

INTERNAL DOSE ASSESSMENT FOR ENVIRONMENTAL MONITORING IN NUCLEAR POWER PLANT ACCIDENTS

by

Fereidoun A. MIANJI^{1,2*}, **Jila KARIMI DIBA**², and **Mohammad Reza KARDAN**^{1,2}

¹Nuclear Science and Technology Research Institute, End of North Kargar, Tehran, Iran

²Iranian Nuclear Regulatory Authority, End of North Kargar, Tehran, Iran

Technical paper

DOI: 10.2298/NTRP1303325M

A method for exploiting human's internal contamination data for radioactive release estimation in nuclear power plant accidents is proposed. Nevertheless, such data is often very rough and uncertain; it is accessible even in toughest situations when most of the active and passive monitors are damaged by the accident. These data can be used in combination with other collectable data for estimating the event scale in severe nuclear power plant accidents. The rationale behind the method is that nuclear power plant accidents are often associated with internal contamination of radiation workers involved in the early stages of emergency response activities mainly due to the release of ¹³¹I in atmosphere. The proposed inverse analytical approach uses the ¹³¹I intake of contaminated workers, their working conditions, chronology of events, and applied personal safety measures during the first hours or days of the emergency response activities to estimate the magnitude of ¹³¹I concentration in the air.

Key words: dose assessment, event scale, Fukushima Dai-ichi, ¹³¹I, nuclear power plant accident

INTRODUCTION

The extremely strong earthquake (8.9 in Richter scale) at 14:46 on March 11, 2011, and the consequent devastating tsunami, almost 30 minutes after the earthquake, hit the northern east of Japan. This caused the most severe nuclear accident after the Chernobyl's 1986 which was due to the human error as the main reason of nuclear industry accidents [1]. Fukushima Dai-ichi nuclear power plant (NPP) with 6 reactors was the center of this accident, where units 5 and 6 were fortunately in the cold shutdown for maintenance. However the other 4 units were shut down automatically by the safety systems. The lack of electricity, serious damages to the controlling systems, and more importantly, failure in the cooling systems, did not allow the reactors to successfully transit to the cold shutdown state [2]. Moreover, the countrywide damages to infrastructures and communicating routs prevented the operator, *i. e.*, Tokyo Electric Power Company (TEPCO), of a timely and efficient response to the emergency situation. Resultantly, an explosion on March 12 seriously damaged the radiological barrier (secondary containment) of reactor No. 1 which in turn caused a major radioactive release to the environment. The situation deteriorated by another explosion in reactor No. 3 on March 14 and then in reactor No. 4

on March 15 releasing further radioactive materials into the environment. Japanese regulatory authority, the Nuclear and Industrial Safety Agency (NISA), announced the scale of this event level 4 on March 12 [2]. The NISA increased the scale of the event to level 7 one month later, on April 12. One of the reasons for such a big mistake and delay in estimating the right event scale was the failure of most of the monitoring devices during the first weeks of the accident. Figure 1 depicts the vast areas of the north east of Japan affected by the earthquake and the location of Fukushima Dai-ichi NPP on the map [3].

In the traditional dosimetry concept, the ultimate goal of dose assessment is evaluating the effective dose for mankind both in the internal and external terms [4]. This paper shows that the result of the internal dose assessment can also be valuable, indeed in conjunction with other data, for estimating the order of serious releases associated with major NPP accidents. In other words, the method proposes assuming that the human body is a power supply-free and noise-free active sampling device in nuclear accidents. It is worth emphasizing that this does not mean intentional use of human for this purpose. To verify this idea, using the primary results of internal dose assessment for the radiation workers involved in the early stages of the emergency response in Fukushima Dai-ichi NPP, the concentration of ¹³¹I in their workplace was estimated.

* Corresponding author; e-mail: fmianji@aeoi.org.ir

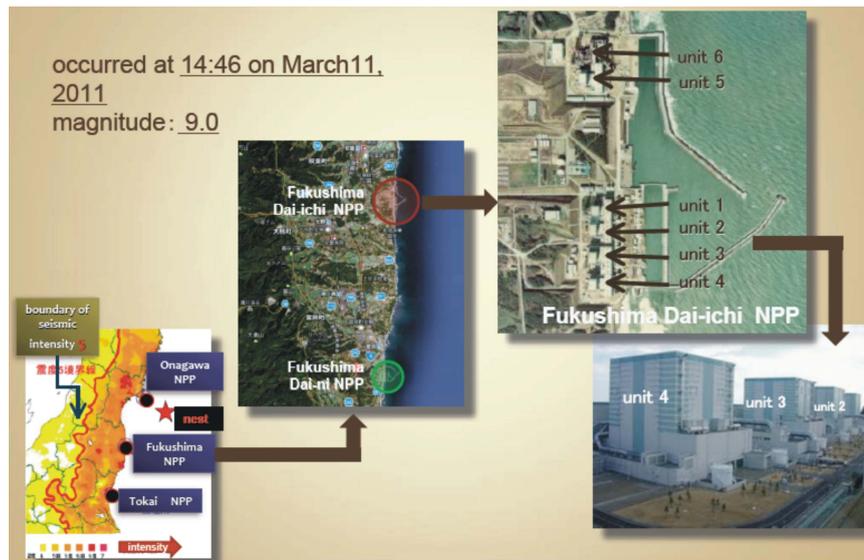


Figure 1. The Great East Japan Earthquake [5]

The appraised figure was then compared with the records of the fixed and mobile monitors which were still working after the accident. Then, with all these estimated and recorded data and using a very simple model the ^{131}I release during the first days after the accident was estimated very roughly. The outcome of this model was then benchmarked with the report of NISA submitted to the government of Japan on April 12. The comparison showed that the proposed method can provide worthy inputs to event scale estimating models, where, many parameters shall be considered for a sound estimation of the release order. The proposed method is referred to as Internal Dose Assessment for Environmental Monitoring (IDAEM) and is noted as IDAEM in the rest of this article.

THE INTERNATIONAL NUCLEAR EVENTS SCALE

The international nuclear events scale (INES) was designed by an international group of experts convened jointly in 1989 by the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency (NEA) of the Organization for Economic Co-operation and Development [5]. Promptly communicating to the public the safety significance of events reported at nuclear installations is the main objective of INES. It puts events into proper perspective, *i. e.*, the Scale, in order to ease common understanding among the nuclear community, the media, and the public. The INES introduced 7 levels for scaling nuclear events. Levels are in descending order in terms of severity where levels 7 to 4 are called accident owing to their offsite risks and levels 3 to 1 are called incident due to their very unlike offsite consequences. According to INES the accidents with significant offsite risks (5 to 7) can be expressed in terms of external release of radioactive

materials in quantities radiologically equivalent to release of hundreds to tens of thousands of TBq of ^{131}I . Therefore, a sound prediction or estimation of ^{131}I equivalent release in atmosphere can be used for defining the event scale in sever accidents. This in turn is crucial in defining the appropriate intervention level for implementing necessary countermeasures.

INTERNAL DOSE ASSESSMENT FOR ENVIRONMENTAL MONITORING IN NPP ACCIDENTS

The principal of internal dose assessment for environmental monitoring (IDAEM) is straight forward. There are often radiation workers involved in the very first hours or days of a sever accident trying to monitor or control the situation in an NPP site. Inhaling some radioactive materials, particularly ^{131}I , is unavoidable by these workers in accidents associated with release from the nuclear reactors. This was exactly what happened in Fukushima Dai-ichi. In addition to the aforementioned likely scenario, following presumptions are often true about NPP accidents associated with damage to both reactor and secondary containment:

- in local/site scale, radioactive materials often disperse in atmosphere in all directions due to reactor pressure and unstable wind direction, contamination in one point in air is thus a reason for contamination in a very large volume [6, 7],
- the radionuclide release continues for a long period until the necessary sealing coverage is provided [8], and
- the inhalation of radioactive material by emergency workers involved in the emergency response activities often takes place distant to the origins of the release, the concentrations of radioactive material at inhalation points are much lower that at points near to the releasing origins.

Table 1. Internal doses of radiation workers in March, April, and May in Fukushima Dai-ichi; values are in CED

Dose [mSv]	Number of workers vs. internal dose		
	March	April	May
Greater than 250	5	0	0
200-250	1	0	0
150-200	1	0	0
100-150	5	0	0
50-100	79	0	0
20-50	256	2	0
10-20	647	39	1
<10	2721	3422	2720
Total personnel	3715	3463	2721
Max. individual internal dose	590	41.8	10.1
Average internal dose	8.9	0.7	0.2
Total internal dose	33063.5	2424.1	544.2

According to the NISA reports in June 10, 2011, two radiation workers received a total dose of 643 and 678 mSv including, respectively, 540 and 590 mSv as the internal doses, *i. e.*, committed effective doses (*CED*). Further investigation by TEPCO validated these figures and the most complete report was issued in August 10, 2011, by TEPCO [9]. Table 1 tabulates the internal dose assessment statistics of the radiation workers over the first three months after the accident.

Several points can be concluded from tab. 1 as follows.

A very large fraction of the total internal doses received by the workers over these three months belongs to March, *i. e.*, 91.76%.

The average internal dose in March is about 13 times of April's and 44.5 times of May's.

All the overexposure cases (5 persons with 250 mSv < *CED*) and cases with 50 mSv < *CED* < 250 mSv (86 persons) occurred in March. Moreover, 256 out of 258 (99.2%) cases of 20 mSv < *CED* < 50 mSv took place in March. It is worth mentioning that according to the nuclear law of Japan, the maximum allowed absorbed dose for personnel involved in emergency responses is 250 mSv (including internal and external doses).

Further details are given in tab. 2. It shows the *CED* for 12 radiation workers as of July 8, 2011.

The IDAEM proposes the use of ¹³¹I intake value of radiation workers during the first days (or even hours, if possible) after a severe accident to guess estimate the concentration of ¹³¹I in the air. It focuses only on ¹³¹I owing to the fact that it is a good release indicator (and the main one) in an NPP accident and it is easy to measure in body. The procedure for implementing the IDAEM is as follows.

- Measure the amount of intake using a thyroid counter.
- Obtain ¹³¹I concentration in air (*ca*) using formula (1)

Table 2. Internal doses of radiation workers over than 100 mSv. Values are in CED

Case number	<i>CED</i> [mSv]
1	590.0
2	540.0
3	433.1
4	327.9
5	259.7
6	241.8
7	166.1
8	137.3
9	120.0
10	119.6
11	117.3
12	101.3

$$ca \text{ [Bqm}^{-3}] = \frac{\text{intake [Bq]}}{wh[h] \cdot br[\text{m}^3 \text{ h}^{-1}] \cdot fc \cdot tbc} \quad (1)$$

- Use the obtained figure as the environmental monitoring result in addition to all the other applicable data such as the approximate inhalation time, wind speed and direction, period of release, data from the monitoring devices, *etc.*, to estimate the ¹³¹I release order using the appropriate models.

The abbreviations *ca*, *wh*, *br*, *fc*, and *tbc* in formula (1) stand for ¹³¹I concentration in air, working hour, breathing rate, filtering coefficient for breathing filter, and thyroid blocking coefficient for iodine tablet, respectively.

RESULTS AND DISCUSSION

To validate the proposed method with Fukushima accident's data, since the intake values are not reported, the *CED* values of tab. 2 were used for calculating the ¹³¹I intake. We assumed that the reported *CED* values were mainly due to ¹³¹I intake, nevertheless, the precise ¹³¹I intakes have been directly measured using thyroid counters at the site. The calculated intake values were then combined with the information gathered by investigating the conditions and the chronology of the events.

As the representative of the internally exposed workers, any of the *CED* values from tab. 2 can be used, but, for simplicity we take the two maximum *CED* values *i. e.*, 540 mSv and 590 mSv. This is reasonable because there are many cases with similar order of *CED* values (over 100 mSv) comparable to the maximum values. Provided that the thyroid of all the personnel involved in the emergency response had been routinely counted, the maximum intakes were measurable directly at site on March 12 or 13. Therefore, based on the idea of IDAEM, it was possible to roughly estimate the order of ¹³¹I release from the beginning of the emergency response. This figure, beside the other collected data, was in turn applicable for calculating the INES level.

Table 3. Case study on the two maximum CED

Case and CED values	Period of operation	Tentative date of intake	More precise date of intake	Personal protective measures	Main failure leading to the intake
Case 1: total 678 mSv, internal 590 mSv	March 11 to May 2	April 6	March 12	(1) Dusk mask in the central room (2) Charcoal mask in the operation site (3) Stable iodine prophylaxes: 2 tablets on March 12	Gap between the charcoal mask and frame of glasses
Case 2: total 643 mSv, internal 540 mSv	March 11 to May 4	April 7	March 13	(1) Dust mask in the central room (2) Charcoal mask in operation site (3) Stable iodine prophylaxes 2 tablets on March 12, 1 tablet on May 3, 2 tablets on May 12, 2 tablets on May 20, and 1 tablet on May 21	Not clear

The two maximum CED cases were reported by Japan's National Institute of Radiological Science (NIRS) after studying their chronological and conditional details [10]. Table 3 presents the results of this report.

The other cases of tab. 2 have claimed similar reasons for their high intakes. The most common reasons have been [10]:

- a gap between mask and frame of glasses,
- the charcoal mask not easily available in some cases,
- the use of charcoal mask for too long period of time,
- a delay in ordering stable iodine,
- eating/drinking in central control room where radiation level was high, and
- smoking with a mask taken off.

Considering the information for cases 1 and 2 from tab. 3 and the aforementioned reports from the other 10 cases with high intakes, followings can be concluded:

- assumption 1: the cases 1 and 2 have not used the mask properly. Case one agrees that the mask has not been fitted on his glasses appropriately and many of the other cases complain about difficulty in access to the charcoal mask,
- assumption 2: both cases 1 and 2 had taken enough blocking iodine on the main dates of the intake. The problem with using stable iodine has been delay in reordering it for the extent of the emergency response whereas they had received their doses in the first two days, and
- assumption 3: the first explosion (reactor No. 1) happened on March 12 and the precise date of intake for cases 1 and 2 have been, respectively, March 12 and March 13. The total intakes for them are thus roughly assumed to have happened over one working day.

With these basic assumptions, the calculation of ^{131}I concentration in air using the average value of cases 1 and 2 was performed. The values of the parameters in formula (1) are as follows:

- working hour (*wh*) of radiation workers was assumed 12 hours per day,
- breathing rate (*br*) for adults is $1.2 \text{ m}^3/\text{h}$ in normal activities and $1.6 \text{ m}^3/\text{h}$ in physically demanding conditions. This was an emergency response activity, we assumed thus $br = 1.6 \text{ m}^3/\text{h}$ [11],

- filtering coefficient for many filters such as active-coal filters is over 99%, hence, fc would be 0.01 if the mask is worn properly. But, the mask was not worn properly, therefore, we may roughly assume $fc = 0.1$, and
- a typical thyroid blocking efficiency for iodine tablets is 99% which means $tbc = 0.01$. According to tab. 3, thyroid blocking tablets were taken at the same date of the first explosion in reactor 1. Regarding the fact that even 3–4 hours delay in taking the tablets still provides a substantial thyroid protection, and presuming that the tablets were administered almost coincident with the first explosion, we may conservatively consider $tbc = 0.05$ for our two selected cases [12, 13].

Averaging the CED values for case 1 and case 2, $CED_{av} = 565 \text{ mSv}$. In this example we have CED values instead of the ^{131}I intake values, therefore, we first need to calculate the intake values using the following formula

$$Intake[\text{Bq}] = \frac{CED[\text{Sv}]}{dc[\text{SvBq}^{-1}]} \quad (2)$$

where dc is the dose coefficient for ^{131}I ($1.1 \cdot 10^{-8} \text{ Sv/Bq}$) [11].

Using formula (2) the average intake was calculated: $intake_{av} = 5.136 \cdot 10^7 \text{ Bq}$. Then, using formula (1) ca was calculated: $ca = 5.35 \cdot 10^8 \text{ Bq/m}^3$. It is worth mentioning that instead of average of case 1 and case 2, ca for all the cases in tab. 3 can be calculated individually. This depends on the method and model used for release estimation. Every internally contaminated person may be assumed as an active fixed or mobile filter for the monitoring purpose depending on his or her moving map during the inhalation period of the radioactive material.

To benchmark the obtained result, we compared the order of expected dose rate due to this level of ^{131}I contamination with the monitoring data recorded in different points inside or on the boundary of the NPP by fixed and mobile electronic monitors. First we considered the atmosphere of NPP as an array of hypothetical unit cubes with the calculated ca as ^{131}I point sources in the center of the cubes. The lowest possible dose rate for the working place of cases 1 and 2 would happen in the corner of every cube where 8 cubes are

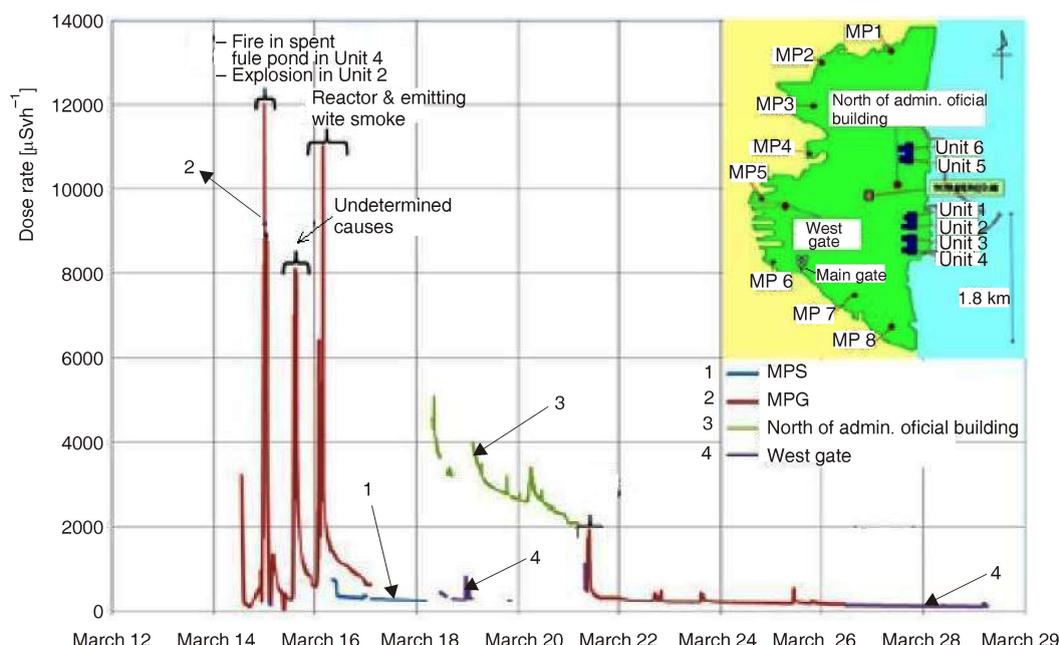


Figure 2. Fukushima Dai-ichi dose rate measurements at fixed monitoring points from March 14th 2011, 13:15 to March 28th 2011, 21:00 UTC [14]

Table 4. Dose rates of the fixed monitoring points for March 12 and 13

Fixed monitoring points	M1	M4	M6	M8
Dose rate and recording time & date	17 μSv/h at 11:40, March 13	40 μSv/h at 3:08, March 13 47.1 μSv/h at 12:20, March 13	0.07 μSv/h at 4:00 March 12 3.1 μSv/h at 2:50, March 13 26 μSv/h at 9:30, March 13	0.07 μSv/h at 4:00, March 12 45 μSv/h at 2:50, March 13

in neighborhood. The distance of the corner to each adjacent point source is $d = 0.75^{0.5}$. Therefore, neglecting the effect of the point sources other than the 8 adjacent ones for simplicity, the dose rate due to the calculated ca at the corner is

$$\dot{D} = 8 \Gamma_{131I} A : d^2$$

$$8 \cdot 7.647 \cdot 10^{-5} \frac{\text{mSv}}{\text{hMBq}} \cdot 535 \text{ MBq} : 0.75^2 = 0.4364 \frac{\text{mSv}}{\text{h}}$$

where Γ_{131I} is the gamma factor (specific gamma-ray dose constant) of ^{131}I and A – the activity of point sources.

Figure 2 shows a graph of the NPP site area with the record of monitoring points (MP) [14]. This graph only shows the records of some of the fixed monitors from the noon of March 14 to the end of March 28. The high peaks, as depicted in the graph, are due to some incidents in spent fuel pond, reactor No. 2, etc. The highest rates were recorded for MP6, north of administration official building, and MP5, though over different periods of time. It is worth noting that this graph doesn't show the dose rates for March 12 and 13, when several explosions have occurred in reactors No. 1 and 3. Furthermore, the dose rates near to these two units, as the main sources of the radioactive release, have been indeed much higher. As the supplementary information, some data from the early hours of the accident

Table 5. Results of the site boundary routine mobile monitoring for March 12

Time (March 12)	06:29	06:47	10:44	11:26	14:30	18:08
Dose rate at site boundary [μSv/h ⁻¹]	1015	141.8	64.2	59.1	47.9	40.0

were also gathered and are depicted in tabs. 4 and 5. Table 4 shows the available data from some of the fixed monitoring points for March 12 and 13 and tab. 5 shows the mobile monitoring results on the boundary of the NPP site [14].

Scrutiny of tabs. 4 and 5 reveals that the sharp and dramatic increases in ambient dose rates have been happening in all directions of the site after the accident. These could be good evidences at hand in the first days of the accident showing that the radioactive release were moving in all directions. Moreover, it proves that there have been very high peaks (not shown in fig. 2) due to the explosions in units 1 and 3 between March 12 and 14 which were detectable by fixed monitoring stations too. Therefore, a high contamination of the site atmosphere was presumable during the first days of the accident as well. It is remarkable that the estimated dose rate by our method (only due to ^{131}I) is for the central part of the NPP area, *i. e.*, almost near to the reactor buildings, but, tabs. 4 and 5 present the dose rates for boundary area. Therefore, it can be concluded that the recorded dose rates by mo-

bile monitoring device on March 12 and fixed monitoring stations on March 13 all confirm our estimated *ca*.

Indeed, due to the lack of information about ^{131}I concentration in air or the dose rate near to the damaged reactors in the first days of a severe accident in NPP, calculating the event scale is very difficult. In order to very roughly show the applicability of IDAEM for event scale estimation, a very simple model was adopted. We assumed a similar concentration of the calculated *ca* over all site area with the height of 10 m for 1 hour only. This is a very conservative model because all the data in tabs. 4 and 5 and the continual reactor explosions over the first days after the accident show that there had been a continuous radioactive release in the site. Furthermore, cases 1 and 2 have not been near the leaking points where the concentration of radioactive material in air has been indeed much higher than the calculated *ca* on March 12 and 13. The third reason of conservativeness of the model is that we have limited the contaminated atmosphere to the site area of Fukushima Dai-ichi which is only 3.5 km², whereas the severely contaminated area around the NPP has been drastically wider than this area. Figure 3 shows the region with the ambient dose rate much higher than the background due to the Fukushima accident. The high dose rate area (from all released radionuclides) is approximately 15,000 km², *i. e.*, about 4300 times of the site area. Such a large contaminated area confirms the massive release and transfer of the radioactive material in all directions.

Using 3.5 km² as the contaminated area, 10 m as the height of the contaminated volume, and the ob-

tained *ca* as the average contamination of the air in this volume, the total release of ^{131}I is 1.872 10¹⁶ Bq. Referring to the INES levels, this falls in category 7. It is therefore clearly a category 7 accident owing to the fact that all our assumptions were very conservative. To validate this figure and the method, it is compared with the reported value by the government of Japan on April 12, 2011 [11], *i. e.*, 1.3 10¹⁷ Bq. The soundness of the proposed method despite all the inherent uncertainties and the underestimations that we conservatively had to undergo is clear. Even using cases 3 to 12 of tab. 2 will yield results of very proximate order. It should be emphasized that this very simple scenario does not intend to undervalue the dramatic efforts made by the parties involved in the emergency response of Fukushima NPP neither it means the event scale estimation is a simple and straight forward task. The IDAEM is only an idea for obtaining the urgent useful information from the subjects that are not traditionally assumed as data acquisition means. The prerequisite for efficient implementation of IDAEM is conceptually considering it as a part of the monitoring network in NPP accidents.

CONCLUSIONS

Nevertheless, the Fukushima Dai-ichi nuclear accident was not responsible for any of the about 25,000 deaths or missing toll of the 2011 Japan's earthquake; it overshadowed the non-nuclear aspects of the disaster. This is owing to the extensive and long term environmental impacts and trans-boundary consequences of severe nuclear accidents. A timely and correct estimation of the event scale is thus of vital importance in any nuclear accident management. It is the basis for an effective emergency response planning through appropriate provisional measures. Moreover, it transfers a global message for protecting people and environment in the international level.

In this paper a new perspective of internal dose assessment in NPP accidents is introduced. The method, namely IDAEM, proposes using the data of internal contamination of emergency workers involved in an NPP accident for estimating ^{131}I contamination in air. In other words, it suggests using internally contaminated personnel during the emergency response activity as environmental monitors. Obviously, this does not mean planned use of uncontaminated people for this purpose. The obtained results from IDAEM in addition to the other important data collected from the accident are helpful for guesstimating ^{131}I radiologically equivalent release order through appropriate models. An experiment using the real data from Fukushima Dai-ichi NPP was carried out and the results validated the soundness of the proposed method.

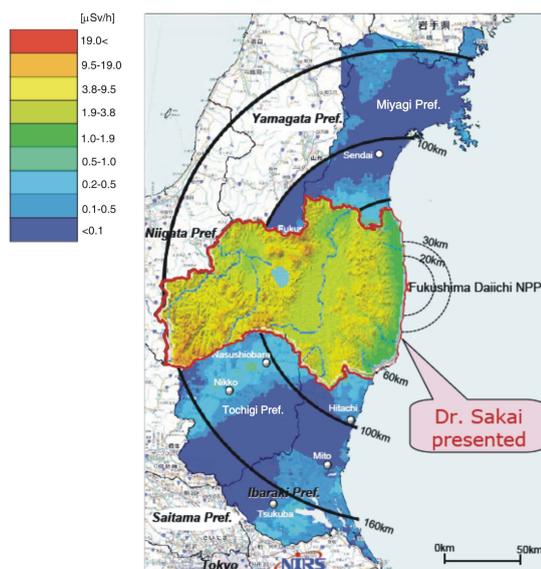


Figure 3. Ambient dose rate estimated from aerial survey on 160 km zone of Fukushima Dai-ichi NPP [15]; 3rd monitoring map within 80 km from NPP 1F by MEXT (presented on July 8, 2011)

AUTHOR CONTRIBUTIONS

The reports issued by the TEPCO and the NISA were collected and analyzed for continuity and comprehensiveness by J. K. Diba and F. A. Mianji for near two years after the accident. J. K. Diba also provided the internal dosimetry information and F. A. Mianji processed the data and extracted the chronology of the accident. He also gathered other references for completion of the work and prepared the figures and tables. All authors worked on the proposed idea, discussed its applicability, and analyzed the experimental results. The manuscript was written by F. A. Mianji, however the co-authors particularly M. R. Kardan contributed to the proof reading.

REFERENCES

- [1] Barati, R., Setayeshi, S., Human Reliability Analysis of the Tehran Research Reactor Using the SPAR-H Method, *Nucl Technol Radiat*, 27 (2012), 3, pp. 319-332
- [2] ***, Prime Minister of Japan and His Cabinet Additional Report of the Japanese Government to the IAEA – The Accidents at TEPCO's Fukushima Nuclear Power Stations (Second Report), Sept. 2011 http://www.kantei.go.jp/foreign/kan/topics/201106/iaea_houkokusho_e.html
- [3] Suzuki, T., IAEA Regional Meeting in Occupational Radiation Protection in Emergency Exposure Situations, Occupational Exposure in Fukushima Accident, Chiba, Japan, Nov 23, 2011
- [4] Pešić, M. P., Estimation of Doses Received by Operators in the 1958 RB Reactor Accident Using the MCNP5 Computer Code Simulation, *Nucl Technol Radiat*, 27 (2012), 3, pp. 199-221
- [5] ***, IAEA, Nuclear Installation Safety Net. Appendix VI – The International Nuclear Event Scale Tutorials – Regulatory Control of Nuclear Power Plants, <http://www.iaea.org/ns/tutorials/regcontrol/chapters/appendix.pdf>

- [6] Taira, Y., *et al.*, Environmental Contamination and External Radiation Dose Rates from Radionuclides Released from the Fukushima Nuclear Power Plant, *Radiation Protection Dosimetry*, 151 (2012), pp. 537-545
- [7] Takada, M., Suzuki, T., Early in Situ Measurement of Radioactive Fallout in Fukushima City Due to Fukushima Daiichi Nuclear Accident, *Radiation Protection Dosimetry*, 155 (2013), 2, pp. 181-196
- [8] Gering, F., *et al.*, Potential Consequences of the Fukushima Accident for off-site Nuclear Emergency Management: A Case Study for Germany, *Radiation Protection Dosimetry*, 155 (2013), 2, pp. 146-154
- [9] ***, Tokyo Power Electric Company evaluation status of internal exposure " Over 20 mSv and less or equal to 50 mSv" in March and April – Attachment 2 Aug. 2011, http://www.tepco.co.jp/en/press/corp-com/release/betu11_e/images/110810e18.pdf
- [10] Sakai, K., IAEA Regional Meeting in Occupational Radiation Protection in Emergency Exposure Situations, Lessons Learnt from Fukushima accident, Chiba, Japan, November 23, 2011
- [11] ***, IAEA, Methods for Assessing Occupational Radiation Doses Due to Intake of Radionuclides, Safety Reports Series No. 37 2004
- [12] ***, IAEA, Generic Procedures for Monitoring in a Nuclear or Radiological Emergency, TECDOC-1092, 1999
- [13] ***, NCRP, Management of Persons Contaminated with Radionuclides, NCRP-161, 2008
- [14] Tatsuzaki, H., IAEA Regional Meeting in Occupational Radiation Protection in Emergency Exposure Situations, Medical Management of Emergency Workers, Chiba, Japan, November 23, 2011
- [15] ***, Nuclear and Industrial Safety Agency Report of Japanese Government to the IAEA Ministerial Conference on Nuclear Safety – The Accident at TEPCO's Fukushima Nuclear Power Stations, NISA Jun. 2011 http://www.kantei.go.jp/foreign/kan/topics/201106/iaea_houkokusho_e.html

Received on March 4, 2013

Accepted on August 26, 2013

Феридун А. МИАНЏИ, Џила Карими ДИБА, Мохамад Реза КАРДАН

ПРОЦЕНА УНУТРАШЊЕ ДОЗЕ РАДИ МОНИТОРИНГА ОКОЛИНЕ ПРИ АКЦИДЕНТИМА У НУКЛЕАРНОЈ ЕЛЕКТРАНИ

Предложена је метода за коришћење података о унутрашњој контаминацији људи за процену ослобођене радиоактивности услед акцидента у нуклеарној електрани. Иако су овакви подаци често веома груби и непоуздани, доступни су чак и у најгорим ситуацијама када је већина активних и пасивних монитора оштећена акцидентом. Ови подаци могу се користити удружени са другим прикупљеним подацима ради процене скале догађаја код већих акцидента у нуклеарној електрани. Образложење за ову методу је да су акциденти у нуклеарној електрани често повезани са унутрашњом контаминацијом радника укључених у раним фазама реаговања у ванредним ситуацијама, углавном због ослобађања ^{131}I у атмосферу. Предложени инверзни аналитички приступ користи унос ^{131}I контаминираних радника, њихове услове рада, хронологију догађаја и примењене мере за личну заштиту током првих сати или дана реаговања у ванредним догађајима, ради процене концентрације ^{131}I у ваздуху.

Кључне речи: процена дозе, скала догађаја, Фукушима Даи-ичи, ^{131}I , акцидент у нуклеарној електрани