

## ASSESSMENT OF PERSONAL INHALATION INTAKE OF I-131 FOR RADIOISOTOPE PRODUCTION WORKERS BY MOTION DETECTION APPLICATION

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### ABSTRACT

*Time-microenvironment patterns spent by radiation workers were determined by a motion detection application installed on smart phones. Simultaneously, indoor air hourly was sampled by using portable air samplers. Then we estimated the actual individual intake of airborne I-131 for a group of workers producing radioisotopes. The results showed all the individual intakes were low.*

**Keywords:** Personal intake, motion detection, I-131.

### TÓM TẮT

***Đánh giá thâm nhập cá nhân cho các nhân viên sản xuất đồng vị phóng xạ do hít phải I-131 bằng ứng dụng cảm biến chuyển động***

*Thời điểm các nhân viên bức xạ ra vào các tiểu môi trường được ghi nhận nhờ vào một ứng dụng cảm biến chuyển động trên điện thoại. Đồng thời, không khí được lấy mẫu hàng giờ bằng máy xách tay. Sau đó lượng thâm nhập của I-131 do hít phải của nhóm nhân viên sản xuất đồng vị phóng xạ được tính toán. Kết quả cho thấy các lượng thâm nhập cá nhân đều ở mức thấp.*

**Từ khóa:** thâm nhập cá nhân, cảm biến chuyển động, I-131.

### 1. Introduction

Iodine-131, a volatile substance, is widely used for diagnosis and radiotherapy of thyroid diseases [5]. Distilling of I-131 from activated product may lead to release a significant amount of I-131 to the indoor air. As a result, the internal contamination could occur through inhalation to radiation workers. Many papers showed that there were some workers working with radioiodine product had been committed with I-131 at significant doses and they needed to be personally monitored. [2, 8]

Assessment of personal intake is a complex problem. In order for estimate personal inhalation intake of indoor air, we need to investigate two events occurring jointly: concentration of interest airborne radionuclides and time-microenvironment (time-ME) spent by the workers [16]. Time-ME pattern of monitored objects can be obtained from some methods such as personal GPS tracking, activity diaries or

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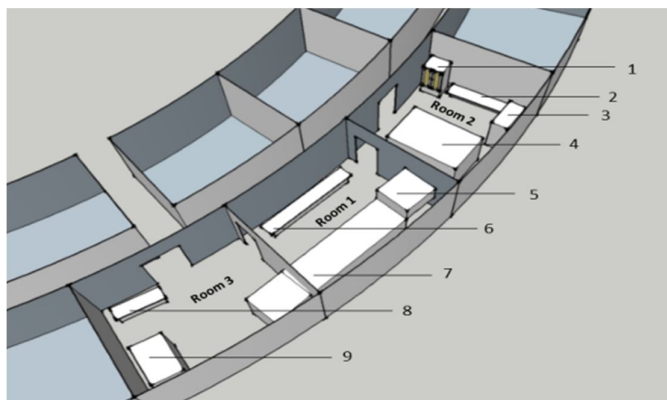
questionnaires [1, 11]. There are some advantages as well as disadvantages in each method. For airborne radioiodine, it is necessary to determine exactly the spatiotemporal variation of workers and concentration correspondingly [1, 13, 16]. Therefore, a motion detection application installed on smart phone could be used to record the actual time-ME pattern of workers when they enter and leave the monitored areas. The representativeness of inhaled air should be considered [15]. For compounds that disperse readily in the air, samples from static or portable air samplers can provide a reasonable representation of inhaled radioactive materials, especially in small rooms. [2, 15]

This study aims to assess the short-term inhalation intake of I-131 for radiation workers working at radioisotope production in Nuclear Research Institute by using low-cost and unwearable devices including a mobile phone's motion detection application and portable air sampler. Also, the paper showed a detailed picture of personal exposure of these workers.

## 2. Materials and methods

### 2.1. The study area

The study was carried out at the radioiodine production area of Nuclear Research Institute which consists of three rooms (Fig. 1): distilling room (room 1), capsule processing room (room 2) and hot cell room (room 3). Each of these MEs has a dimension of 5m (L) × 5m (W) × 4m (H) with a door and no window. The three rooms were connected with two internal doors of room 1 and workers can enter the rooms from an enclosed corridor. Exhaust and air supply systems run continuously during the work time. As the result, the air concentration in each room is regarded as quite uniform.



**Figure 1.** Schematic sketch of the radioiodine production area in Nuclear Research Institute (1, 3, 4: Shelves; 2, 6, 8: Tables; 5: Air filter box; 7: Distilling box; 9: Hot cell)

## 2.2. Air sampling

Two portable air samplers that are F&J Specialty Products Model LV-1E [4] and Eberline Model RAS-1 [14], and the activated carbon cartridges impregnated with TEDA (Hi-Q Model TC-12) were used to sample intermittently. The cartridge holder was settled near the breathing zone at 1.5m height from the floor.

Due to the concentration differs significantly from time to time, so in order to minimize data uncertainty, we decided to divide the work time into 1-hour periods. The sampling time was about 5 minutes per sample at the flow rate of 70 L/min, 3 samples an hour in each room with the interval of about 15 minutes at different sampling points. And the average concentration was calculated for each time-segment particularly. In order to demonstrate the representativeness of inhaled air, the two samplers were used at the same time for comparison.

## 2.3. Time-ME recording

We had used a motion-sensitive software named Motion Recorder – a Symbian-based application – installed in smartphones to detect motion. The smart phones were connected to a battery storage so this system could live during the work time. All the movement happening in front of the phone was recorded to a video file. When workers enter and leave the rooms, the software records the motion and attach the real time in hh:mm:ss type as soon as these motions occur. As the result, the time-ME patterns will be more accurate and easier to analyze. Two recorder systems were fixed to the wall next to the doors to confirm that the monitored view was minimized.

## 2.4. Concentration determination

Radioiodine activity distribution along the charcoal cartridge axis depends on sampled air volume [12]. There are several studies showed that radioiodine was found within the front 5 mm and average depth was about 2 mm while the cartridges that were in place for up to one week or at the high air volume (1,647 m<sup>3</sup>) [3, 12]. The cartridges in this study were sampled in 5÷10 min corresponding the volume of 0.35÷0.70 m<sup>3</sup>. Accordingly, the counting system had been calibrated appropriately for this situation. From the radioactivity at the counting time of the cartridge, the concentration of airborne radioactivity can be calculated by using the Eq. (1) [7].

$$C_i = \frac{A_{Si}}{F_i \times t_{Si} \times \varepsilon_F} \quad (1)$$

where  $C_i$  is the average airborne radioactivity concentration at  $i^{\text{th}}$  work hour,  $A_{Si}$  is the radioactivity at the sampling time of the cartridge,  $F_i$  is the sampling flow rate,  $t_{Si}$  is the sampling time and  $\varepsilon_F$  is efficiency of the cartridge.

## 2.5. Personal intake estimate

Time-ME pattern of workers at radioiodine production varies strongly from person to person and time to time. Therefore, in this study we used the consecutive

method which has been developed by some researchers [9, 10, 16]. The daily personal intake was calculated from separated hourly exposure at a particular ME by Eq. (2)

$$I_i = R \times \sum_{j,k} E_{ijk} = R \times \sum_{j=1}^J \sum_{k=1}^K (C_{jk} \times \Delta t_{ijk}) \quad (2)$$

where  $I_i$  is the daily average intake of individual subject  $i$ ,  $R = 1.2 \text{ m}^3/\text{h}$  is the breathing rate [5],  $E_{ijk}$  is the exposure of individual subject  $i$  in ME  $j$  for the  $k^{\text{th}}$  time period,  $C_{jk}$  is the average airborne radioactivity concentration in ME  $j$  for the  $k^{\text{th}}$  time period, and  $\Delta t_{ijk}$  is the sum of the time individual  $i$  spent in ME  $j$  in the  $k^{\text{th}}$  time period.

The uncertainty of the evaluated intake at a particular period of time in each ME for a worker were calculated by:

$$\frac{\Delta I}{I} = \sqrt{\left(\frac{\sigma C}{C}\right)^2 + \left(\frac{\sigma t}{t}\right)^2} \quad (3)$$

where  $C$  is the concentration at a particular period of time in each ME,  $\sigma C$  is calculated from Eq. (1);  $t$  is the sum of time spent by a person in each period of time at a certain ME.

### 3. Results and discussion

#### 3.1. Concentration measurement

At Nuclear Research Institute, radioiodine product distilled from activated product is produced once a month. This task is done within a weekend day (Saturday). During the distilling and handling the product,  $^{131}\text{I}$  may be evaporated or sublimated and released into the indoor air from any step of the process. In this study, however, we did not intend to find out what steps or where the sources could release the iodine aerosol as well as the physical properties of the indoor air.

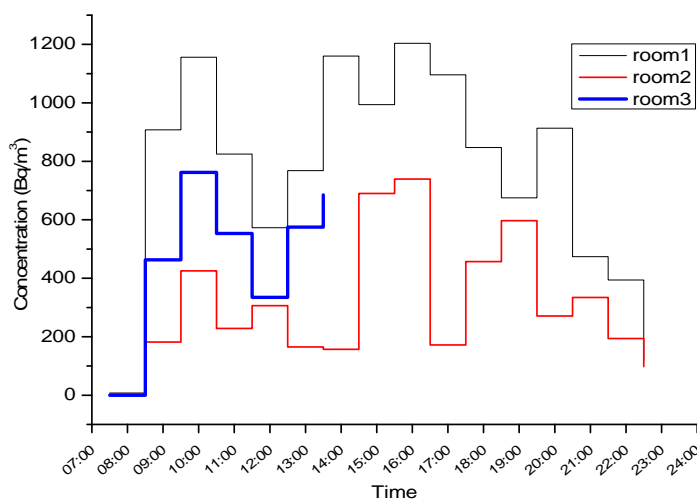
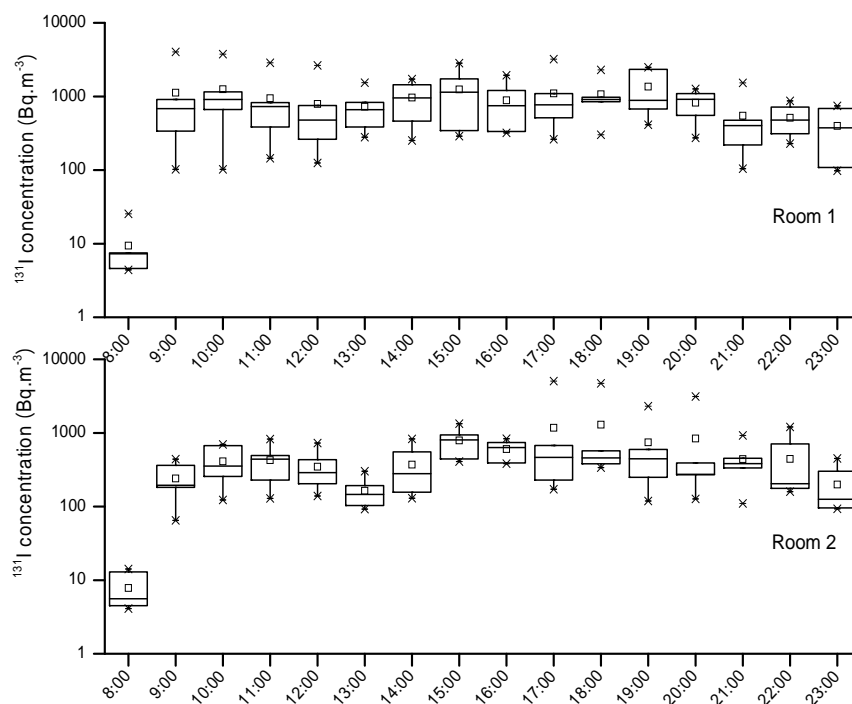


Figure 2. Hourly average  $^{131}\text{I}$  concentrations in three rooms on April 11<sup>th</sup> 2015

During the work day, the air was sampled three times an hour per room then the average concentration was calculated for each particular one-hour segment. The value in this study had been obtained in six months, from January to June 2015. Fig. 2, for example, shows the average  $^{131}\text{I}$  concentration of the three rooms on 11 April 2015. On this day, the radiation worker group had worked from 8:15 to 23:00. The concentration in room 1 was higher than those observed in the others, average  $757.1 \text{ Bq/m}^3$  (room 1) compared to  $313.8 \text{ Bq/m}^3$  (room 2) and  $481.8 \text{ Bq/m}^3$  (room 3). In room 3, however, with respect to the cost and time, we measured the concentration in the morning only without fulltime because the workers rarely occupied this room in the afternoon and the evening.

The hourly airborne I-131 concentration of the three rooms differs sharply (Fig. 3). For instance, in room 1, from 14:00 to 15:00 and at 19:00, radioiodine concentration distribution changes strongly. In contrast, radioiodine concentration vibrates in small range in room 2 at 13:00 and 18:00. Generally, airborne radioiodine concentration in room 1 was higher and had wider amplitudes than others. Therefore, we estimated the intakes hourly instead of overall in order to minimize the uncertainty.



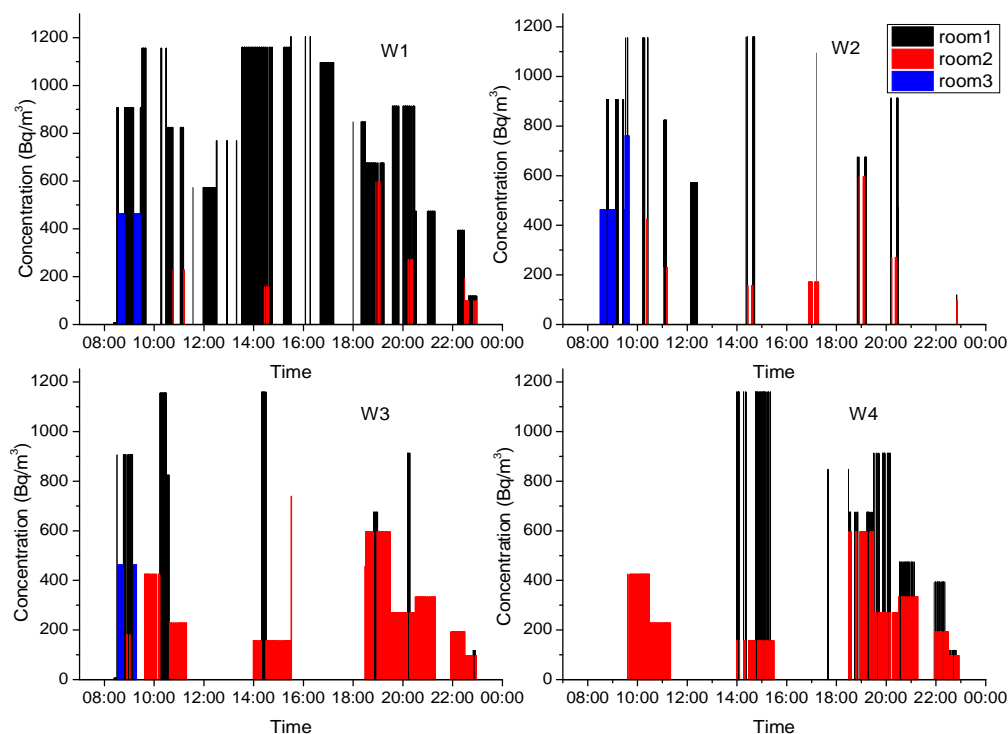
**Figure 3.** The box charts show the hourly  $^{131}\text{I}$  concentration distribution in the two rooms on April 11<sup>th</sup> 2015 plotted from monitored dataset of six months of 2015

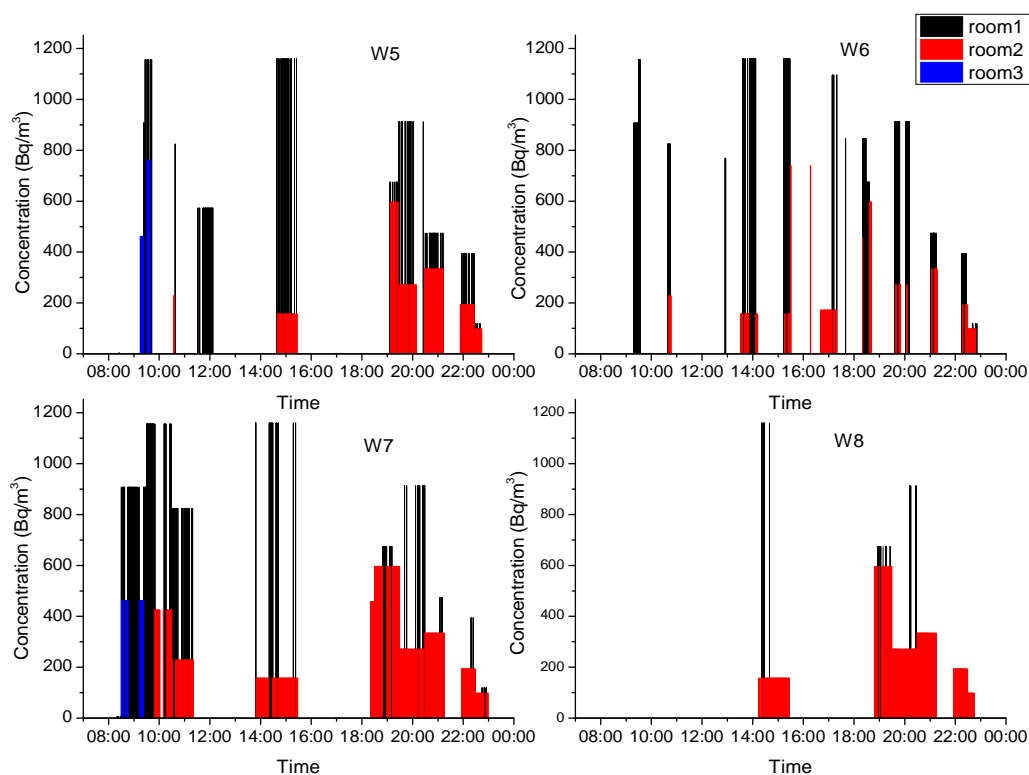
### 3.2. Time-ME pattern and intake estimate

Eight profiles shown in Fig. 4 are examples from the dataset collected on 11 April 2015 illustrating how concentration and spatiotemporal data are integrated to analyze

an individual intake profile. The patterns show the good time resolution with time differential is 1 minute. This means that, the exposure of the workers were determined minute by minute. Therefore, short-term intake could be easily calculated on any period of time.

Time spent by the workers at the three MEs are generally different. In profile W1 (for worker 1), sum of 451 minutes was recorded, whereas for profile W2 a sum of 153 minutes was recorded. Due to workers' specific task, the frequency of room-entering times differ considerably between the workers. Worker 5, for example, had larger frequency than those of others. He had 130 times entering the three rooms while worker 8 had 27. The data gaps in Fig. 4 show the time workers spent outside the monitored rooms. Most of the worker had left the rooms at noon and late of afternoon. Worker 8 had not been in the rooms during the morning of 11 April 2015. Whether the workers had inhalation exposure to outdoor airborne I-131 or not, this assessment excluded this problem.





**Figure 4.** Eight workers' exposure profile at 1-minute resolution on April 11<sup>th</sup> 2015. The colors indicate which MEs the person was at defined time. Personal intake can be derived from this profile

Monthly intake of  $^{131}\text{I}$  by inhalation for 8 workers are shown in Table 1. The intake uncertainty in a particular period of time was estimated from Formula (3). Four factors affecting the total uncertainty are sample counting, time statistic, air sampling and sampler system. Among these four factors, the sampling uncertainty is largest one, varies between 7% and 42%. Although the time relative uncertainty ranged from 0.1% to 50%, its average was about 3% and was not a noticeable factor.

**Table 1.** Estimate of personal I-131 intake (SD) of eight workers on six months [ $\times 10^3$  Bq]

Worker code	10.01.2015	01.02.2015	14.3.2015	11.4.2015	23.5.2015	20.6.2015	Ave.
W1	1.38 (0.28)	4.30 (0.62)	10.57 (1.48)	6.98 (0.86)	2.16 (0.33)	6.56 (0.79)	<b>5.33</b>
W2	0.84 (0.26)	0.93 (0.10)	3.21 (0.44)	2.19 (0.42)	0.18 (0.03)	0.54 (0.17)	<b>1.32</b>
W3	0.89 (0.24)	1.36 (0.24)	3.68 (0.68)	3.91 (0.57)	1.94 (0.28)	5.46 (0.48)	<b>2.87</b>
W4	0.17 (0.04)	1.77 (0.33)	2.98 (0.61)	3.21	1.80	3.59	<b>2.25</b>

				(0.42)	(0.20)	(0.29)	
W5	0.41 (0.14)	0.86 (0.20)	2.59 (0.87)	2.73 (0.33)	0.36 (0.07)	0.19 (0.02)	<b>1.19</b>
W6	0.43 (0.06)	2.58 (0.34)	4.80 (0.77)	2.54 (0.30)	1.39 (0.20)	3.95 (0.56)	<b>2.62</b>
W7	0.21 (0.04)	2.34 (0.35)	3.43 (0.47)	4.90 (0.69)	2.23 (0.30)	3.90 (0.39)	<b>2.84</b>
W8	0 (0)	0.67 (0.18)	0.57 (0.22)	1.69 (0.30)	1.32 (0.25)	3.86 (0.36)	<b>1.35</b>
<b>Ave.</b>	<b>0.54</b>	<b>1.85</b>	<b>3.98</b>	<b>3.52</b>	<b>1.42</b>	<b>3.51</b>	

On 10 January 2015 (in Table 1), the 8 workers had been exposed to  $^{131}\text{I}$  and had their intake in the range of between  $(170 \pm 40)$  Bq and  $(1,380 \pm 280)$  Bq and the averaged value was 540 Bq, lowest compared to other months. Worker W8 did not present in rooms of interest and his intake was zero. The reason why the exposure in January so low may be the amount of  $^{131}\text{I}$  produced in this month was much less than the next months.

The person who obtained the highest level of personal intake is W1 on 14 March  $(10,570 \pm 1,480)$  Bq. His average intake in six months was 5,330 Bq while the lowest one was 1,190 Bq for W8. The daily intake varies not only from worker to worker but also from day to day. For instance, W3 had received  $(890 \pm 240)$  Bq on 10 January and it jumped to  $(5,460 \pm 480)$  Bq on 20 June.

The values shown in Table 1 are deep lower than the  $^{131}\text{I}$  annual limit intake (ALI) given by ICRP-30 [6]. The highest personal intake for six months estimated in this paper is  $0.033 \times 10^6$  Bq while the ALI of ICRP-30 is  $10^6$  Bq (for a half of year). However, this data set may be useful in minimizing risk of radiation workers.

#### 4. Conclusion

The existing literature reveals the variety of methods used for personal intake estimate of indoor radioactive aerosol materials. Some methods have used modern devices such as GPS system to locate person's position, the others have used published census data to determine the time spent by persons in each ME although they may be located far from the monitoring sites. The recent estimates also often ignore what exactly employed persons who need to present their inhalation exposures.

Personal monitoring using motion detection application can provide detailed insight into a person's individual short-term exposure in a specified ME. In this paper, we applied and improved the indoor method to estimate the inhalation intake of  $^{131}\text{I}$  for radiation workers with respect to minimizing the cost and giving more precise measurements of the real spent time of the target persons. This work is preliminary only, and there is still a shortage of information about the radioiodine concentration



distribution as well as an independent result for comparison. A comprehensive study on personal exposure assessment has been going recently.

It is hoped that the method suggested in this paper can be applied to other indoor environmental media and that this method proposed here will be improved and more clearly documented for estimating personal intake in the future.

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