Statistical treatment of hazards result from radioactive material in metal scrap

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ABSTRACT

Radioactive sources have a wide range of uses in medicine and industry. Radioactive materials entering the public domain in an uncontrolled manner may creating a serious risk of radiation exposure for workers and the public as well as excessive costs for plant decontamination and waste of product to be borne by the metal industry. This paper describes the major accidents that had happened in the last decades due to radioactive material in metal scrap, provides assessment of associated hazards and lessons learned. This will help Regulatory Authority to introduce measures capable to avoid the recurrence of similar events. The study highlights the situation for metal scrap incidents in Egypt.

1- INTRODUCTION

Nowadays, scrap metal is an important source material for the metal production industry contributing a large fraction (about 50% for steel) of the final product. This fact shows the hugeness importance of the metal scrap as raw material resources for human race. There have been several accidents over the past decades involving orphan radioactive sources or other radioactive material that were inadvertently collected as scrap metal that was destined for recycling. In the USA alone, over 5,000 incidents were recorded in 2004 that involved various types of radioactive metal scrap [1]. According to the forecast of the United Nations Economic Commission for Europe (UNECE) it is expected that the number of incidents with radioactive scrap will increase despite of the efforts, on the world scale, to avert such incidents. The melting of an orphan source with scrap metal or its rupturing when mixed with scrap metal has also resulted in contaminated recycled metal and wastes. If radioactive substances found in metal scrap and not detected in time, in the process of melting they may be incorporated into ferrous or nonferrous metals and various articles manufactured from them. This may lead to hazardous consequences for the health of the workers and the population and radioactive contamination of the environment. Also leads to negative economic, trade and social consequences. According to the data of the international Atomic Energy Agency (IAEA) for a ten-year period, until 1998, in the world there have occurred average 30 incidents per year when radioactive sources have been melted in metallurgical enterprises during the process of reprocessing of metal scrap [1] . During 2004, only in the USA, about 250 cases man-made radioactive sources were found in metal scrap (orphan, abandoned, lost or stolen). In Bulgaria for the period 1998-2006 were registered a total of 125 incidents with radioactive scrap, i.e. on the average 14 cases for this 9 year period. In 120 of the cases components with increased content of natural radionuclides were found, while in 5 cases orphan radioactive sources were found (Cs-137 and Co-60).In all of these cases no radioactive consequences were established for the Bulgarian population and the environment, but nevertheless such type of incidents should not be allowed to occur, which requires implementing preventive and response measures on a national scale. Reducing the magnitude of the problem by prevention, detection and subsequent reaction requires the cooperative efforts of all concerned parties, that is, the scrap metal carriers, the authorities.

2- CATEGORIZATION OF RADIOACTIVE SOURCES

The categorization system set out five categories. This number is considered sufficient to enable the practical application of the scheme, without unwarranted precision [15]. The categorization system is based on the resulting ratio A/D, where A the source activity and D its dangerous factor [5]. Table (1) illustrates the category of radioactive source according to hazard strength. Within this categorization system, sources in Category 1 are considered to be the most 'dangerous' because they can pose a very high risk to human health if not managed safely and securely. An exposure of only a few minutes to an unshielded Category 1 source may be fatal. At the lower end of the categorization system, sources in Category 5 are the least dangerous; however, even these sources could give rise to doses in excess of the dose limits if not properly controlled, and therefore need to be kept under appropriate regulatory control.

Table (2) Categorization of sources according to deterministic effects:

Category	A/D	Risk due to direct exposure
1	A/D> 1000	Extremely dangerous
2	1000>A/D> 10	Very dangerous
3	10>A/D> 1	Dangerous
4	1>A/D> 0.01	Les dangerous
5	0.01>A/D> Exemption level (EL)	No dangerous

3- ASSESSMENTS THE ORIGINS OF RADIOACTIVE SCRAP METAL

Radioactive scrap metal can occur in a number of different ways. Some of the main origins are :(a) Demolition or decommissioning of industrial facilities processing raw materials containing naturally occurring radionuclides. These industries include phosphate ore processing and oil and gas recovery and processing. The pipes and metal vessels from such facilities are sometimes lined with significant deposits of naturally occurring radionuclides and they may, on occasions, be mistakenly collected as scrap metal. (b) Decommissioning of nuclear installations (such as nuclear power plants and other nuclear fuel cycle facilities) and other facilities. This can produce significant amounts of various metals. A fraction of this material is radioactively activated or contaminated and is normally decontaminated or disposed of as radioactive waste but, on occasions, it may be mistakenly released for recycling. Material from decommissioning or demolition containing artificial or naturally occurring radionuclides at levels below the regulatory clearance level may be released with the approval of regulatory authorities for possible recycling. (c) Loss of sources. Sealed radioactive sources are sometimes lost or mislaid. They may be collected as scrap metal, often with the sealed sources still housed within their protective containers. Industrial radiography sources are used for testing welds on pipework and may be lost in the field. The loss of radioactive sources used in medicine sometimes occurs through poor accounting. d) Delivering as metal scrap of devices, goods and articles containing radioactive materials or radioactive sources remaining out of regulatory control or containing naturally occurring radionuclides.

4- INTERNATIONAL DATABASES

4-1- Iaea Illicit Trafficking Database (Itdb):

From January 1993 to December 2011, a total of 2164 incidents were reported to the ITDB by participating States and some non-participating States. 399 incidents involved unauthorized possession and related criminal activities. Incidents included in this category involved illegal possession, movement or attempts to illegally trade in or use nuclear material or radioactive sources. Sixteen incidents in this category involved high enriched uranium (HEU) or plutonium. There were 588 incidents reported that involved the theft or loss of nuclear or other radioactive material and a total of 1124 cases involving other unauthorized activities, including the unauthorized disposal of radioactive materials or discovery of uncontrolled sources see figure(1).

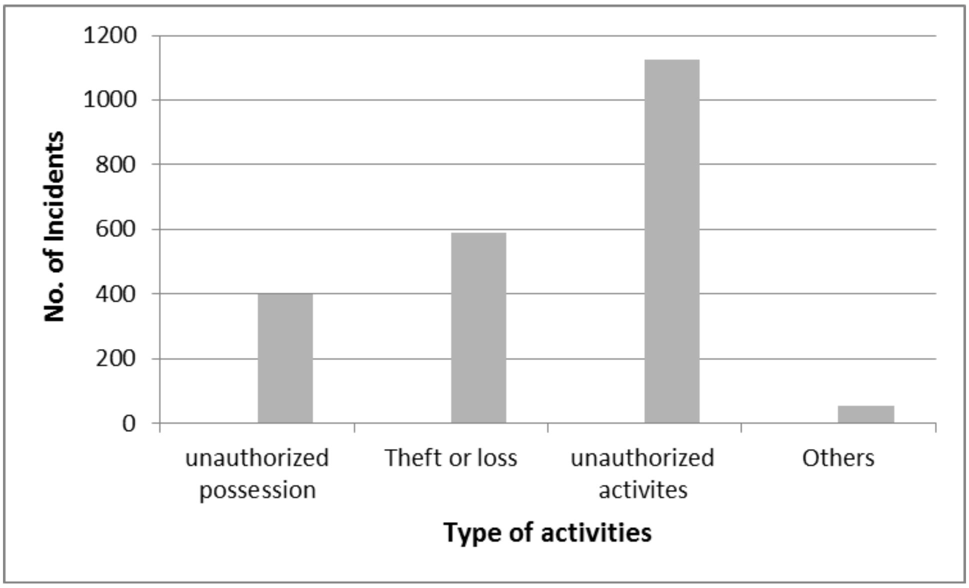

Figure (1) IAEA ITDB (1993-2011) : 2164 cases

The majority of incidents involving ‘other unauthorized activities or events’, fall into one of three categories: the unauthorized disposal (e.g. radioactive sources entering the scrap metal industry), unauthorized movement (e.g. scrap metals contaminated with radioactive material being shipped across international borders) or the discovery of radioactive material (e.g. uncontrolled radioactive sources). The occurrence of such incidents can indicate deficiencies in the systems to control, secure and properly dispose of radioactive material [17]. Figure (2) represented the number of incidents involving ‘other unauthorized activities that were happened in the period 1993 to 2011. It is clear that the number of incidents from 1993 to 1999 represent 5% from the total incidents, where 95 % in the period 2000 to 2011.There is evidence that this rise is related to the increased number of radiation portal monitoring systems that have been deployed at national borders and scrap metal facilities.

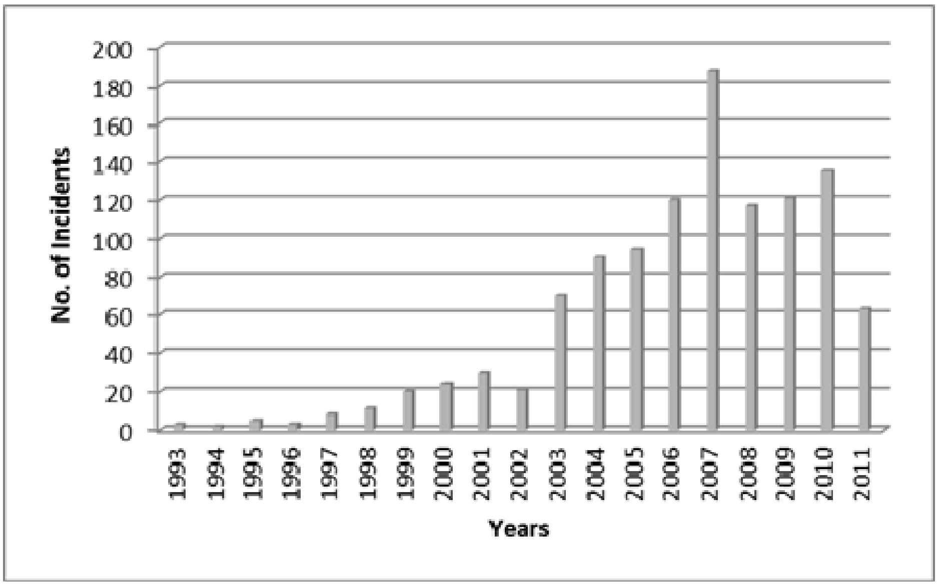

Figure (2) number of incidents involving 'other unauthorized activities in the period 1993 – 2011

4.2- The US NRC Records:

U.S. Nuclear Regulatory Commission (NRC) has reported that it has lost track of over 1,500 sealed sources since 1996, more than half the number have never been traced. In fact, the U.S. National Nuclear Security Administration (NNSA) has a major ongoing programme for the recovery of orphaned sources. A European Union (E.U.) study estimated that about 70 sources are "orphaned" every year. A recent European Commission report estimated that about 30,000 disused sources in the E.U. that were held in local storage at the users' premises were at risk of being lost from regulatory control [12].

5-STATISTICAL NALYSIS OF MAJOR RADIOACTIVE METAL SCRAP ACIDENTS

The metal recycling industry itself recognizes the harm which it could suffer if consumers become concerned about the safety of their products. The British Metals Federation wants no detectable radiation permitted in their products above normal background levels. In the US, steel manufacturers there are concerned about the impact on their industry. The industry maintains zero tolerance level for allowing radioactive contaminants into steel smelters, but it has been plagued by illegal dumping. The US Steel Manufacturers Association reports 50 incidents in which materials released for recycling were contaminated at levels higher than the free release threshold [13]. Significantly, in the US the industry's concerns may be winning through with recent reports that the US Energy Secretary has imposed a moratorium on the release of further contaminated scrap for recycling Exactly how many orphan sources there are in the world is not known, but the numbers are thought to be substantial. Based on the data of the NRC (USA) annually about 200 incidents have been reported with theft, loss of abandoned radioactive sources [1]. In the USA alone, over 5,000 incidents were recorded in 2004 that involved various types of radioactive metal scrap .UK record 20 incidents turning up scrap yard in the period of 1997-2000. At the period 1998 –2006 Bulgaria recorded 125 radioactive metal scrap incidents. Since January 1997- October 1999, 113 incidents were recorded in Italy. During the period from 1983 to 1998 there are around sixty two reported incidents with melted radioactive sources in different countries in the world [1]. The data demonstrate that the two radionuclides most commonly implicated in melting incidents are Cs-137 (48.8%) and Co-60 (26.7%), as in figure (3). In 1983 -1996 there were 25 confirmed accidental melting of radioactive sources at U.S. mills [3]. Disposal and cleanup cost plant where a melting occurred average of $10 million at one mill up to $23 million [3]. Table (3) represents the major accidents with radioactive sources in scrap metal, the causes and their consequences.

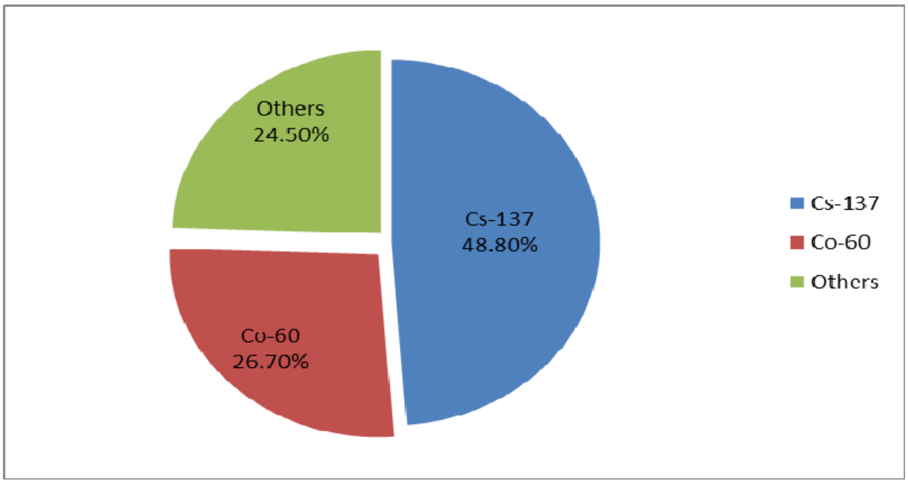

Figure (3) Scrap metal accidents according to the radionuclide type

Table (2) Magor Accidents Involving Radioactive Sources In Scrap Metal

Date and place	Radionuclide	Consequences
Juarez, Mexico 1983	Co-60 37 TBq	75 people received doses between 0.25 and 7 Gy, 814 houses demolished and 16000 m3of soil waste and 4500 tonnes of metal waste were collected
Goiania, Brazil 1987	Cs-137 (50 TBq)	4 people died and 21 people with dose above 1 Gy, 200 people form 41 houses were evacuated and 7 houses were demolished and 3500m^3 of wastes were collected.
Jilin, Xinzhou, PR China, 1992	cobalt-60 (10curie)	3 fatalities and 5 injuries
Tammiku, Estonia 1994	Cs-137 (7.4 TBq)	1 people died from radiation exposure and 4- suffered significant deterministic effect

Istanbul, Turkey 1998	Co-60 (3.3 TBq; 23.5 TBq; 21.3 TBq)	18 people hospitalized: 5 with doses of about 3 Gy, 1 with a dose of about 2 Gy and others with doses below 1 Gy
Los Barrios, Spain 1998	Cs-137	The radiological consequences of this event were minimal, with six people having slight levels of caesium-137 contamination. However, the economic, political and social consequences were major. The estimated total costs for clean-up, waste storage, and interruption of business at the affected Companies exceeded $25 million US dollars.
Samut Prakarn Thailand, 2000	Co-60 (15.7 TBq)	10 people received high doses, 3 (all workers at a scrapyard) died. Source recovered intact
UK, 2000	Pu-238 (140 GBq) melted in foundry	The doses involved were negligible but the clean-up and disposal costs are several million US dollars.
Nigeria, 2002	Am-241/Be (721 GBq, 18 GBq)	Sources detected in a scrap metal, shipment in Europe
Mayapuri, India 2010	C0-60 it was dismantled and was cut into eleven pieces	6 people was hospital as a result of radiation exposure and one died.

From table (2) it is clear that Mexico accident and Goiana accident still the worst accidents until now. Mexico accident provides an example of a combination of causes: Illegal importation of the Co-60 sources in 1979 preventing regulatory oversight and the authorities were unaware of it with long term insecure storage before use until 1983 and loss of staff key and member of staff had no knowledge of the hazard [5]. The accident required a large-scale cleanup program both in Ciudad Juårez. In most cases of scrap metal radioactive accident the radiological consequences were minimal, however the economic cost for decontamination process were major.

5.1-Risk assessment due to radioactive metal scraps accidents

It is noticed that the commonly sources in melting accident are Co-60. Cs-137, Am/Be and Pu-238. Table (3) demonstrates the dangerous index (A/D) and the risk due to direct exposure.

Table (3): Risk due to direct exposure:

Source	Activity (A)	D value	A/D	category	Risk due to direct exposure
Co-60	37(TBq)	0.03	1233.33	1	Extremely dangerous
Am-241/Be	0.721(TBq)	0.06	12.85	2	Very dangerous
Cs-137	50(TBq)	0.1	500	2	Very dangerous
Pu-238	0.140(TBq)	0.06	2.33	3	dangerous

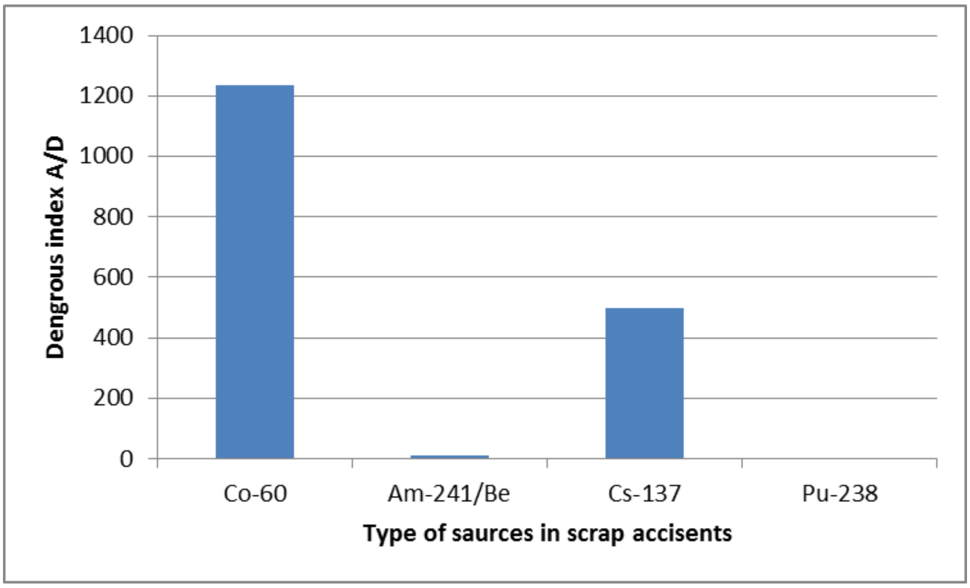

Figure (4) the relation between dangerous index and risk due to exposure

Figure (4) indicates that Co-60 and Cs-137 are major dangerous source cause and hazard.

6- REPORTED SCRAP METAL INCIDENTS IN EGYPT AND THE NEED TO IMPROVE THE REGULATORY CONTROL REGIME

In 1998 radioactive cesium-137 was found in exporting scrap metal to Amsterdam, the Netherlands. The license was withdrawn from the exported company, which reported that the shipment was radiation-free in violation of the truth [16]. A Container of neutron source which used to measure moisture in the soil was found at scrap dealer in Sabteia District – Cairo in 2001. The source quoted by the Atomic Energy Authority. In recent incidents were detected by regulatory inspectors from Atomic Energy Authority. There was detection of high radiation level from Cars carrying a load out from the border of Damietta Port two times. It was doubt in both cases that the contamination may be due to the Cargo on the Cars. More investigations showed that the contamination was due to cobalt-60, the first was in a small steel area from the trailer (0.5 mSv/h on the surface of the contaminated area), and the second was in the steel center of the wheel of the Car with activity 0.04µCi (3 µSv/h). This indicates that lost Cobalt-60 source not follow up and was melted during the metal recycling industry, resulted a contaminated metal.

In Oct-2012 detection gate monitoring Damietta Port Maritime warning voice recording readings from natural background radiation during the passage of truck carrying 8 tons of supplies (Pipes - Tubes - Motors) made of iron coming from India. Alarm was confirmed by a detection device and multi-channel analysis radioactivity and make sure that the contamination was due to cobalt-60. Detection monitoring reading was 300 count/sec and survey meter reading was 0.5 µSv. The truck was prevented from entering and returned to the country of origin. The government should establish a policy and strategy for the control of radioactive material recovered in the metal recycling. The policy and strategy should be developed in cooperation with the metal recycling and production industries, the regulatory body and organizations for the management of radioactive waste. An obligation to notify of any temporary or permanent disuse of sources or their removal from operational use, would allow the regulatory authority to perform a closer follow up of all sources no longer in use and prevent loss of control of these sources [7]. National regulatory requirements should include an obligation to report missing and found sources and abnormal events with radiation sources. If radioactive scrap metal is discovered, the scrap metal owner (national or foreign), is obliged to cover all expenses associated with the recovery and disposal of the material and any clean-up costs. Basically Regulatory Authority should take into consideration geographical identification of all radioactive sources used in the country in the different practices. All radioactive materials are sent for storage at the radioactive waste repository operated by the country radioactive waste organization and the information is recorded by the Nuclear and Radiological Regulatory Authority. Regulatory authority should bound scrap yard places, stimulates owners to introduce a system of radioactive detection, to effective control the possibility to receive an orphan source and give license according to safety requirements. The operator of a metal recycling and production facility should establish a response plan. The response plan should be consistent with the national radiation emergency plan. The objective of the response plan should be to ensure the protection of workers, members of the public and the environment. The response plan should be documented, exercised, kept under review and updated as necessary.

CONCLUSION

The root causes of the radioactive scrap metal accidents are lack of regulatory control and theft from unsecured building for reprocessing as scrap metal. Reducing the probability of loss of control of orphan sources requires in most countries establishment of a national specific strategy focused on improving regulatory controls regimes. Reports and analyses of incidents involving radioactive scrap metal are valuable to the national and international scrap metal community as a means of learning from the experiences of others; where IAEA implemented unified system for information exchange web site. Increasing number of radiation portal monitoring systems that have been deployed at national borders to cover portals all over the country.

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