

Estimation of the total population moving into and out of the 20 km evacuation zone during the Fukushima NPP accident as calculated using “Auto-GPS” mobile phone data

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Abstract: The first objective data showing the geographical locations of people in Fukushima after the Fukushima Dai-ichi nuclear power plant accident, obtained by an analysis of GPS (Global Positioning System)-enabled mobile phone logs, are presented. The method of estimation is explained, and the flow of people into and out of the 20 km evacuation zone during the accident is visualized.

Keywords: Fukushima Dai-ichi NPP accident, evacuation, reconstruction of early internal dose

1. Introduction

The severe accident involving the Fukushima Dai-ichi nuclear power plant (NPP)¹⁾ was triggered by the Great East Japan Earthquake which took place at 14:46:18 on March 11, 2011 (Japan Standard Time — all times hereafter are in the same timezone), and the tsunami which followed. It is estimated that the accident released about 900 PBq in radioactive materials,^{1),2)} of which ~ 500 PBq was iodine 131.²⁾ The effect of radioactive iodine inhalation in the early phase of the accident is of much health concern, especially regarding the thyroids of infants who were near the NPP.

The SPEEDI (System for Prediction of Environmental Emergency Dose Information) simulation published on March 23, 2011 by the Japanese government indicated that infants living close to the NPP may have received a thyroid equivalent dose well in excess of 100 mSv (see Fig. 1).³⁾ The health risk assessment recently published by the World Health Organization (WHO) estimated the highest first-year thyroid dose for 1-year-old infants to be 122 mSv in the town of Namie.⁴⁾ In the WHO report,

doses within a 20 km radius around Fukushima Dai-ichi NPP were not assessed, under the reasoning that “most people in that area were rapidly evacuated”, but it is feared that if there were people who did not in fact evacuate quickly, the potential health risk would have been higher.

The Japanese government issued evacuation orders for people living within a 3 km radius of the Fukushima Dai-ichi NPP at 21:23 on March 11, within a 10 km radius at 5:44 on March 12, and within a 20 km radius at 18:25 on March 12.

A survey of evacuees was conducted for the official report of The Fukushima Nuclear Accident Independent Investigation Commission, The National Diet of Japan (NAIIC), to find out when the residents learned that their residential area was an evacuation zone, and when they actually started to evacuate. The results of the survey (figure 4.2.2-3 of the NAIIC report⁵⁾) indicate that more than 90% of the residents of Futaba, Okuma, Tomioka and Naraha had evacuated by midnight on March 12, but, being outside of the 20 km zone, more than 80% of the residents of Iitate (and presumably many evacuees who fled to northwest of the NPP) were still in the village at midnight on March 14.

According to the source term estimate carried out by the Japan Atomic Energy Agency (JAEA)⁶⁾ and the atmospheric dispersion simulation by the National Institute for Environmental Studies (NIES) based on this source term,⁷⁾ the largest amount of

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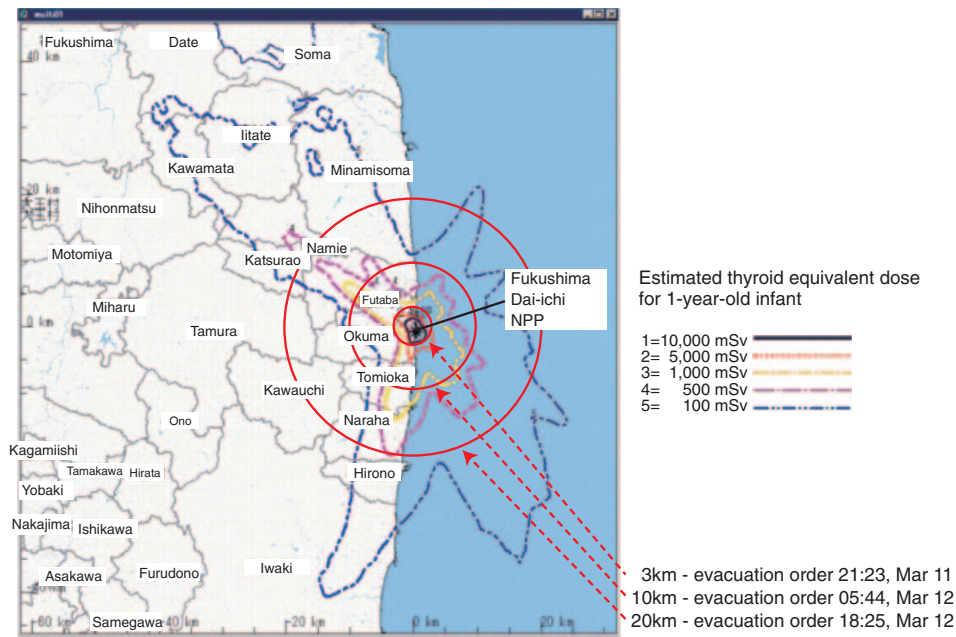


Fig. 1. The thyroid equivalent dose (for 1-year-old infant) contours estimated by the Japanese government using the SPEEDI system. The 3 km, 10 km and 20 km evacuation radii are also shown. Figure adopted from Ref. 2.

iodine 131 was dispersed throughout these towns during the 24 hours beginning at midnight on March 14th and ending at midnight on March 15th. It is therefore of the utmost importance to estimate the number of people present at the time of the worst emissions, and their geographical distribution.

It has recently become known that the “Auto-GPS” mobile phone data (explained below) can be used for this purpose. Although there are certain technical limitations, the data presented in this paper are the first objective assessment of the geographical distribution of Fukushima residents in March 2011.

2. Methods

“Auto-GPS” is a subscription-based service offered by NTT DOCOMO, INC., a leading Japanese mobile phone service provider, which allows subscribers to receive location-specific information and services. Once subscribed, the user’s handset sends the location information obtained by the handset’s internal GPS (Global Positioning System) receiver, along with a unit identification number (uid), to the server at least every 5 minutes. In Fukushima, about 1-in-150 residents (*i.e.*, about 0.7%) subscribe to this service.

ZENRIN DataCom Co., LTD., a major developer and provider of mobile navigation services in Japan, uses the Auto-GPS data provided by

DOCOMO to generate traffic congestion statistics data called “*konzatsu-tokei*”, which is generally used for various marketing surveys.

In the present study, we gridded Fukushima into 250 meter by 250 meter meshes, and counted the number of Auto-GPS-enabled handsets within each mesh every hour, between 0:00 on March 10, and 24:00 on March 18. The uid information was not used, and hence this study is completely anonymous. By multiplying the known ratio of Auto-GPS subscribers to the number of residents in Fukushima to the number of observed handsets, the number of people in each mesh was estimated. When a person was found to have moved from one mesh to another within one hour, we assigned a fractional number to each mesh according to the fraction of time spent within.

The accuracy of the number of people within the 20 km radius derived in this way is estimated to be about ~20% when the total number of people is 10,000. This was estimated by comparing the number of residents in various parts of Japan calculated with the “Auto-GPS” data, with the 2010 population censuses data.⁸⁾ When this number decreases, the estimate becomes less accurate (~50% when the total number of people is 1,000), since the statistical fluctuation inherent in the method becomes more pronounced.

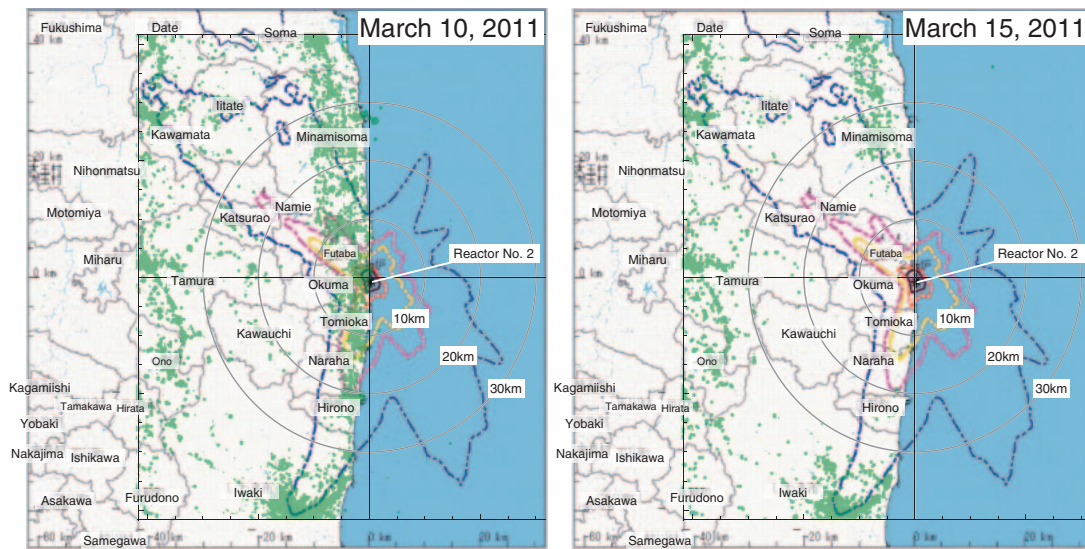


Fig. 2. The 24-hour integrated distribution of people on March 10, 2011 (left) and on March 15, 2011 (right).

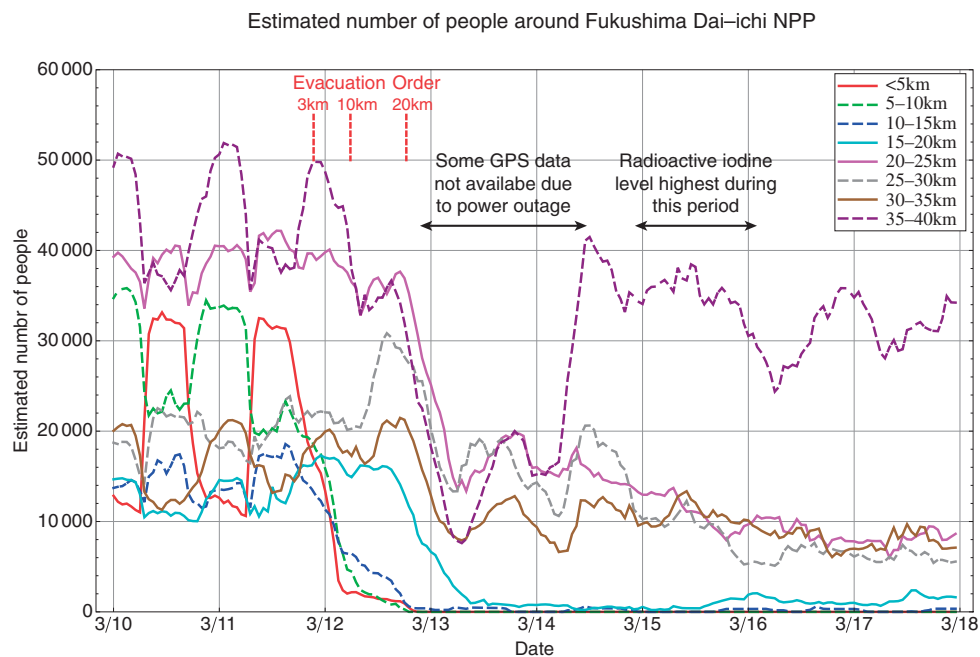


Fig. 3. The estimated number of people for each hour between concentric circles of 5 km increments, centered at the Fukushima Dai-ichi NPP, from March 10, 2011, to March 18, 2011.

3. Results

We show in green dots the locations of people estimated from the Auto-GPS data for March 10, 2011 (a day before the accident) on the left panel of Fig. 2 (integrated for 24 hours) and for March 15 on the right panel.

In fact, we have such data for each hour, based on which we made Fig. 3, which shows hourly estimates of the number of people located in each of the 5 km concentric bands extending from the Fukushima Dai-ichi NPP out to 40 km, from March 10 to March 18, 2011. The timing of the evacuation orders are also indicated.

Figure 3 illustrates the following:

1. On March 10, a day before the accident, the traffic of people to and from Fukushima Dai-ichi is clearly visible (the population within 5 km radius increases during working hours). This demonstrates that the present method can actually track the movement of people. The average number of people within the 20 km radius on March 10 was $\sim 76,000$.
2. After the evacuation orders were issued on March 11 and 12, the residents started to evacuate relatively quickly. See the red (< 5 km), green (5–10 km), dark blue (10–15 km) and cyan (15–20 km) curves, which all show decreasing trends due to the evacuations. Note also that the number of people in 15–20 km (cyan) band momentarily increased around midnight on March 11, due to the arrival of evacuees.
3. The dip visible in even the most distant bands on March 13–14 was caused by the failure of the mobile phone network system due to power outages, which recovered in most of the areas (but not around the Fukushima Dai-ichi NPP) around noon on March 14.
4. The estimated number of people within the 20 km radius when the atmospheric iodine level was believed to be the highest, between midnight on March 14 (after the mobile phone network recovered) and midnight on March 15, is very small, ~ 2000 individuals at most.

4. Concluding remarks

The present study is the first (and probably sole) objectively-derived data able to visualize the flow of people into and out of the 20 km evacuation zone during the Fukushima Dai-ichi NPP accident. The estimated number of people remaining within a 20 km radius of the power plant on March 14–15 is approximately 2,000 at most. It is not possible, however, to infer how many infants were actually in the 20 km region at this time from the present method alone. Correction of count losses due to power outages, which is yet difficult to estimate reliably, was not applied.

Using “Auto-GPS” data, it is technically possible, with the consent of the owner, to trace the movements of each individual handset. Such studies

would reveal in detail the typical routes taken by the evacuees, as well as their speed, stops, and other aspects of their movement, and could greatly help in the reconstruction of early internal and external doses for the population as a whole.

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