REVIEW PAPER OF RADIONUCLIDE MONITORING IN FOOD SAMPLE

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Abstract

The uncontrolled release of radionuclides into the atmospheric and aquatic environments may occur as the result of a nuclear or radiological accident. Monitoring of the accidental release at its source and especially direct monitoring of the environmental contamination with radionuclides is necessary for assessment and application of public protective actions and longer term countermeasures as well as emergency workers' protection. In areas historically contaminated with long lived radionuclides monitoring it is essential to protect the public and substantiation of any radiological incidents. Also, dietary pathways can be contaminated with radioactive materials resulting from natural occurance or man-made applications especially during routine operation, accidents and migration of radionuclides from radioactive waste disposal repositories into the biosphere. Therefore, efforts should be made to determine the presence of radionuclides in a potentially high radiation area especially in operational nuclear facilities. This paper will review the strategies for food monitoring that has been adapted in most countries to obtain baseline data for future reference. Also, this study is discussing the type of food selection commonly collected as sample for radionuclide analysis in different countries over the years. Sampling procedure and analysis also included in this review for better understanding of the analysis. Stakeholders' involvement is considered as an important asset in the establishment of monitoring strategies. As a conclusion, future plans for food monitoring programme in Malaysia are recommended as a preparation to embark on the Nuclear Power Plant programme.

Keywords: radionuclide, contamination, food, monitoring

Abstrak

Pelepasan radionuklid yang tidak terkawal ke persekitaran atmosfera dan marin terjadi akibat dari kemalangan nuklear atau radiologi. Pemantauan bagi pengeluaran tidak sengaja pada sumber terutamanya pemantauan secara langsung pada persekitaran yang mengandungi radionuklid adalah perlu bagi menilai dan memastikan perlindungan masyarakat dan tindakan jangka panjang serta perlindungan kecemasan bagi pekerja. Perlindungan orang awam dan juga kesan dari setiap insiden radiologi adalah satu keperluan bagi kawasan yang mempunyai sejarah kontaminasi radionuklid berjangka hayat panjang. Selain itu, punca makanan terdedah kepada bahan radioaktif hasil dari kejadian alam atau aplikasi buatan manusia terutamanya semasa operasi rutin, kemalangan dan perpindahan radionuklid dari repositori pembuangan sisa radioaktif ke biosfera. Oleh itu, usaha perlu dilakukan untuk memastikan kewujudan radionuklid di kawasan yang mempunyai potensi radiasi yang tinggi terutamanya di kemudahan operasi nuklear. Kertas kerja ini akan meninjau strategi bagi pemantauan makanan yang telah diadaptasi di kebanyakan Negara untuk memperoled data asas untuk tujuan di masa hadapan. Selain itu juga, kajian ini membincangkan pilihan makanan yang dikumpulkan sebagai sampel untuk dianalisa kandungan radionuklid oleh pelbagai Negara sepanjang tahun. Prosedur persampelan dan analisa juga termasuk dalam kajian ini untuk menambah pemahaman. Penglibatan pemegang saham dianggap sebagai asset penting dalam pembentukan strategi pemantauan. Sebagai kesimpulan, perancangan masa depan untuk program pemantauan makanan di Malaysia disarankan sebagai persiapan untuk memulakan program Tenaga Nuklear.

INTRODUCTION

In many years, the impact of radiological health hazard by human activities, especially in the production of energy, research and medical applications of nuclear facilities have intrigued great concern and remarkable interest in the field of radiation protection. One of the main issues that concern the most is food safety. After the Chernobyl nuclear power plant accident on 26 April 1986, large quantities of radioactive substances were discharged to the environment, which eventually settled down in the soil and vegetation. Many individual countermeasures have been developed since the Chernobyl accident to preserve food production [Alexander et al. 2005]. The main aim of the development is to monitor the environment and diet of people who live or work near nuclear sites in order to estimate exposures for those small groups of people who are most at risk from the disposals of radioactive waste. A recent study reported by Nisbet et. al. indicated that around 40 potential management options were exist for evaluating the impact of radiocaesium and radiostrontium contamination of the food chain [Nisbet et al. 2004]. More attentions have been focusing on the concept of ‘from farm to fork’ adapted into researches as an effort to reduce the contamination of foods by concentrating on source-directed measures. Preventing contaminated raw materials from entering the food chain are more effective to ensure the food safety compared to conventional market control. In a radiation situation, the availability of uncontaminated food and food raw materials to consumers and to the entire production chain is a challenge, especially during the growing season [Rantavaara et al. 2005].

Based on study by Arogunjo et. al., contamination of the food chain is resulting from direct deposition of these radionuclides on plant leaves, root uptake from contaminated soil or water and animals that ingesting contaminated plants, soil or water [Arogunjo et al. 2005]. In any accidental releases of radioactivity cases into the environment, a potential of widespread and long-term contamination on the agricultural land need to be suspected and consequently a potential long-lasting impact on food. This situation required the development of the monitoring network in the agricultural field especially in the contaminated area to maintain a safe food produced.

Monitoring programme for foodstuff is important to identify the existence of radionuclides and to obtain the quantitative information on transfer processes. Additionally, evaluation on present, future and sometimes past situations is a possible way to select short-term or long-term counter-measures. The authorities are fully responsible to inform the actual levels of radioactivity or in other words the safety of the foodstuff to the public. Basically, the monitoring programme is focused on long-term, low-level exposure but the programme should meet the requirements of detecting accidents as quickly as possible [Varga et al. 2006].

Therefore, efforts should be made to determine the presence of radionuclides in a potentially high radiation area especially in operational nuclear facilities as a benchmark data to assess transfer factor into the food chain.

DISCUSSION

Food Selections

In Malaysia, especially in Nuclear Malaysia, bioindicators are involved in normal sampling programme to get the radionuclides activities information during the whole year. However, consuming food samples are able to provide data about the specific activity of different radionuclides in different medium, time dependency and spatial distribution of radionuclides to assess ingestion doses and mainly to support decision-makers in the case of accident happen at a radioactive facility.

In Hungary, paper written by Varga et. al. stated that each laboratory in their country has to collect and analyse more than 100 samples per year from various places of the respective region in the frame of the routine monitoring. The samples were taken from harvested products from open-air production and some of consumable parts of plants are measured [Varga et al. 2006]. They focused on daily food intakes such as dairy products, potatoes, vegetables and fruits.

Alternatively, in Nigeria, they highlighted on the main staple foods for radionuclides monitoring which were cereals and starchy tubers. This action was due to the built up of a research reactor at the Centre for Energy Research and Training (CERT) in Zaria in the northern part of the country and a Tandem linear accelerator that is already operational at the Centre for Energy Research and Development (CERD) at Ile-Ife in south-western

Nigeria [Arogunjo et al. 2005].

Some country like Argentina, milk was produced over large areas (approximately 1,000,000 km^2) and collected daily at dairy farms [Desimoni et al. 2009]. Since milk and milk products are important components of human diet, the establishment of radioisotope concentrations will provide meaningful information that will contribute to the knowledge of population exposure and to the setting up of a regional baseline.

Several literature reports are concern about radionuclide transfer from soil to fruit and the other parts of the plant to fruit [Carini and Bengtsson 2001;Green et al. 1997;Monte et al. 1990]. It is a complex process where many interactions involved between biotic and abiotic components and strongly depends on the local circumstances. A study by Oncsik et. al. investigated the transfer of Cs-134 to strawberry after an acute release in the form of wet deposition during the year 2000 [Oncsik et al. 2002]. Leaf-to-fruit, soil-to-fruit and direct fruit pathways were examined.

Materials and methods

a. Sampling procedure and preparation

The primary purpose of this task is to check on the level of radioactivity in food and the environment. This is to demonstrate that the safety of people is not compromise and that doses, as a result of discharge of radioactivity are below the dose limit. Table 1 presented the dose coefficient which are the factors determining the radiation exposure of individual organs and the whole body by incorporated radioactive substances . It is depend on the radionuclide, the incorporation type (inhalation/ingestion), the chemical compound of the radionuclide and the age of the person.

Table 1: Dose coefficient for the calculation of the organ dose or the effective dose due to ingestion of radionuclides

Nuklide	Organ	Dose factor in Sv/Bq		
		< 1 year	7-12 years	> 17 years
Tritium, H-3	Effective dose	$6.4.10^{-11}$	$2.3.10^{-11}$	$1.8.10^{-11}$
Carbon, C-14	Effective dose	$1.4.10^{-9}$	$8.0.10^{-10}$	$5.8.10^{-10}$
Strontium, Sr-90	Bone surface	$2.3.10^{-6}$	$4.1.10^{-6}$	$4.1.10^{-7}$
	Effective dose	$2.3.10^{-7}$	$6.0.10^{-8}$	$2.8.10^{-8}$
Iodine, I-131	Thyroid	$3.7.10^{-6}$	$1.0.10^{-6}$	$4.3.10^{-7}$
	Effective dose	$1.8.10^{-7}$	$5.2.10^{-8}$	$2.2.10^{-8}$
Cesium, Cs-137	Effective dose	$2.1.10^{-8}$	$1.0.10^{-8}$	$1.3.10^{-8}$
Radium, Ra-226	Bone surface	$1.6.10^{-4}$	$3.9.10^{-5}$	$1.2.10^{-5}$
	Effective dose	$4.7.10^{-6}$	$8.0.10^{-7}$	$2.8.10^{-7}$
Plutonium, Pu-239	Bone surface	$7.4.10^{-5}$	$6.8.10^{-6}$	$8.2.10^{-6}$
	Effective dose	$4.2.10^{-6}$	$2.7.10^{-7}$	$2.5.10^{-7}$

A few aspects need to be considered in sampling and measuring radionuclides activities in food samples to achieve the best information about the specific radiological situation. In order to investigate long-term tendencies, the same pattern of monitoring data needs to be produced. Therefore, monitoring schedule has to follow the changes and sometimes the actual consumption-structure too [Varga et al. 2006]. Following are the aspects were taken into account to start a monitoring procedure in agricultural field [Varga et al. 2006]:

- Role of agriculture in the national economy
- Changes in the structure of agriculture and food consumption
- Geographical distribution of production
- Features of territorial units and administrative units

- Organisation of public administration
- Capacity of radiochemical laboratories
- Obtaining a reasonable data set for statistical evaluation

Referring to these aspects, researchers in Hungary collected samples from harvested products from open-air production. However, in Nigeria, the food samples were purchased from farmers in parts of Nigeria where they are largely generated [Arogunjo et al. 2005]. Carini stated that, the food processing can greatly decrease the radioactive content of final edible products; therefore neglecting the losses during food processing can lead to overestimation of the calculated dose [Carini 1999]. In an area where raw foods are staple edible products, omitting contributions from all pathways can lead to underestimation of the average food concentration.

A systematic study of the gamma-emitter radionuclide content (natural and anthropogenic) is widely consumed in Argentina. Samples coming from different productive regions of Argentina and neighbouring countries were analyzed. Liquid milk samples were collected from 31 commercial farm cow and ranch cattle over a long time period from 2000 to 2007. According to the literature, there are no climatic anomalies were registered during the collection period. Also natural phenomena or nuclear accidents that may have an impact on redistribution of radionuclides on the grass eaten by the cows producing milk did not occur. Therefore, they used the monitoring results as a baseline for gamma-emitter radionuclide content in Argentinean milk. Table 2 shows the age groups and annual dietary intakes for various food classes and the total, calculated from data in the EPA report .

Table 2: The annual dietary intakes for various food classes and the total, calculated from data in the EPA report

Food class	**Age group**									
	< 1	1-4	5-9	10-14	15-19	20-24	25-29	30-39	40-59	60 & up
Dairy (fresh milk)	208 (99.3)	153 (123)	180 (163)	186 (167)	167 (148)	112 (96.5)	98.2 (79.4)	86.4 (66.8)	80.8 (61.7)	90.6 (70.2)
Egg	1.8	7.2	6.2	7.0	9.1	10.3	10.2	11.0	11.4	10.5
Meat	16.5	33.7	46.9	58.4	69.2	71.2	72.6	73.4	70.7	56.3
Fish	0.3	2.5	4.0	4.6	6.1	6.8	7.6	7.1	8.0	6.3
Produce	56.6	59.9	82.3	96.0	97.1	91.4	99.1	102	115	121
Beverage (tap water)	112 (62.3)	271 (159)	314 (190)	374 (226)	453 (243)	542 (240)	559 (226)	599 (232)	632 (268)	565
Misc	2.0	9.3	13.3	14.8	13.9	10.9	11.9	12.5	13.3	13.0
TOTAL ANNUAL INTAKE (kg/y)	418	594	726	832	905	922	937	965	1001	930

a) Computed from daily intake values in grams per day provided in (EPA 1984b). The total annual intakes are rounded to nearest 1 kg/y
b) Fresh milk is included in the dairy entry, and tap water used for drinking is included in the beverage entry. The total annual intakes (kg/y) for fresh milk and tap water are also given separately in parentheses.

Sampling is focused on nuclear sites licensed by the HSE under the Nuclear Installation Act, 1965 (United Kingdom-Parliament, 1965) in the UK [Government October 2010]. Other than to fulfil statutory duties under the Radioactive Substances Act, 1993 (United Kingdom-Parliament, 1993) and the Environmental Permitting (England and Wales) Regulations, 2010, an additional sampling is conducted in areas isolated from nuclear sites to establish the general safety of the food chain, drinking water and the environment. The results are used as background data to compare with the results from around nuclear sites to show the variation of levels across in the UK. Monitoring programme is still on-going for the Insular States and Northern Ireland to take account the possibility of long-range transport of radionuclides due to Chernobyl accident.

Channel Islands monitoring is conducted on behalf of the Channel Island States, consisting of sampling and analysis of seafood, crops and indicator materials [Government October 2010]. This is to measure the potential effects of UK and French disposals into the English Channel and historic disposal of solid waste in the Hurd Deep. Furthermore, monitoring on terrestrial foodstuffs is conducted on behalf of the Department of Local

Government and the Environment in the Isle of Man. Samples were taken are analysed for Chernobyl, Sellafield and Heysham related radionuclides, also monitoring of seafood is directed at the effects of disposal from Sellafield. Additionally, the Northern Ireland programme is directed at the far-field effects of disposals of liquid radioactive wastes into the Irish Sea [Government October 2010].

b. Sample analysis

In most countries, samples were analysed by Gamma Ray Spectrometry using a Canberra vertical high-purity coaxial germanium crystal (HpGe) with NaI (Tl) detector. To assure the accuracy of the quantitative measurements, the detector are calibrated with adequate energy and efficiency calibration of the system according to standard sources from the International Atomic Energy Agency (IAEA), Vienna [Arogunjo et al. 2005;Varga et al. 2006;Jibiri et al. 2007]. The concentrations of the different radionuclides were calculated based on the detector efficiency and energy calibration measurements in the energy range from 100 to 1500 keV [Akinloye et al. 1999]. In some country, for example in Hungary, they used Gross-alpha measurement to measure ashes food and plant samples. Gross-alpha measurement is integrated by ultra low-background alpha-beta counters operating with P10 gas. They also used liquid scintillation technique to measure tritium content in leafy plants and water of Danube, Hungary.

c. Intercomparison analysis

In general, intercomparison analysis are organised for the network regularly, once or twice a year. Normally natural samples were chosen, from which a large amounts of samples were collected and their activities were about or significantly above the typical natural levels. The samples were distributed among the laboratories after homogenisation and testing were completed. Participation in the intercomparison has been mandatory for the stations of the network in Hungary. In 2000, a proficiency test for 90-Sr was managed using a certified reference material originating from the National Office of Measures, in this case the suggestions of Analytical Quality Control Service (AQCS) of International Atomic Energy Agency (IAEA) were kept in view [Varga et al. 2006]. In other words, the intercomparison analysis is important to assure the quality of management system for the laboratories. In addition, the annual meetings are organised for the network, where each problem is discussed, some exercises are held and solutions are harmonised.

Involvement of stakeholders

The involvement of stakeholders in radionuclide monitoring for food is important to develop an interactive group in providing expert views, exchanging informations and recommending intervention precautions with practicable measures. This will allow effective information sharing and the provision of true, credible and consistent information to all interest groups of the food chain [Rantavaara et al. 2005]. The importance of stakeholder involvement was experienced by UK Agriculture and Food Countermeasures Working Group in the development of recovery strategies while experiencing environmental release of radioactivity. A large number of potential countermeasures have been identified including radioecological effectiveness, technical feasibility, capacity and cost involved, radiological and environmental impact, and social acceptability [Alexander et al. 2005]. These successfully identified countermeasures were applicable and acceptable for the UK. Also, the working group has examines in detail all the specific issues that are likely to present major challenges should any nuclear incident affecting the UK.

The stakeholder involvement in Hungary helps coordinating the work of the network, providing guidance and technical support, and helping in every field of work. The monitoring schedule is revised yearly according to the changes in the structure of food consumption and agricultural production [Varga et al. 2006].

Whereas in Finland, stakeholder group representing the food supply chain was invited to take part in the discussions on sustainable restoration of food production systems after radioactive contamination. They also involved in the evaluation of the practicability of rural countermeasures. This project was carried out under the network project FARMING (Food and Agriculture Restoration Management Involving Network Groups).

CONCLUSION

Various food monitoring studies, including food selections, sampling procedure and analysis were compiled from different organisations and countries were presented in this study. It can be concluded that this measure is important to ensure constant monitoring of public exposure to radionuclides and that most of the countries in the world are implementing it as a safety precautions should a nuclear incidents occur. The involvement of stakeholders was proven to be significant in ensuring a smooth and efficient operation in both the food monitoring processes and guideline development procedures.

In Malaysia, food monitoring measures are yet to be implemented. Measurement of natural background and radioactivity in food products especially agricultural products need to be established in Malaysia as baseline data of natural radiation levels. The measurement will help in the development of standards and guidelines for the usage and management of these materials [Lee et al. 2009]. The regulations should ensure the safety and quality of food and feedstuff. Furthermore, stakeholders should cooperate to merge the findings of the science, practice and lessons learned from the events that occurred worldwide. Malaysia needs to evaluate the strategies adapted worldwide in order to establish a well documented baseline data for future needs.

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