO, and Foreign Press Monitoring Files, 4,010 pages of CIA, Department of Defense, Department of Energy, Congressional, GAO, and foreign press monitoring files related to the Chernobyl Nuclear Accident. On Sunday April 26, 1986, at the Chernobyl Nuclear Power Plant near Pripyat, Ukraine, reactor #4 exploded. For the 25 years from 1986 to 2011, this incident has been referred to as the world's worst nuclear power plant accident.

**Internet-link:** [http://www.paperlessarchives.com/chernobyl\\_nuclear\\_accident\\_doc.html](http://www.paperlessarchives.com/chernobyl_nuclear_accident_doc.html)

**Date:** 1-1-2013

**Total number of words publication:** 2 135

**Total number of words disaster:** 453

**Publication:**

According to reports filed with International Atomic Energy Agency (IAEA) on April 25, 1986, technicians at the Chernobyl plant launched a poorly executed experiment to test the emergency electricity supply to one of its Soviet RBMK type design reactors. The test was meant to measure a turbogenerator's ability to provide in-house emergency power after shutting off its steam supply. During the experiment the technicians violated several rules in place for operating the reactor. During the experiment, the emergency shutdown system was turned off. The reactor was being operated with too many control rods withdrawn. These human errors, coupled with a design flaw that allowed reactor power to surge when uncontrolled steam generation began in the core, set up the conditions for the accident. A chain of events lasting 40 seconds occurred at 1:23 AM on April 26. The technicians operating the reactor put the reactor in an unstable condition, so reactor power increased rapidly when the experiment began. Subsequent analysis of the Soviet data by U.S. experts at the Department of Energy, suggests the power surge may have accelerated when the operators tried an emergency shutdown of the reactor. According to Soviet data, the energy released was, for a fraction of a second, 350 times the rated capacity of the reactor. This burst of energy resulted in an instantaneous and violent surge of heat and pressure, rupturing fuel channels and releasing steam that disrupted large portions of the core. The surge destroyed the core of reactor unit four, containing approximately 200 tons of nuclear fuel. Some of the shattered core material was propelled through the roof of the reactor building. The hot core material of reactor 4 started about 30 separate fires in the unit 4 reactor hall and turbine building, as well as on the roof of the adjoining unit 3. All but the main fire in the graphite moderator material still inside unit 4 were extinguished in a few hours. It was a day and a half before the people living in Prip'yat were ordered to evacuate. The residents were told they would only be gone for several days, so they left nearly everything behind. They never returned. Soviet authorities made the decision not to cancel May 1, May Day, outdoor parades in the region four days later. The graphite fire continued to burn for nearly two weeks carrying radioactivity high into the atmosphere, until it was smothered by sand, lead, dolomite, and boron dropped from helicopters. Despite the wide spread of radiation, Soviet officials at first said very little publicly about what happened at Chernobyl. It was not until alarms from radiation detectors in other countries, many hundreds of miles away, forced the Soviets to admit to the Chernobyl accident.

**Publication ID:** 050

**Reference:** Chernobyl Nuclear Power Plant Accident, Detection and Monitoring

Larry Gilman. Encyclopedia of Espionage, Intelligence and Security. Volume 1. Detroit: Gale, 2004.

**Internet-link:** <http://www.omnilogos.com/2012/06/15/chernobyl-nuclear-power-plant-accident-detection-and-monitoring/>

**Date:** 1-1-2013

**Total number of words publication:** 1 439

**Total number of words disaster:** 462

**Publication:**

On April 26, 1986, a nuclear reactor in the town of Chernobyl (in the Ukraine, then a member state of the Soviet Union) exploded, collapsing the building in which it was located and releasing a radioactive plume that deposited material over much of Europe and Scandinavia. Although the Soviet government was unwilling to release information, satellite photographs by military and civilian satellites, as well as direct radiation measurements downwind, confirmed the event.

The accident and its consequences

The town of Chernobyl, some 60 miles (96 km) north of the city of Kiev (population 2.5 million), is the site of a nuclear electricity-generating station comprising four identical units of the Soviet-designed RBMK1000 type. Each of the four units is designed to produce 1,000 megawatts of electricity; one of the units is still in operation. On April 25, 1986, operators began an experiment at Unit No. 4 to take advantage a scheduled annual



maintenance shutdown. The goal of the experiment was to see if the station's turbine generator could deliver temporary power to certain cooling pumps after cut-off of its steam supply. As a first step, the unit's operators deliberately disconnected the reactor's emergency core cooling system; such a system is necessary because every large reactor core can generate millions or billions of watts of thermal power (heat); this energy must constantly be removed by a flow of coolant, or the core may cause a steam explosion, melt down, or even (in reactors using highly-enriched fuel) a relatively small nuclear explosion. The emergency core cooling system is supposed to keep the core cool when the usual systems have failed. Unit No. 4's operators had not left the emergency core cooling system disconnected, but had committed a series of further errors that allowed the reactor's power output to fall far below planned levels. In attempting to restore the reactor's power output, the operators caused it to go out of control. In a period of approximately 5 seconds, the core's heat output increased exponentially to the point where a steam explosion occurred. This blew a 1,000-ton concrete lid off the reactor and damaged the roof of the reactor hall. A few seconds later, an even larger explosion occurred when hydrogen released by the breakdown of water exploded. Burning chunks of graphite (a form of carbon of which 1700 tons were present in the reactor core) flew through the air and landed on other parts of the complex, starting fires. The remaining graphite started to burn, releasing a plume of radioactive smoke that was carried by the wind first north, toward Scandinavia, and later west and south over much of the rest of Europe. The graphite fire burned for over a week, but was finally brought under control by firefighters, many of whom died of radiation burns.

**Publication ID:** 051

**Reference:** Chernobyl, by Deniz Arika, Alexandra Ginieres, Jung-Hwan Hong, March 1998

**Internet-link:** [http://econc10.bu.edu/economic\\_systems/NatIdentity/FSU/Ukraine/CHERNOBYL.html](http://econc10.bu.edu/economic_systems/NatIdentity/FSU/Ukraine/CHERNOBYL.html)

**Date:** 1-1-2013

**Total number of words publication:** 2 579

**Total number of words disaster:** 262

**Publication:**

One of the worst man-made industrial disasters in history happened on April 26, 1986, in a Nuclear Energy Plant in Chernobyl. Most people had no idea that such city even existed, but after that day its anonymity vanished forever. Chernobyl is located just about 120 kilometers north of Kiev, a major city in Ukraine. This accident was a major humanitarian catastrophe of the twentieth century. In one of the four reactors of the Nuclear Energy Plant, Unit 4, an explosion occurred at around 1:24 am local time, while an experiment was being made. The experiment was to test how long the turbines would supply power in case of a loss of main electrical power supply. The biggest cause of the explosion was the reactor itself. It was a Soviet made reactor, which had designing faults and was being operated by inadequately trained personnel. Also during the experiment, parts of the safety system of the reactor were shut off in addition to breaking of some other operating rules. There were two explosions. The first destroyed the roof of the reactor building, and the second one exposed the reactor core. Both inside and outside of Unit 4 were on fire, releasing large amounts of fuel containing fission products, including radioactivity. Burning fuel and graphite from the core of the reactor caused the main release of radioactivity into the environment. The graphite burned for nine days releasing radioactivity. During these next nine days, radioactivity spread almost all around Eastern Europe and Scandinavian countries (Sweden, Finland, etc.) with help from changing meteorological conditions and wind directions.

**Publication ID:** 052

**Reference:** Globaltruth.net Eric Laval in Chernobul, After 2009

**Internet-link:** <http://www.globaltruth.net/CHERNOBYL1.html>

**Date:** 1-1-2013

**Total number of words publication:** 1 573

**Total number of words disaster:** 455

**Publication:**

On 25 April, prior to a routine shutdown, the reactor crew at Chernobyl 4 began preparing for a test to determine how long turbines would spin and supply power to the main circulating pumps following a loss of main electrical power supply. This test had been carried out at Chernobyl the previous year, but the power from the turbine ran down too rapidly, so new voltage regulator designs were to be tested. A series of operator actions, including the disabling of automatic shutdown mechanisms, preceded the attempted test early on 26 April. By the time that the operator moved to shut down the reactor, the reactor was in an extremely unstable condition. A peculiarity of the design of the control rods caused a dramatic power surge as they were inserted into the reactor

The interaction of very hot fuel with the cooling water led to fuel fragmentation along with rapid steam production and an increase in pressure. The design characteristics of the reactor were such that substantial damage to even three or four fuel assemblies can – and did – result in the destruction of the reactor. The overpressure caused the 1000 t cover plate of the reactor to become partially detached, rupturing the fuel

channels and jamming all the control rods, which by that time were only halfway down. Intense steam generation then spread throughout the whole core (fed by water dumped into the core due to the rupture of the emergency cooling circuit) causing a steam explosion and releasing fission products to the atmosphere. About two to three seconds later, a second explosion threw out fragments from the fuel channels and hot graphite.

There is some dispute among experts about the character of this second explosion, but it is likely to have been caused by the production of hydrogen from zirconium-steam reactions. Two workers died as a result of these explosions. The graphite (about a quarter of the 1200 tonnes of it was estimated to have been ejected) and fuel became incandescent and started a number of fires<sup>f</sup>, causing the main release of radioactivity into the environment. A total of about 14 EBq ( $14 \times 10^{18}$  Bq) of radioactivity was released, over half of it being from biologically-inert noble gases. About 200-300 tonnes of water per hour was injected into the intact half of the reactor using the auxiliary feedwater pumps but this was stopped after half a day owing to the danger of it flowing into and flooding units 1 and 2. From the second to tenth day after the accident, some 5000 tonnes of boron, dolomite, sand, clay and lead were dropped on to the burning core by helicopter in an effort to extinguish the blaze and limit the release of radioactive particles.

**Publication ID:** 053

**Reference:** Factbox: Key facts on Chernobyl nuclear accident, Thomson Reuters.  
Kiev, Tue Mar 15, 2011

**Internet-link:** <http://www.reuters.com/article/2011/03/15/us-nuclear-chernobyl-facts-idUSTRE72E42U20110315>

**Date:** 1-1-2013

**Total number of words publication:** 1 983

**Total number of words disaster:** 105

**Publication:**

The Chernobyl nuclear power complex, which is now closed down and being decommissioned, is located 100 km north-west of Kiev, close to the border of Belarus. The accident occurred at 01:23 on 26 April 1986, resulting from a fatal combination of design fault and operation of an illegal and unauthorised experiment. There were two explosions in one of the reactors, which blew off the 1000 tonnes of cover plate and the roof of the building. This was followed by influx of air into the reactor's graphite core, which started to burn, discharging noble gases, fission products, and uranium fuel into the atmosphere (Savchenko, 1995)

**Publication ID:** 054

**Reference:** The Chernobyl Accident Megan Worleyon Jul 27, 2008

**Internet-link:** <http://suite101.com/article/the-chernobyl-accident-a61966>

**Date:** 1-1-2013

**Total number of words publication:** 879

**Total number of words disaster:** 166

**Publication:**

Seventy miles outside the Ukrainian capital of Kiev, at 1:24 a.m. April 26, 1986, two huge explosions shook the Chernobyl nuclear power plant.

The cause of the incident

Over the weeks following the official report it was discovered the serious errors had been made on the part of workers in the plant. The first discovery was that the indirect cause of the explosions had been an unauthorized test. The test was an attempt to figure out what would happen if the power to the plant had failed.

During that unauthorized test many mistakes were made that eventually lead to the explosions. The first and most important mistake was turning off the emergency coolant system. During the test the core of the reactor was allowed to reach 5000 degrees Celsius, the temperature rising from an unexpected power surge. This extremely high temperature produced molten metal. The metal then reacted with the cooling water to produce hydrogen gas and steam, which was the direct cause of the explosion.

**Publication ID:** 055

**Reference:** The Chernobyl Disaster, Created Sep 3, 2004, Updated Jan 25, 2006

**Internet-link:** [http://www.h2g2.com/approved\\_entry/A2922103](http://www.h2g2.com/approved_entry/A2922103)

**Date:** 1-1-2013

**Total number of words publication:** 4 856

**Total number of words disaster:** 465

**Publication:**

The Chernobyl power complex is located in Ukraine, former Soviet Union. On 25 April, 1986, reactor four was to be shut down for routine maintenance, so it was decided to take advantage of this to run a test. Ironically, the

test was designed to improve safety. The reactor's cooling pumps relied on electrical power, so the operators wanted to see how long the turbines could produce sufficient energy to keep the pumps running in the event of a loss of power. The reactor's emergency cooling system was deliberately disabled, as they didn't want it cutting in when the main pumps slowed. To reduce cooling requirements, the reactor was to be run at low power, despite the fact that these reactors were known to be unstable at low power settings. The test had been attempted on two previous occasions but never completed. There were two main cooling systems excluding the back-up, each with four main pumps. Four of these pumps were powered by the generator that was to 'fail.' Prior to the experiment, with reactor power reduced and all eight pumps operating, water flow exceeded permitted levels. The amount of water in the steam-raising circuit reduced steam production. Additionally, the extra water was absorbing neutrons and causing power to fall. Power fell to less than 1% of capacity, so the operators manually removed control rods to compensate, switched off automatic regulators and eventually stabilised the reactor at the planned test power level. At one point only six-eight control rods were being used. According to procedure, at least 30 are required to maintain control, and if there are any less the reactor should have been shut down. They allowed the test to continue, despite knowing that about 20 seconds would be required to lower all the rods and shut down the reactor in the event of a power surge. Then both generators were shut down to start the test. The cooling pumps slowed, reducing water flow in the core and producing more steam. The excess water had up until then been absorbing neutrons, so the formation of steam pockets caused neutron flux to increase (the positive void coefficient). At 01:23 hours on 26 April, reactor power increased exponentially, up to an estimated 100 times nominal. The control rods could not be re-inserted in time; the fuel overheated and some of the rods ruptured.

The resulting explosion, thought to be caused mainly by steam pressure and chemical reaction with the exposed fuel, blew the 1000-tonne lid clear of the core. A second explosion threw out fragments of burning fuel and graphite from the core and allowed air to rush in, causing the graphite moderator to burst into flames. The exact cause of the second explosion remains unknown, but it is thought that hydrogen may have played a part.

**Publication ID:** 056

**Reference:** No.12 Disaster at Chernobyl, 2 May, 2012, by Declan Lynch

**Internet-link:** <http://www.nce.co.uk/features/nce-40-years/no12-disaster-at-chernobyl/8629897.article>

**Date:** 1-1-2013

**Total number of words publication:** 472

**Total number of words disaster:** 216

**Publication:**

A flawed reactor design operated by poorly trained staff resulted in the biggest ever nuclear accident when one of the four reactors exploded at Chernobyl's power plant in April 1986.

The accident occurred in the early hours of 26 April when its number four reactor exploded following an experiment to determine how long turbines would spin and supply power to the main circulating pumps in the event of a loss of main electrical power supply. Control rods, which regulate the fission process in a nuclear reactor by absorbing neutrons and slowing the chain reaction, were lowered to reduce output to about 20% of normal output. However, too many rods were lowered and output dropped too quickly, resulting in an almost complete shutdown. Concerned by possible instability, engineers began to raise the rods to increase output. At this point the reactor began to overheat and its water coolant turned to steam. Engineers attempted an emergency shutdown but the reactor became extremely unstable and there were two explosions. The uranium fuel in the reactor overheated and melted through protective barriers. As the reactor did not have a containment structure - common in all western nuclear power stations - radioactive material from the explosion, including plutonium, iodine, strontium and caesium were scattered as far as Scandinavia and the UK.

**Publication ID:** 057

**Reference:** Chernobyl Design Flaws Made Accident Worse, Soviet Report Concedes, Los Angeles Times, August 23, 1986, Robert Gillette, Times Staff Writer

**Internet-link:** [http://articles.latimes.com/1986-08-23/news/mn-15781\\_1\\_design-flaws](http://articles.latimes.com/1986-08-23/news/mn-15781_1_design-flaws)

**Date:** 1-1-2013

**Total number of words publication:** 1 100

**Total number of words disaster:** 228

**Publication:**

Human error was the overriding cause of the Chernobyl nuclear accident, but the reactor's design made it a difficult one to manage, according to nuclear safety experts who have read the Soviet Union's government report

on the disaster. These analysts say that Soviet authorities appear to recognize that operator errors at the Chernobyl plant on the night of April 25-26 were not the sole cause of the accident, and that technical flaws in the reactor's design contributed to the worst accident in the 44-year history of nuclear energy. In particular, they said, a distinctive feature of the Chernobyl design, which sets it apart from conventional nuclear power plants in most of the world, is its tendency to generate a sudden and uncontrollable burst of power if large steam bubbles, or "voids," are allowed to form in the reactor core, as they did before the accident. This peculiarity of the Chernobyl type of graphite reactor, called a positive void effect, is now seen as a decisive factor in the accident, one that transformed successive blunders on the part of Soviet operators over a period of hours into a catastrophe.

#### Death Toll Revised

Thirty-one people have died as a result of the accident; 203 others are still suffering from acute radiation sickness, and 135,000 people had to be evacuated from the area around Chernobyl and Kiev, the Soviets have reported.

#### **Publication ID:** 058

**Reference:** Year After Chernobyl, Fallout Over Flawed Nuke

Reactors Lingers, Chicago Tribune News, April 26, 1987|By Jon Van.

**Internet-link:** [http://articles.chicagotribune.com/1987-04-26/news/8702010338\\_1\\_rbnk-reactors-chernobyl-graphite-moderated/2](http://articles.chicagotribune.com/1987-04-26/news/8702010338_1_rbnk-reactors-chernobyl-graphite-moderated/2)

**Date:** 1-1-2013

**Total number of words publication:** 1 098

**Total number of words disaster:** 213

#### **Publication:**

The experiment was intended to explore the extent to which mechanical energy from the rotor in a turbogenerator could be used to supply electrical power to selected in-plant equipment during ``turbine coast-down,`` Soviet scientists told colleagues in Vienna. Several unplanned events happened during the shutdown, including a request to keep the affected reactor supplying power to the grid at a time when technicians had disconnected its emergency core-cooling apparatus from the rest of the system.

Operators also had disarmed the reactor's automatic shutdown system so they could proceed with their experiment. New operating procedures make it much more difficult for operators to disarm, turn off or bypass automatic safety systems intended to prevent runaway energy build-ups. Wilson said he was told by Soviet colleagues that mismanagement, not just operator error, was at the bottom of the Chernobyl disaster, and there is a question whether mere procedural changes could overcome mismanagement. New regulations, for example, require the presence of the plant's chief engineer or his deputy during periods of shutdown and start-up. That might not have been enough, in itself, to have prevented the explosion, Soviet officials told Wilson, because the chief engineer was on vacation and his deputy was the chief proponent of breaking operating rules to perform the unauthorized experiment during shutdown.

#### **Publication ID:** 059

**Reference:** Warning Signs Of Chernobyl Nuclear Disaster Were Ignored, Soviets Say, Chicago Tribune News, August 16, 1986, By New York Times News Service.

**Internet-link:** [http://articles.chicagotribune.com/1986-08-16/news/8603010325\\_1\\_reactor-control-rods-chernobyl-nuclear-plant](http://articles.chicagotribune.com/1986-08-16/news/8603010325_1_reactor-control-rods-chernobyl-nuclear-plant)

**Total number of words publication:** 822

**Total number of words disaster:** 498

#### **Publication:**

The disaster at the Chernobyl nuclear plant last April resulted when workers shut off key operating and emergency equipment for a reactor to do a test, then ignored warning signs of problems, according to a 382-page report prepared by Soviet officials. The report, to be publicly presented at an international symposium in Vienna on Aug. 25, said human error was the primary cause of the disaster, which killed at least 30 people and was the worst commercial nuclear accident in history. The report noted a variety of safety violations by operators. Although the translated details were incomplete and raised questions, they added significantly to public knowledge about the explosion and fire at Chernobyl in the early hours of April 26. Included in the report was the conclusion that there was no meltdown of the nuclear fuel. American experts said that statement appears to be contradicted by the type and magnitude of radioactive particles found in Europe several hundred miles from the reactor after the accident. The events leading to the accident were said to have begun at 1 a.m. on Friday, April 25, when operators began to reduce power in reactor No. 4 for a test to measure residual energy produced by the turbine and generator after the reactor is shut down. Over the next 24 hours, operators shut off the reactor's emergency cooling system. They also shut off the power regulating system and the automatic shutdown

system, even though they continued to keep the reactor itself running at low power. With those key safety systems off, problems began to develop, including a rise in the reactor power level. But the operators, according to the report, did not realize the significance of the problems and continued their tests. When the operators finally recognized the problems, they tried to shut the reactor down by inserting control rods into the core to stop the chain reaction. But by this point, the report said, only a quarter of the rods went into place. Forty seconds after 1:23 a.m. on Saturday, April 26, there was a loud bang and the control rods stopped partway into the core. Twenty seconds later there were two explosions and a fireball. The reactor was out of control. The Chernobyl unit was a type of reactor that is particularly difficult to run and control, nuclear experts have said. It is one of the earlier reactor designs, originally developed for weapons production; it is cooled by water and uses graphite to facilitate the chain reaction by trapping neutrons. Newer designs, including all but one commercial American unit, do not use graphite, a flammable material that can readily produce explosive hydrogen under reactor accident conditions. In new reactors, which use water to slow neutrons, the loss of cooling water decreases power as neutrons escape. The test undertaken by the Chernobyl operators, if successful, would have told how long the turbine and generator would run pumps and other safety equipment if the reactor was abruptly shut down for some reason.

**Publication ID:** 060

**Reference:** The Chernobyl accident: What happened, BBC News

**Internet-link:** <http://news.bbc.co.uk/2/hi/europe/778477.stm>

**Date:** 1-1-2013

**Total number of words publication:** 4 637

**Total number of words disaster:** 167

**Publication:**

Reactor Four at the Chernobyl nuclear power plant began to fail in the early hours of 26 April, 1986. Seven seconds after the operators activated the 20-second shut down system, there was a power surge. The chemical explosions that followed were so powerful that they blew the 1,000 ton cover off the top of the reactor. Design flaws in the power plant's cooling system probably caused the uncontrollable power surge that led to Chernobyl's destruction. Serious mistakes had also been made by the plant operators, who had disengaged several safety and cooling systems and taken other unauthorised actions during tests of electrical equipment. With procedures intended to ensure safe operation of the plant operating less than effectively, the Chernobyl unit was even more vulnerable to unforeseen power discharges. The Chernobyl plant did not have an effective containment structure, and without that protection, radioactive material escaped into the wider environment. The crippled reactor is still encased in a hurriedly constructed concrete sarcophagus, which is growing weaker over time.

**Publication ID:** 061

**Reference:** About Chernobyl Chernobyl Children Appeal (NI) Ltd. Charity based in Northern Ireland, 2000

**Internet-link:** [http://www.ccanireland.com/wordpress/?page\\_id=203](http://www.ccanireland.com/wordpress/?page_id=203)

**Date:** 1-1-2013

**Total number of words publication:** 799

**Total number of words disaster:** 232

**Publication:**

In the early morning hours of April 26, 1986, reactor No. 4 was operating at very low capacity (6 to 7 percent) during a planned shutdown. Plant personnel intended to monitor the performance of turbine generators, which supplied electric power for the plant's own operation, during a changeover from standard to a backup source of power. The reactor's design made it unstable at low power, and the operators were careless about safety precautions during the test. After a sudden power surge, two explosions destroyed the reactor core and blasted a large hole in the roof of the reactor building. Radioactive debris moved up through this hole to heights of 1 km (0.6 mi), carried by a strong updraft. Fires caused by the explosion and the heat of the reactor core fed the updraft. An estimated 100 to 150 million curies of radiation (primarily radioactive isotopes of iodine and cesium) escaped into the atmosphere before cleanup crews were able to bring the fires under control and stabilize the situation some two weeks later. Initially, prevailing winds carried the radioactivity northwest from the plant across Belarus and into Poland and Sweden, where heightened radiation levels detected on April 28 first brought the accident to the world's attention. Subsequently, from May 1 to 5, wind patterns shifted so that the bulk of radioactivity was carried more directly north and northeast, over Belarus and southwestern Russia.

**Publication ID:** 062

**Reference:** Articles And Information / Chernobyl: A Short History Of The Human Impact, 06.05.2009

Chernobyl: A Short History of the Human Impact, By Lisa Horne

**Internet-link:** [http://www.sras.org/chernobyl\\_short\\_history\\_human\\_impact](http://www.sras.org/chernobyl_short_history_human_impact)

**Date:** 1-1-2013

**Total number of words publication:** 1 968

**Total number of words disaster:** 115

**Publication:**

On April 26, 1986 the worst nuclear accident in history took place in Chernobyl, Ukraine as a result of an unnecessary safety test. Workers at Reactor No. 4 turned off the emergency cooling system to find out if there would be enough electricity in the grid systems that cooled the core if the reactor were to lose power. As a result of several factors, including a reactor design flaw, operational errors, and flouted safety procedures, there was a power surge, a steam explosion, and finally a nuclear explosion that shot the reactor's 500 ton roof and almost nine tons of toxic waste straight up into the air at 1:26 am on Saturday, April 26, 1986.