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How did media present the radiation risks after the Fukushima accident: a content analysis of newspapers in Europe

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Abstract
Any activity that might result in exposure of a population to contaminants requires communication of the associated risks. This communication is complicated by several factors including public perceptions, distrust, uncertainties in risk assessment and news media. These factors are especially prominent in communication of risks from ionizing radiation. A number of guidelines about the communication of risks related to radiation exposures have been made by national and international authorities and other stakeholders. The present paper investigates whether those guidelines were followed and evaluates how the radiation risk related information was presented in European newspapers and Russia in the aftermath of the Fukushima accident. It examines the use of measurement units and risk comparisons, the quality of the statements on radiation risk related issues and the use of visual materials in 1340 newspaper articles from Belgium, Italy, Norway, Russia, Slovenia and Spain. Our results indicated several misinterpretations and misrepresentations of radiological risks in the newspaper articles. We also show an inconsistency in the information that was reported with advice provided to risk communicators (e.g. authorities and experts) in the guidelines. The results suggest that risk communicators should improve their communication practices regarding radiological risks, in order to improve emergency management response.

Keywords: radiation risks, risk communication, media analysis, Fukushima

(Some figures may appear in colour only in the online journal)

1. Introduction

Any activity that might result in exposure of a population to contaminants requires communication of the associated risks. But there are several obstacles to a successful risk communication. These include: social and psychological factors that influence how people perceive risks (Douglas 1982, Fischhoff 1995, Siegrist *et al* 2000, Renn 2003, Sjöberg 2003, Slovic 2010, Perko *et al* 2014b), distrust between public and communicators (Sjoberg 2001, Renn 2003, Trumbo and McComas 2003, Viklund 2003, Earle and Siegrist 2006, Loefstedt and Six 2008, Slovic 2010), uncertainties and knowledge gaps in risk assessment and news media (Poumadere 1995, Covello and Sandman 2001, Chauvin *et al* 2008, Chryssochoidis *et al* 2009).

Radiation risk communication is further confounded by the fact that the public's perception of radiation risk differs from that of experts (Hämäläinen 1991, Slovic 2012, Perko 2014, Perko *et al* 2014a). For example, Perko (2014) confirmed that general population had higher perceptions of natural radiation, but lower perception of medical x-rays compared to the experts.

Since the late 1970s, when risk communication research began (for an overview see Fischhoff 1995), a number of recommendations have been made concerning communication of risks related to radiation exposures. According to the International Atomic Energy Agency (IAEA) one should be very careful in the use of quantitative information and radiation units when communicating with public about radiological events (IAEA 2012). Numerical information is often hard for the public to comprehend (Fagerlin *et al* 2007) and when this is combined with unfamiliar radiation units (Perko *et al* 2012b), it can lead to confusion. It has been suggested that the relation between different units (e.g. how activity concentrations relate to doses) should be presented and explained (Shore 2013), if quantitative information is to be disseminated. But this might simply add another layer of confusion about the message to be conveyed.

In general, comparisons are considered to be a more effective and meaningful way of communicating radiation risks, although that should also be done with caution (Covello 1989, Covello 2011, Slovic 2012). Comparisons that are only similar by virtue of statistical significance, such as comparing radiation to smoking or driving a car, are not considered useful. In the case of a radiological emergency, exposures related to the accident would be better compared to a legal standard (Covello 2011), to exposures from other sources of radiation (e.g. background radiation, medical exposures, flying) or to exposures of workers in nuclear industry (Slovic *et al* 1981, IAEA 2012).

Finally, the presentation of risks via measurement units and comparisons of exposures alone does not provide all necessary information to the public (Health Physics Society 2013). People are often more interested in the health effects that can be caused by exposure to radiation.

The media have a very important role in delivering risk information to the public (Wåhlberg and Sjöberg 2000, Covello and Sandman 2001). The mass media reach a large number of people simultaneously. This gives the media an important role in risk communication, as they allow individuals to take an informed decisions and a swift action to ensure safety measures for those who could be affected in case of an emergency. Those who are responsible for the welfare of the public must communicate openly and transparently about the risks during an emergency situation. Misinformation and contradictory messages should be avoided, since they would evoke distrust to the institutions responsible for the public safety. In most cases, people are not aware or knowledgeable about the specific threats or risks. Mass media can play a major role in framing and interpreting certain risks and can directly or indirectly affect risk perception (Vyncke *et al* 2016). The theory of social amplification of risk (Kasperson *et al* 1988, Renn 2008, pp 214–7) suggests that certain elements of hazardous events may be intensified by mass media. Research on media reporting about nuclear emergencies proves that even without radiological consequences, those events are considered newsworthy. For instance, the event at Krško nuclear power plant in Slovenia (2008) was classified as level 0 on International Nuclear Event Scale, however, it was reported in all major European media (Perko *et al* 2012a). Another aspect of media effect on communication to public is that journalists work under constant pressure of deadlines, competition with other reporters (Slovic 1986, Cottle and Ashton 1999, Scott 2005) and expectations of little margin for errors. This has only increased since the development of the digital production system (Saltzis and Dickinson 2008). Although the journalists themselves claim that such work conditions do not influence the quality of the reporting (Saltzis and Dickinson 2008) it is interesting to see how they handled a complex issue of radiological risks. In a complex situation like a radiological emergency, the media has to depend primarily on the available expert sources (Slovic 1986), and trust that these would provide them with accurate and understandable radiation risk related information.

The accident at the Fukushima Daiichi nuclear power plant received immense media coverage throughout the world and it provides a unique opportunity to analyse what kind of information related to radiological risk is reaching the public through media in a case of radiological emergency. It also offers a possibility to investigate the way in which quantities and units related to ionizing radiation were used in public communication and whether they were correctly interpreted.

The present paper investigates and evaluates how the radiation risk related information was presented to public in different European newspapers in the aftermath of the Fukushima accident. It examines the use of measurement units and risk comparisons in the articles, the quality of the statements on radiation risk related issues and the use of visual materials. We also discuss the possible implications that these results could have on radiation risk related communication practices. Finally, we make suggestions for improvement to the risk communicators, specifically, nuclear emergency authorities, experts and other stakeholders.

2. Theoretical background

There is a considerable body of knowledge about the way people process risk related information (McGuire 1973, Shiffrin and Schneider 1984, Chaiken and Stangor 1987, Eagly 1992, Lang *et al* 1999, Trumbo 2002, Eysenck and Keane 2005, Lang 2006, Zaller 2006). Research shows that people use two ways of information processing: heuristics and systematic (Shiffrin and Schneider 1984, Petty and Cacioppo 1986, Griffin *et al* 1999, Trumbo 2002). Heuristic information processing stresses the mental shortcuts individuals use when they have to deal with information, for instance, previous experiences or associations, or simply trust in the information provider. Systematic information procession is effort-intensive and deep. Petty and Cacioppo (1986) suggested that low prior knowledge leads to heuristic information processing, while high prior knowledge leads to systematic processing. Risk communication is often related to heuristic information processing (Tversky and Kahneman 1974, Visschers 2007, Visschers *et al* 2009, Perko *et al* 2013), and support for this comes from the 'risk-as-a-feeling' theory (Loewenstein *et al* 2001) and the 'affect heuristic' theory developed by Slovic *et al* (2004). These theories explain that individuals' risk perception is also based on what they feel about the risk and not only on what they know about it. Moreover, extremely negative emotions such as strong fear stimulate heuristic information processing (Jepson and Chaiken 1990). This suggests that people respond to risk based on direct emotional influence rather than on facts (Renn 2008).

These studies showed that the content of the text should be tailored to the individual's knowledge and that it is useful to use visuals and associations in risk communication. Associations of one risk with another have '*a spontaneous role when people respond to an unknown risk or interpret a risk communication: people often associate unknown risks with known risks*' (Visschers *et al* 2007, p 726). Since it is known that the public lacks knowledge about ionizing radiation and has only rarely (acknowledged) experiences with radioactivity (Kuklinski *et al* 1982, Miller 1998, Van Aeken *et al* 2007, Perko *et al* 2010), dissemination of information should use associations of known radiological risks (e.g. use of radiation in medicine) with unknown risks (e.g. radioactive residues in food products).

Providing information about radiation doses is not usually sufficient as they are only a transition between exposure and risk (Gale and Hoffman 2013), and additional information is needed on the health risks associated with the exposures. However, there is also a debate about the best way to present the health risks from ionising radiation to public. It has been proposed that health risks should be put into context with the general cancer risk in human life; furthermore, the excess or additional risks arising from the exposure from the accident should be compared with the baseline cancer risks expected in the exposed populations (Gale and Hoffman 2013). In other words, one can present both the absolute risks (e.g. the number of cancers expected in the population) and/or the relative or excess relative risks (e.g. the relative increase in baseline rates). For instance, the World Health Organisation (WHO) report on health effects of the Fukushima disaster states that there will be no observable increase of the baseline cancer rates in the general population, but that an increase in specific cancers can be expected, and that these will vary with age, gender and cancer type (WHO 2013).

Expressing of such risk information in a comprehensive form to the general public has its difficulties, even if the content of a message is defined (Ancker *et al* 2006). Previous studies showed that mass media can have an influence on risk perception (e.g. Coleman 1993). More specifically, the influence of mass media on radiological risk perception was recognised also in studies related to media communication during and after the Fukushima nuclear accident (e.g. Sugimoto *et al* 2013, Vyncke *et al* 2016). Although the inter-media-agenda setting research shows an influence of one media to other media (e.g. Boomgaarden and de Vreese 2007, Vliegenthart and Walgrave 2008, Wien and Elmelund-Præstekær 2009), different audiences interpret media messages differently, in accordance with local context or culture (Morley 2006). Visual presentation of risk information is considered an effective way to inform public about the risks and help them understand the data in a given context (Lipkus and Hollands 1999) and, therefore, should be actively used in risk communication.

Based on these theories, the overarching aim of the study was to investigate the degree to which the above-mentioned guidelines were followed when information about radiation risks were provided to the general public through the mass media. Specifically, whether:

- recommendations on the use of radiological measurement units were followed,
- associations of known radiological risks with unknown radiological risks were provided
- explanations of health issues related to reported exposures were mentioned,
- visual representation of radiological risks were used in media,
- and whether the information about the radiological risks due to the nuclear accident were factually correct.

3. Materials and methods

The study was based on an analysis of newspaper articles from five European countries and Russia, published between 11.03.2011 and 11.05.2011. Two quality newspapers were chosen in each country: '*Le Soir*' and '*De Standaard*' in Belgium ($N = 260$); '*Corriere della Sera*' and '*La Repubblica*' in Italy ($N = 270$); '*Aftenposten*' and '*Dagsavisen*' in Norway ($N = 133$); '*Komsomolskaya Pravda*' and '*Izvestiya*' in Russia ($N = 172$); '*Večer*' and '*Delo*' in Slovenia ($N = 158$) and '*El País*' and '*El Mundo*' in Spain ($N = 315$). The countries for the analysis were chosen based on their different status with regard to the production of nuclear energy. Belgium is in a process of phasing out of nuclear energy production, Slovenia, Russia and Spain produce nuclear energy to different extent, while in Italy all nuclear power plants were closed as result of the referendum in 1987. Norway does not produce nuclear energy and has two research reactors only, but was significantly affected by the Chernobyl accident. All newspapers chosen are representative of the high quality press within each country.

News articles ($N = 1340$) directly and indirectly related to Fukushima were selected using the search words 'Fukushima' and 'nuclear' or synonyms in accordance to linguistic properties of each language. Articles were assessed through the online databases or the official archives of the newspapers in Belgium, Norway, Slovenia, Italy and Spain. In Russia, a manual search of the library was undertaken, as there were no electronic database of newspapers available. Repeated articles or articles, which contained the search words, but did not report about the accident, were excluded from the analysis.

A system of codes was developed to determine whether the radiation information was presented in a quantitative and/or qualitative way in each article. Examples of quantitative representation of information related to radiation risk include data on activity concentrations or dose rates; while qualitative representation involved a comparison between different radiation risks, such as a comparison with medical or background exposures, or a comparison to limits or norms. A list of the variables coded in these two categories is given in table 1.

After the coding had been carried out, direct quotations of relevant information were collected from the newspaper articles containing radiation units and risk comparisons. These quotations were analysed qualitatively and examined for misinterpretations and mistakes. All articles were also checked for the presence of visual information on radiation doses and effects.

Each article was coded by two independent coders for each language, plus a master coder who made decisions on the code in the case of disagreement. All the coders received training prior to the start of the coding procedure. The intercoder reliability was calculated using Krippendorf's alpha, which was >0.84 for both variables.

Data for this study was collected as a part of bigger media study and the current article addresses only two of the 12 different variables coded (risk units and comparisons). Articles analysing other aspects of the media coverage of Fukushima accident in European and Russian newspapers are under review.

4. Results

4.1. Measurement units

The results of the study showed that only 16% of the articles across all the countries contained numerical radiation data. The percentage of articles containing quantitative information varied among the countries, being lowest in Italy (7%) and highest in Spain (27%). The quantitative information was expressed in the form of radiation measurement units such as

Table 1. Variables coded in the content analysis.

Type of information		Type of variable coded
Quantitative	Radiation measurement units	mSv (milli sievert)
		$mSv \cdot h^{-1}$ (millisievert per hour)
		$\mu Sv \cdot h^{-1}$ (microsievert per hour)
		$nSV \cdot h^{-1}$ (nanosievert per hour)
		Sv (Sievert)
		$Sv \cdot h^{-1}$ (Sievert per hour)
		$Bq \cdot kg^{-1}$ (Bequerel per kilogram)
		$Bq \cdot g^{-1}$ (Bequerel per gram)
		$Bq \cdot l^{-1}$ (Bequerel per litre)
		$kBq \cdot kg^{-1}$ (kilo Bequerel per kilogram)
		$MBq \cdot kg^{-1}$ (mega Bequerel per kilogram)
		$Bq \cdot m^{-2}$ (Bequerel per square meter)
		$Bq \cdot cm^{-2}$ (Bequerel per square centimetre)
		$kBq \cdot cm^{-2}$ (kilo Bequerel per square centimetre)
		$MBq \cdot m^{-2}$ (mega Bequerel per square metre)
		$MBq \cdot km^{-2}$ (mega Bequerel per square kilometre)
		$TBq \cdot km^{-2}$ (terra Bequerel per square kilometre)
		No measurement units related to radioactivity in the article
		Other units related to radiation
Qualitative	Risk comparisons	No comparisons
		With risks from medical purposes (e.g. x-ray)
		With risks from flying
		With natural radiation background
		With workers' exposure to radiation at nuclear inst.
		With something else (open variable)
		With (legal,..) limits, norms
		With a historical nuclear accident (like Chernobyl)

activity, activity concentration, dose rate, ground deposition etc. (full list of coded measurement units is given in table 1). The most commonly used measurement units were dose and dose-rate related (millisievert and millisievert per hour, and microsievert per hour respectively). For detailed results on the types of the units in the articles see (Perko *et al* 2015). The analysis showed that globally 28% of articles mentioning radiation measurement units (with a variation of between 5 and 50 % depending on the country) reported more than one unit at a time.

4.2. Risk comparisons

Newspapers were more likely to use a qualitative representation of radiation data, such as a comparison to natural background radiation, risk from medical exposures (e.g. x-ray), etc. (see table 1), than a presentation of units. One in four articles across all counties presented information this way (figure 1). Newspapers in Spain and Russia used comparisons the most (36% and 33% respectively) while in Norway, such way of presenting was least frequent (14%). Note that some comparisons included radiation units, while others did not.

Half of the articles containing risk comparisons referred to legal norms and limits, probably because information on these are the most commonly available (Example 1). Second most

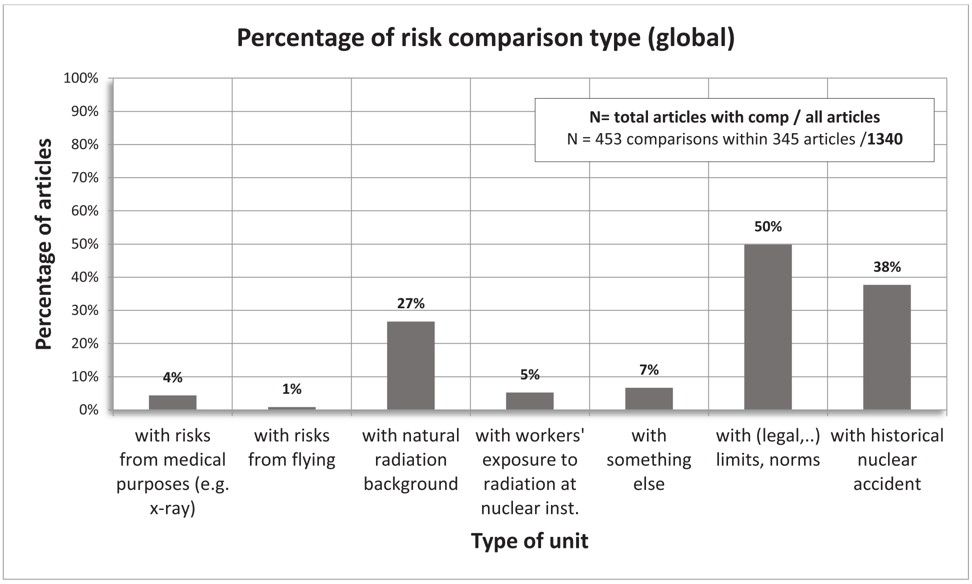

Figure 1. The use of different risk comparison in the newspaper articles (global).

popular comparison (38 %) was to use historical accidents (Chernobyl, Three Mile Island) as a reference (Example 2), followed by comparisons with natural radiation levels (27%) (Example 3). Very few comparisons related to workers' exposure in nuclear institutions (Example 4) or to medical exposures (like x-ray) (Example 5).

Example 1 '…the amount of radioactive iodine is 10 000 times the legal limit'—Corriere della Sera, 02.04.11

Example 2 'Fukushima is a slow-motion Chernobyl'—El País, 13.04.11 'Japan's Chernobyl'"—El Mundo, 14.03.11

Example 3 'Reuters measured 0.16 microsievert per hour in the center of capital (Tokyo), this is lower than natural background radiation in the world, which varies from 0.17 to 0.39 microsievert per hour'.— Dagsavisen, 28.03.11

Example 4 'According to some reports, the technicians were exposed to 400 millisieverts of radiation per hour, which is 20 times more than the allowable annual limit for workers in nuclear power plants and uranium mines!'—De Standaard, 16.03.11

Example 5 'The levels of radiation are very low—0.5 milliroentgen. This is less than the dose one receives while taking an x-ray at dentists'.—Komsomolskaya Pravda, 16.03.11

Some differences were observed in the types of comparisons that were predominantly used in each country (figure 2), although there was general similarity with the most and least used comparisons. For instance, although for the other countries, a most widely used comparison was with legal norms and limits, in Italy, more comparisons were made with the historical nuclear accidents. In Russia, on the other hand, journalists often used other comparisons than those included in the codebook. For example, they would often present doses in a form of 'dangerous/safe'.

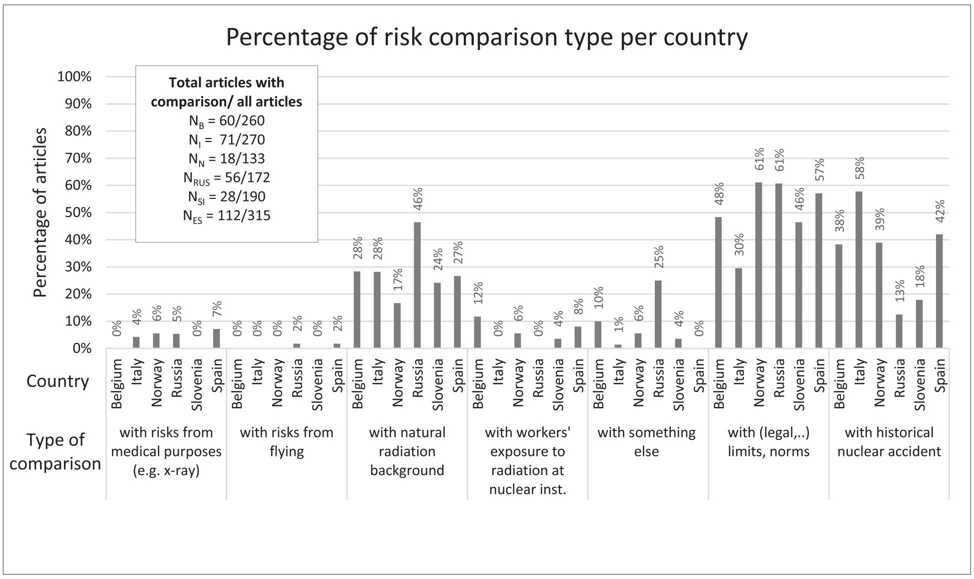

Figure 2. Types of risk comparisons used in the newspaper articles of different countries.

4.3. Use of measurement units and comparisons together

From the articles containing numerical information on radiation units, 81% also included comparisons, although not necessarily related to the numerical unit itself. On the other hand, half of the articles containing information in form of risk comparisons, included information on actual units.

One out of five articles presenting radiation units, failed to provide an explanation of how those numbers should be understood (Example 6).

Example 6 ‘Some 50 kilometres northwest of the center, 0.8 mSv per hour have been recorded this week’—El País, 03.04.11

Half of the articles presenting information as risk comparisons provided no information on actual measurement data or limits (Example 7), while some of the articles provided no numerical information at all, just a qualitative statements (Examples 8–10).

Example 7 ‘Spinach, grown a hundred kilometres from Fukushima, contains 27 times more radioactive iodine and four times more radioactive caesium than allowed’.—De Standaard, 22.03.11

Example 8 ‘… exposed to significant levels of radiation that would be harmful to health for a long time’.—El Mundo, 8.04.11

Example 9 ‘WHO reported that radiation in food (for example in milk and vegetables) was anyway higher as initially assumed’—Vecer, 22.03.11

Example 10 ‘Radioactivity way beyond permitted levels was measured in all together eleven types of vegetables in Fukushima’.—Aftenposten, 24.03.11

The results also showed that only 6% of articles presented information using more than one risk comparison and even fewer (4%) were providing information on measurements at the same time. However, analysing whether more than one comparison was present was complex, as comparisons were often present in different parts of the articles and referred to different exposures.

4.4. Representations of health risks

Although the articles contained information related to radiation risks, only one in ten article mentioned possible health impacts arising from the exposures they were reporting. In 44% of the cases, these health impacts were provided for very high doses only. These refer to the types of tissue damage and fatalities caused by doses in the order of Sieverts (Examples 11–13).

Example 11 ‘Irradiation dose of 1–2 Sievert per hour (which means 1–2 million microsievert) can cause acute radiation syndrome. One-time dose of 3–5 Sievert damages bone marrow so that every second person exposed will die within month or two if not treated appropriately. Even higher doses will damage lungs and gastrointestinal tract, the death will occur after 10–20 d. A dose higher than 15 Sievert can kill a man in some few days’.—Izvestiya, 17.03.11

Example 12 ‘The radiation dose of 500 000 microsievert can cause dizziness and fatigue after some hours. A dose of 750 000 microsievert will cause hair loss within two–three weeks and a dose of one million will result in bleedings. The deadly dose is 4 million microsieverts’.—Aftenposten, 17.03.11

Example 13 ‘Radiation sickness appears from a dose of 1000 millisieverts, said Bastin. At 4000, 50% of irradiated persons die’.—Le Soir, 16.03.11

One in three articles reporting on health impact mentioned cancer risks, but the quality of those statements differed. The articles mostly mentioned cancer as a possible health consequence and expressed the risks of getting it in a qualitative way without giving any concrete estimates (Examples 14–18).

Example 14 ‘Since the beginning of the crisis at the nuclear plant, 17 workers have been exposed to more than 100 millisievert, the level at which the risk of getting cancer exists’.—De Standaard, 28.03.11

Example 15 ‘If people ingest too much contaminated foods, it might lead to cancer in the long term’.—De Standaard, 08.04.11

Example 16 ‘… level[6], which rose from 370 to 1000 Becquerel per kilogram, significantly increases the risk of diseases such as cancer’.—El País, 03.05.11

Example 17 ‘… these limits were set to 250 millisieverts in Fukushima, which is within the international recommendations (that amount up to 500 mSv). These doses are still under the limits for serious and acute health consequences, the risk for cancer increases only slightly... According to available data, the current doses of the Fukushima workers are lower from those, where instant death effects would appear…’—Delo, 25.03.11

Example 18 ‘Workers were exposed to radioactivity levels between 170 and 180 millisieverts. An exposure of 100 millisieverts per year is considered the value above which there is a risk of developing cancer’.—El País, 25.03.11

Only a few articles attempted to explain what kind of increase in cancer rates can be expected from a given radiation exposure (Example 19) or how cancer risks from radiation exposure could be calculated (Example 20).

Example 19 ‘Japanese specialists have been observing the 87 500 survivors of the atomic bombing of the two cities during all the years since. The average radiation dose then was 240 millisievert. With this, increased cancer rates in the

[6] Referring to EU’s increase in maximum permitted levels of Cs-134 and Cs-137 in dairy products imported from Japan. THE EUROPEAN COMISSION 2011. COMMISSION IMPLEMENTING REGULATION (EU) No 297/2011 of 25 March 2011 imposing special conditions governing the import of feed and food originating in or consigned from Japan following the accident at the Fukushima nuclear power station. Official Journal of the European Union L80, 25.11.2011, pp 5–8 (EN).

following years constituted 9%. No difference between cancer rates (expected and observed in reality) at doses less than 100 millisievert were established in the world'.—Izvestiya, 17.03.11

Example 20 '… if 10 000 people were exposed to a dose of 10 000 microsievert in small doses spread through their whole life, an additional five–six people in this group would die from cancer compared to if they were not exposed to radiation'. —Aftenposten, 17.03.11

4.5. Misrepresentations and mistakes in the text of newspaper articles

In as many as 19% of the articles, where radiation risk related information was mentioned, a number of mistakes and misrepresentations were identified. One of the most common misinterpretations was referencing to norms, which do not exist (like norms for radionuclide content in the seawater) (Example 21–22) or using the wrong norm (Example 23). In addition, articles often referred to 'norm' or 'normal level' without explaining what is meant by a normal level (Example 24).

Example 21 'The water streams are also mixing the cards: the iodine-131 is heading South, cesium-137 follows a route toward east: in the sea at 300 meters from the plant, an amount equal to 20 times the normal level has been found. And the list can be enriched, going as far as a mile and a half from the shore, this time toward North, to once again find radioactive iodine in the seawater samples, 1155 times the permitted maximum level'.—Corriere della Sera, 2.04.11

Example 22 'Monday, in the sea water near Fukushima, levels of iodine-131 and caesium-134 were measured to be 126.7 times and 24.8 times higher than official standards, respectively'.—Le Soir, 21.03.11

Example 23 'The level of iodine-131 to less than 350 meters from the nuclear plant has reached 180 000 Becquerel per litre, the legal maximum for freshwater consumption for adults is 300 Becquerel per litre'.—El Mundo, 01.04.2011

Example 24 'At the moment that I'm writing these lines, radiation level beside Kolskaya NPP by Murmansk is 0.07 microsievert per hour and beside Leningradskaya NPP—0.1 microsievert per hour. Both parameters are well below the norm'.—Izvestiya, 29.03.11

Another mistake was mixing up of the allowed levels for the population and for the emergency workers. It is clear from Example 25 that people, receiving dose inside the power plant, must have been workers, but the accepted dose for the general public is used in this comparison.

Example 25 'Radiation in the turbine section of "Fukushima" was 10 000 times higher than normal. There are first victims too—17 people received dose of more than 100 millisievert (the accepted limit in Japan is 1 millisievert per year)…'—Komsomolskaya Pravda, 25.04.11

Journalists were often mixing up dose and dose rate or simply did not present the difference between them (Example 26–28).

Example 26 'The picture shows one of the measurements—2.23 microsievert per hour on the dosimeter. The dangerous dose starts from 1.2 microsievert'.—Komsomolskaya Pravda, 22.03.11

Example 27 'After the Japanese Government started to fight Fukushima, the legal limit/dose of radiation was increased to 250 millisieverts per year, which is five-times more than the allowed limit in USA. Health experts claim that negative consequences cannot be avoided if a person is exposed to more than thousand millisieverts'.—Delo, 6.05.11

Example 28 'Level of radiation which is dangerous for people is 120 microroentgen per hour'—Izvestiya, 21.03.11

Another issue found was misrepresentation, or oversimplification, of the rationale behind the official norms and limits. In some of the articles, permitted levels of radiation were referred to as safe (Example 29–31)

Example 29 'Radioactive iodine was found in the tap water in Tokyo, in quantity of 210 Becquerel per liter, although its safe level is 100 Bq'.—Komsomolskaya Pravda, 24.03.11

Example 30 '210 Becquerel per kilo was measured in one of the water samples (drinking water). The Japanese limit for what is considered to be safe for children is 100 Bq per kg'.—Aftenposten, 24.03.11

Example 31 'Another Greenpeace-team have tested spinach and other vegetables in the gardens of Minamisoma inhabitants. The tests have shown radioactivity levels that are much higher than the official levels of what is considered safe'.—Dagsavisen, 7.04.2011:

4.6. Visuals

The majority of articles (72% on average) contained some visual information in the form of photos of the accident affected power plant, affected inhabitants, maps of how contamination was distributed in air and sea, etc. However, almost no articles (<2) from the whole sample in each country used visual material in order to present radiation data in a more effective way. The examples of such material are given in figure 3. The illustration on the left provided information on effects of various doses from low to high, while the picture on the right presented effects of high doses, which was irrelevant for the situation, since as mentioned before, no one has been exposed to such doses in Fukushima.

5. Discussion

Despite the recommendations of IAEA, every fifth article on the Fukushima nuclear accident presented information on radiation data together with radiation measurement units. Moreover, a third of those articles, mentioned several units in the same text, without explanation about their relationships. This can be confusing to readers, who cannot distinguish different measurement units and how they relate to each other (Miller 1998). On the positive side, the majority of the articles (3/4) presenting information on radiation units did attempt to put them into context by providing a benchmark for comparison. However, the comparisons given were not always helpful or were given in a different context than units.

Overall information in the form of risk comparisons was more frequent, being present in one third of the articles. Nevertheless although presenting unknown radiation risks in association with already known risks is a preferable way of risk communication, our analysis indicates that this is not without complications. The three main types of comparisons used were legal norms and limits, background radiation and historical accidents.

The frequent use of comparisons with legal norms and limits can be explained by their availability for use as a reference point. However, the reference to such norms (e.g. permitted levels of exposure or permitted radionuclide concentration in foodstuffs) should include some explanation about what they mean or how they are derived. Permitted levels were sometimes deemed to synonymous with being a level of what is safe, which is not the case. This is also related to the problem of assuming that levels above limits are dangerous, as discussed below.

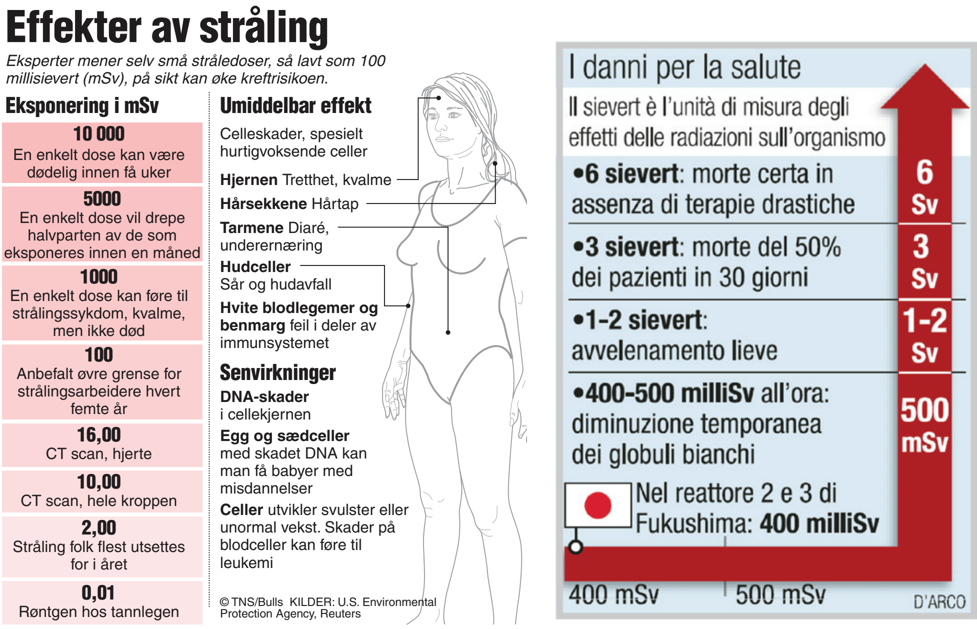

Figure 3. Visuals representing effects of the different radiation dosed on human organism from newspaper articles in Norway (on the left) (figure reproduced from Aftenposten 2011, copyright TNS/BULLS) and Italy (on the right) (figure reproduced from Corriere Della Sera 2011, copyright RCS Madiagroup S.p.a.).

Data on the natural background radiation levels are easily available, which might explain their frequent use in the media articles, and they are also recommended as a good source of comparison. However, the public perceives radiation from natural and anthropogenic sources in the different ways (Hämäläinen 1991, Sjöberg 2007, Sjöberg and Drottz-Sjöberg 2008, Perko *et al* 2015a) and it should be remembered that such comparisons should be used with caution.

Comparing Fukushima to other historical accidents like Three Mile Island and Chernobyl is probably logical in the eyes of the journalists, but it also carries a heavy negative emotional charge. The memory of Chernobyl in particular is a strong image, and using it as a benchmark for comparison could be perceived as sensationalism. This is particularly problematic if the differences between Fukushima and Chernobyl are not made clear. Chernobyl had deaths from radiation sickness in firefighters and widespread direct environmental impacts (e.g. forest death) due to the high doses. This was not the case in Fukushima, but the type of heuristic information processing used by the public might create the impression that a similar situation existed at Fukushima.

Surprisingly, comparison of risks from the nuclear accident with the risks of medical use or risk from flying were rarely presented in the media, although these types of comparisons are recommended by IAEA. This may suggest that either media were not interested in publishing such a comparison or perhaps there was no such comparison offered to them by the scientific community.

The most common type of risk comparisons were made in connection with exposure levels (doses) or activity concentrations rather than with estimates of health risk following the exposure, although this is an important societal concern (Samet 1997). This might be explained by the more readily available information on the various exposure levels (legal norms, background radiation, etc.). Additionally, when health risks were mentioned, they were often related to the types of effects that can be seen after exposure to high doses of radiation, in order of Sieverts. Such high doses were nowhere near the actual doses received by the Japanese population or emergency workers (UNSCEAR 2013) and presentation of those detrimental health impacts could cause fear and panic. As mentioned above, these types of exposures and effects were seen in emergency firefighters after Chernobyl and comparisons to the Chernobyl in media could have further fuelled use of such information as an example. Another reason might be that the knowledge about the effects of high doses of radiation is well established, while information on health effects, which can be caused by low dose exposures, is much more complex and arguably more difficult to communicate, even by professionals.

We share the opinion of Covello (2011) that comparisons of legal limits are relevant and legitimate for the use as a reference point. However, the textual analysis of articles has shown that journalists did not always possess knowledge about what the permitted levels meant, or they presented these limits in ways that could result in misinformation of the public. The articles referred apparently to maximum permitted levels for radionuclides in drinking water and foods, but the presentation is misleading (or perhaps the author misunderstood how the legal norms for radiation contamination are set). While it might be acceptable to communicate that activity levels below maximum permitted levels should be considered 'safe' (even though this is a point of debate among radiation protection experts), it is another matter to imply that levels above these limits are dangerous. Although authorities do not recommend consumption of food and water that is contaminated above the permitted levels, the limits are conservative and cancer risks would be expected to remain low. Again, some additional information to put the numbers into context would be helpful. Moreover, results indicate that radionuclide concentrations in seawater were at times compared to permitted level for drinking water in Japan, which is not a correct benchmark for comparison in this case as drinking water is directly consumed by people. It is difficult to discern exactly why these mistakes were made, but the multiple references to limits for radionuclide content in the environment when such regulations do not exist, could suggest that journalists were searching for comparisons without sufficient information on radiation protection norms being available. A similar situation was observed in the use of the measurement units as doses and dose rates were sometimes mixed up. The seriousness of the consequences from certain dose of radiation would depend on the time of exposure; therefore, the difference between these units should be explained.

Reporting radiation measurements without providing some reference level to put those numbers in context is meaningless to a reader, and does little to support an adequate judgment of the situation. Although comparisons are considered a better way of representing radiation data, they should also be used properly. They should be supported by the results of measurements in order to be perceived trustworthy and transparent. As both quantitative and qualitative statements found in the sample had their weaknesses, our results suggest that using only one way of presenting the risk related information is not sufficient. One comparison will not always give the full picture, and presentation of several comparisons with the measurement results can help to put information into context. An example here is taken from an article in *Dagsavisen* on 26.03.11. It started with: '*Reparation works by the reactor 3 in Fukushima Daiichi were stopped yesterday after three workers were exposed to radiation 10 000 times higher than normal level*'. The following statement presents the radiological situation in the form of a comparison with 'normal level', but it does not specify what one should understand as a normal level. In addition, this statement carries limited information and it does not give any explanation on what the health impact of such levels could be. However, further on in the article the level was compared to the exposure limits for nuclear emergency workers, which provided reader with more context to evaluate the situation: '… *All three of them were exposed* *to radiation up to 180 millisievert, which is three times higher than levels allowed for workers at the nuclear power plant and close to limit of what is allowed in an emergency situation*'. While the exposures were undoubtedly of concern, three times ordinary limits and only close to emergency limits sounds arguably less alarming than '… 10 000 times higher than normal level'.

Finally, although visual material was expected to dominate in the representation of radiation related risk, very few of them were found in our sample. In addition, even when presented, this visual information was of varied quality. This suggests that this type of information was either not prepared by the actors responsible for the communication or that it is not easily available. Friedman *et al* in the evaluation of the media coverage of three major nuclear accidents (Three Mile Island, Chernobyl and Fukushima), praised many of the US media organizations for using infographics and multimedia on the their websites to present information about the Fukushima (Friedman 2011). Our study contained printed articles only; however, we think that even in this case more visual presentation of the risks should be expected.

The number of mistakes that appeared in the newspapers suggest that communication coming from experts was not clear and lacked context. It also suggests that journalists did not have the necessary knowledge on radiation issues, to be able to explain that information in the correct way or time to check whether information they presented was correct. This was partly confirmed in the statements given by journalists, who reported about Fukushima in different countries in Europe (Perko *et al* 2014a).

Findings, similar to ours were observed in the other media studies of the Fukushima coverage. For instance, Tollefson in his study of The Daily Yomiuri's coverage of the accident, found that technical information about radiation was presented with little context or explanation, making it difficult for public to understand the actual significance of it (Tollefson 2014). The same study showed that radiation risks were sometimes compared with the risk of getting cancer from smoking or from not eating vegetables, neither of which are considered as good benchmarks for comparison. A two year study of US news on Fukushima showed presence of claims without context and little specifications (Pascale 2016). An example given in the article states: 'The radiation levels reported so far by the Japanese authorities are far above normal but still too small to pose a hazard to human health if the exposure continued for a brief period'. Such statement raises more questions than it gives answers and is not considered an example of good communication.

6. Conclusions

There is clearly room for improvement in the way radiation risks are communicated to the media, and a more rigorous analysis of exactly why the advice for risk communication was not followed, would be highly useful. It is not clear whether the advice was simply not known or deliberately not followed. Nevertheless, the analysis underlines the importance of being clear when communicating about the risks from ionizing radiation. Information should be presented in several ways, giving both the results of the measurements and several benchmarks to compare those levels to. This will help journalists and reader to put this information into context and evaluate the seriousness of the situation. Providing additional information on the health effects that are expected to occur (or not occur) at the levels communicated, will give a clearer picture of the possible consequences of the radiological accident. As no agreement exists on how to communicate the health effects of ionizing radiation, especially in the low dose range, more research should focus on this topic.

The dynamics of the media environment and the time pressure journalists are exposed to, limits their capability to double check the information and search for context to put it into, especially when dealing with such complex issues as radioactivity. This only reinforces the need for clearer communication from experts and authorities.

Given the above: expert risk communicators should be pro-active and attempt to build relationships with the media during 'peace times'. The journalists should be able to know whom to contact for reliable information if an accident occurs, or if there is another need for coverage of radiation related issues. An example of such a proactive approach can be establishment of Science Media Centres like those already existing in UK and Japan. Such centres help establish connections between journalists and scientists and improve the quality of scientific debate in society (Tanaka 2015). Training courses and workshops are also good, although a more complex way of building relationships with the media and providing information about radiation and risks could also be explored.

'A picture is worth a thousand words' is a known adage and this principle is widely used by media for attracting attention and emotional response of the readers. This principle can also be utilized in risk communication. Tables, schematics, pictures and graphs presenting and explaining different measurement units, what they mean and how they are connected with each other, what kind of effects can various radiation doses cause and how are they put in perspective of existing doses and sources public gets exposed to in the normal life, offer a more effective and understandable way to reach public and deliver relevant information to them. However, development of such material requires time and expertise and can hardly be done by journalists who will be under time pressure in case of an accident. These materials should be prepared beforehand by the responsible authorities and research organizations and made easily available for public and media on a general basis (e.g. on their web pages). Analysis of how such material are received by both the media and the public would be another activity that could be explored as part of 'peace time' emergency preparedness.

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