BG9700051

ANALYSIS OF HEAVY RADIOLOGICAL ACCIDENTS IN NPP AND AT GAMMA-IRRADIATORS

V. Angelov[1], T. Semova[2], Ts. Bonchev[2]

The harmless influence of the radioactive substances and their radiation over people is detected early in the 20th century but the society through the decades has accepted the described events as exotic ones and related to the activity of some dedicated scientists looking into one not so conceivable science. The problem became more topical when very frequent and strange diseases have been established among the staff servicing the roentgen equipment and this has led to the appearance of the first regulation of the activity that today we name as „work in ionizing radiation scope".

The two atomic bombs thrown over Hiroshima and Nagasaki in 1945 horrified the mankind but they were a result of deliberate activities at the time of a very hard world war. Announcements about victims of ground nuclear weapons testing appeared latter but this also did not concern the ordinary citizen in an ordinary state. Early in the 60th the global danger of a radioactive contamination arising from nuclear weapons experiments was recognized and beside the hard and complicated political situation the ground experiments have been ceased in practice.

Creation of nuclear-power engineering revealed for the first time a possibility of accident arising, i.e. an unplanned event which could lead unexpectedly to a new type of challenge of health and life of not suspecting anything people. All this at a time when the ways of an efficiently protection and the precise prognoses had not been known. Today the event of this type is called a „grave radiological accident".

Heavy accidents in industry are known since its development, especially in the chemical and military industries. The radiological accidents are something new and because of that and owing to the information media they are accepted by the people as an apocalypse threatening the human civilization. The simply comparison of the victim number of a radiological accident and all other accidents in one and the same period leads to another conclusion but here is not the place to discuss this problem.

Our task was to find out the literature sources concerning heavy radiological accidents, to show their properties and to make an effort to analyze the main causes of their arising. It turns out that the accidents of powerful gamma-irradiators represent not much lower danger to people than the NPP accidents, except for that in Chernobyl. For the sake of brevity the accident data are given in the form of uniform tables.

Table I. Heavy radiological accidents in NPP

No. 1

Object: Site: Accident date:	Heavy water experimental reactor NRX, thermal power 20 MW Chock-River, Canada 12 December 1952
Prime cause: Additional circumstances:	Wrong staff activities, pulling the core control rods At signaling „reactor emergency stop" not all rods fall gravitationally
Accident character:	Reactor heating up to 90 MW thermal power
Radioactivity emission	Reactor rooms contaminated of fission products with activity 10000 Ci
Irradiated people: Victims:	Staff Non
Economical damage:	Restored after 14 months
References:	[1]

[1]Civil Defence Administration, Sofia
[2]Sofia University „St. Kliment Ohridski"

No. 2

Object: Site: Accident date:	Plutonium production plant for military purposes Kishtim, North Ural 29 September 1957
Prime cause: Additional circumstances:	Failure in cooling system Nitrate-cellulose scrap explosion
Accident character:	Throwing great quantity of solutions consisting radioactive substances 11 μCi
Radioactivity emission:	Hard environmental contamination, approximately 15000 km^2
Irradiated people: Victims:	Non Approximately 10000 persons evacuated
Economical damage:	
References:	[2]

No. 3

Object: Site: Accident date:	Graphite-moderated reactor with air cooling for plutonium production Windscale, England 11 October 1957
Prime cause: Additional circumstances:	Wrong working conditions at graphite heating aiming internal stress take off Fire
Accident character:	Heat-eliminating elements melting
Radioactivity emission:	Hot particles and gases emitted in the atmosphere, including ^{131}I at total activity 20000 Ci
Irradiated people: Victims:	Staff and in some extent the population Non
Economical damage:	
References:	[1]

No. 4

Object: Site: Accident date:	Reactor at thermal power 500 MW NPP St. Laurent, France 17 October 1960
Prime cause: Additional circumstances:	At reactor in operation the refueling machine operator locks the automatic control system
Accident character:	Melting of part of the fuel
Radioactivity emission:	Non
Irradiated people: Victims:	Non Non
Economical damage:	
References:	[1]

No. 5

Object: Site: Accident date:	Heavy-water experimental reactor at low power Lusens, Switzerland 21 January 1969
Prime cause: Additional circumstances:	Technical trouble: corrosion of fuel shell
Accident character:	Explosion emitting approximately 1 t heavy-water
Radioactivity emission:	No emissions in the environment
Irradiated people: Victims:	 Non
Economical damage:	
References:	[1]

No. 6

Object: Site: Accident date:	Low-power experimental reactor (thermal 3 MW), SL-1 Idaho, USA 3 January 1961
Prime cause: Additional circumstances:	Involuntarily or purposely pulling out of control rods from the core in repair operation
Accident character:	Increasing the reactor power to 20000 MW in 0.01 s. Fuel melting which after reaction with the pressure vessel water leads to an instantaneous explosion resulting in roof throwing and its falling back again
Radioactivity emission:	High radioactivity in the working rooms
Irradiated people: Victims:	Three operators Three men dead
Economical damage:	
References:	[1]

No. 7

Object: Site: Accident date:	Brown Ferry NPP, three units, total power 1065 MW Alabama, USA 2 March 1975
Prime cause: Additional circumstances:	Plastic coating ignition by candle
Accident character:	Horizontally and vertically spreading fire leading to 2000 cables destruction
Radioactivity emission:	No emissions in the environment
Irradiated people: Victims:	No data Non
Economical damage:	10 bill. $ to repair. Two units not-working in 1 year
References:	[1]

No. 8

Object: Site: Accident date:	Three Mile Island NPP, one of the two units, power 961 MW every one Harrisburg, St. Pennsylvania, USA 28 March 1979
Prime cause: Additional circumstances:	Technical trouble: the operation of condensed system is ceased Water did not enter the steam generator as the valves to the auxiliary pomp have been closed since the last test
Accident character:	Core melting
Radioactivity emission:	Emission of noble gases and approx. 16 Ci Iodine to the atmosphere. High level of radiation in the reactor premises resulting of the noble gases
Irradiated people: Victims:	Staff and partially the population in the vicinity
Economical damage:	Required 1 milliard $ to repair but it is not restored
References:	[1]

No. 9

Object: Site: Accident date:	Gas-cooled reactor B2 Hunterstone NPP, Scotland 2 October 1977
Prime cause: Additional circumstances:	Corrosion leading to sea water rush in steam-generator
Accident character:	Increasing the humidity in gas heat carrier
Radioactivity emission:	Non
Irradiated people: Victims:	Non Non
Economical damage:	13 bill. ponds to repair, 28 months repair
References:	[1]

No. 10

Object: Site: Accident date:	Ginna NPP, power 490 MW New York St., USA 25 January 1982
Prime cause: Additional circumstances:	Tube destruction in steam-generator resulting in I circle water passing to II circle The prime cause is a forgotten disk with an weight of approx. 1 kg in I circle
Accident character:	The accident had been in control and no core melting occurred
Radioactivity emission:	Emission of negligible amounts of radioactive substances and noble gases to the atmosphere.
Irradiated people: Victims:	Staff - slightly Non
Economical damage:	
References:	[1]

No. 11

Object: Site: Accident date:	Chernobyl NPP, Unit IV, 1 GW Chernobyl, Ukraine 26 April 1986
Prime cause: Additional circumstances:	A sequence of operators failures in planned testing
Accident character:	Hydrogen explosion. Entirely distracted core. Fire with graphite combustion
Radioactivity emission:	Over 50 MCi - approx. 3.5% of the reactor radionuclide content at that time
Irradiated people: Victims:	Thousands of people and the population 32 persons
Economical damage:	Much milliards $
References:	[3,4,5]

Table II. Heavy radiological accidents in powerful gamma-irradiators

No. 1

Object: Site: Accident date:	Iridium irradiator containing 10 pellets at total activity of 35 Ci Houston March 1957
Prime cause: Additional circumstances:	Spilling of two pellets because of bad production in container repair operation The operators did not announce for the accident. It has been notified 1 month latter
Accident character:	Radioactive substance spilling
Radioactivity emission	8 houses and 7 cars contaminated
Irradiated people: Victims:	3 persons Non
Economical damage:	Restored after 14 months
References:	[6]

No. 2

Object: Site: Accident date:	Medical gamma-irradiator, ^{60}Co activity 450 Ci Ciudad Juarez, Mexico 6 December 1983
Prime cause: Additional circumstances:	Power gamma-source abandoned without control Source delivering to a metallic scrap melting workshop
Accident character:	Unsealing of a container consisting of 6000 pellets of ^{60}Co. Some pellets got into metal melting oven resulting in contamination of thousands of tons metallic production. Others have been spilled in yards, cars, etc. The contamination detection occurred 1,5 months latter
Radioactivity emission:	Contaminated melting ovens, workshop premises, dust-retaining systems, slugs
Irradiated people: Victims:	7 persons - 3-7 Gy; 73 persons - 0.25-3 Gy; 700 persons - 5-250 mGy Non
Economical damage:	
References:	[7]

No. 3

Object: Site: Accident date:	Medical Cs irradiator, activity of 1400 Ci at the time of accident Goiania, Brazil September 1987
Prime cause: Additional circumstances:	Irradiator abandoned without control after moving the clinic Gathering the source by metallic scrap gatherers
Accident character:	External irradiation and entirely unsealed ^{137}Cs source with specific activity of 15 Ci/g
Radioactivity emission	^{137}Cs contamination of large regions
Irradiated people: Victims:	2 persons - high doses, notified consequences latter in 500 persons 4 persons
Economical damage:	
References:	[8,9,10]

No. 4

Object: Site: Accident date:	^{60}Co gamma-irradiator, 18 kCi San Salvador 5 February 1989
Prime cause: Additional circumstances:	Locked removing sources system Spilling sources in an attempt to unlock the system
Accident character:	Operators irradiation which did not inform the administration. 4 persons more irradiated latter
Radioactivity emission:	
Irradiated people: Victims:	4 persons at high doses 1 person
Economical damage:	
References:	[11]

Table III Radiological accidents in Bulgaria

No.	Date	Object	Accident character	Causes	Irradiated
1	April 1980	LNT-Sofia	Premises contamination by ^{239}Pu. Maximum measured activity 3000 α-particles/cm^2	Careless staff work in a long time	
2	14.01.1983	IRT-2000 BAS	Premises contamination by ^{239}Pu	Operator's failure: solution of metallic ^{239}Pu instead of ^{235}U	Internal contamination
3	06.11.1985	SKTM Radomir	50 Ci ^{192}Ir source dropping at gamma-defectoscope refueling	Not made clear	Non
4	25.12.1985	„LATEX" Biala	^{239}Pu spilling of static electric neutralizers. 20 plates x 5 mCi	Fire	Not clear
5	27.08.1987	CLNT-CMI Sofia	Hand catching of a radioactive source, activity 0.07 Ci	Charging of ^{192}Ir defectoscope considering that inside have not radioactive pellets	8 Ber on the operator's fingers; total irradiation - 10 Ber
6	09.02.1988	HIMMASH Haskovo	^{192}Ir source dropping at gamma-defectoscope refueling	Mechanical failure in gamma-defectoscope	230 mR
7	05.10.1990	Opera in St. Zagora	Spilling of 50 fire annunciators with ^{241}Am and destructing of part of them, ^{239}Pu 0.5 mCi	Fire	Non
8	28.04.1992	Buhovo	Spilling of 18 ^{60}Co sources x 0.5 Ci on open ground	1. Delivered sources at activity of 1.5 Ci (1988) instead of standard sources 2. Careless removal of source container	
9	09.07.1992	Gas station Ihtiman	Source hold by hand, activity approx. 13 Ci. External irradiation of a people group	Falling out of a gamma-defectoscope source which has not been noticed	2 persons - 1-2 rad every one; 10 persons - 400 mrad every one

Some more serious accidents with powerful radioactive sources in Bulgaria

Some conclusions made in reviewing the accident data in Tables I and II are supported by the analysis of accidents with comparably powerful sources in Bulgaria. The main characterizations of these accidents are given in Table III using[12]. Radiological accidents arising in NPP „Kozloduy" are not included.

Main causes of heavy radiological accidents

The causes and characterization of the hravy radiological accidents in Tables I, II and III allow to draw the following conclusions:

1. Heavy radioactive accidents in NPPs have been connected with the human factor role and are due to:
   - flightiness, No.7;
   - carelessness, No8, No.10, No.4(?);
   - training, No.1, No.4, No.11;
   - deliberately, No.6(?);
   - rough technological failures, No.3, No.5, No.9.
2. The probability of arising and the heaviness of an accident depend on the technological failures which could be eliminated at better working devices diagnostics: No.2, N0.5, No.8, No.10.
3. The probability of heavy accident arising increases at time of reactor refueling, repair operations, planned testing: No.1, No.4, No.6, No.8, No.10, No.11.
4. In no one of the cases the plant did not have the readiness to meet and restrict the heavy accident development.

If now look at the accident with powerful gamma-irradiators (Table II) the conclusion could be filled out with:

5. Careless powerful radioactive source keeping: No.2, No.3.
6. Untrained staff to operate with such sources: No.1, No.4 and in Table III: No.2, No.5, No.8, No.9.
7. Fear of operators to announce the event leading to serious consequences: No.1, No.4.
8. The prime cause leading to the Buhovo accident (Table III No.8) has to be specially pointed out. At the time of ordering 18 sources of ^{60}Co early in 80th a change of activity unity occurred, from Curie (Ci) to Beqerel (Bq). This led to a mistake in the order and instead of standard sources of the order of mCi some sources of activity of 1.5 Ci have been delivered. Recognizing this the staff have abandoned the sources in a container from which in 1992 they have been spilled at wrong handling.

Some conclusions

The pointed out causes of heavy radiological accident arising itself prompt the conclusions. Nevertheless we will discuss some of them in details.

It has no doubt that the main cause of a heavy radiological accident arising is the human factor. At first sight the role of this factor would be as lower as is the staff qualification higher. Indeed the gravest accident, the Chernobyl accident, could not arise if the staff recognized the processes in the reactor. The same is the case at Three Mile Island NPP accident. In cases where there is a carelessness and even flightiness this could not be referred only to the qualification. Unfortunately in the literature we have in our possession there is not an analysis of the behavior of people causing an accident. Even an high-skilled specialist is capable of such activities in certain circumstances: overwork, personal troubles, lack of sufficient training etc. It is well-known that the reactor operators spend much of the time observing a variety of instruments being in continuous psychological strain. This lead to some neurosis and psychosis to people with high intellectual properties.

Currently „Kozloduy" NPP is an object of interest and supervision of various external organizations and first of all of IAEA. No doubt that these institutions contributed and contribute to the elevation of plant working level and security. It is an important fact that in official an public attitudes these missions give a high evaluation of the professional properties of our specialists in „Kozloduy" NPP.

References

1. Дж. Коллиер, Дж. Хьюитт, ВВЕДЕНИЕ В ЯДЕРНУЮ ЭНЕРГЕТИКУ, Перевод из англ. под редак. В. В. Хромова. Москва, 1989.
2. REPORT ON THE RADIOLOGICAL ACCIDENT IN NORTH URAL ON SEPTEMBER 29 1957 , INFCIRC/368, 28 July 1989, IAEA.
3. АВАРИЯ НА ЧЕРНОБЫЛСКОЙ АЭС И ЕЕ ПОСЛЕДСТВИЯ, Информация, подготовленная для совещания экспертов МАГАТЭ, (25-29 август 1986 г. ВЕНА), Част I. Обобщенной материал.
4. ОПИСАНИЕ ОБЪЕКТА "УКРЫТИЕ" И ТРЕБОВАНИЯ К ЕГО ПРЕОБРАЗОВАНИЮ, МИНЧЕРНОБЫЛ УКРАИНЫ, АКАДЕМИЯ НАУК УКРАИНЫ, Киев, НАУКОВАЯ ДУМКА 1992.
5. Ц. Бончев, Ив. Манджуков, Б. Манушев, ИСТИНАТА ЗА ЧЕРНОБИЛСКИТЕ ЗАМЪРСЯВАНИЯ В БЪЛГАРИЯ, Университетско издателство "Кл.Охридски", 1990 г.
6. Merril Eisenbud, ENVIRONMENTAL RADIOACTIVITY FROM NATURAL, INDUSTRIAL AND MILITARY SOURCES. Academic Press, Inc., 1987.
7. G. Molina, LESSONS LEARNED DURING THE RECOVERY OPERATIONS IN THE CIUDAD JUAREZ ACCIDENT. IAEA-SM-316/53, Proc.Int.Symp, Vienna, 6-10 November 1989.
8. THE RADIOLOGICAL ACCIDENT IN GOIANIA, IAEA, Vienna, 1988.
9. M. Oberhofer, J. L. Becelar Leao, THE RADIOLOGICAL ACCIDENT IN GOIANIA, IAEA-CN-51/91.
10. RADIOLOGICAL ACCIDENTS, A Historical Review of Sealed Sources Accidents, IAEA-CN-51-92.
11. THE RADIOLOGICAL ACCIDENT IN SAN SALVADOR, A Report Prepared by IAEA in Coordination with PAHO/WHO, IAEA, Vienna, 1990.
12. ПРОТОКОЛ ОТ СЪВЕЩАНИЕТО НА РАБОТНАТА ГРУПА ПО СИГНАЛ ОТ ПРЕДСЕДАТЕЛЯ НА КОМИТЕТА ПО ГЕОЛОГИЯ, МИНИСТЕРСТВО НА ОКОЛНАТА СРЕДА, януари 1994 г.