Between stable iodine prophylaxis and evacuation

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Introduction

Iodine prophylaxis is a countermeasure that can protect the thyroid against irradiation in the event of exposure to radioactive iodine that might result from an accident to a nuclear power plant. In these circumstances radio-iodines are an important potential hazard, especially to children as the Chernobyl accident has so clearly demonstrated. Some 2000 cases of thyroid cancer in those who were children at the time of the accident have been confirmed as resulting from exposure to radio iodine.

Why is iodine so important in a nuclear accident?

Iodine is a very volatile element and so at reactor operating temperatures is a vapour and diffuses rapidly in the fuel pin and release starts as soon as the pin containment is breached. If there is no secondary containment and the primary containment is breached, release to the environment is inevitable. The Chernobyl accident illustrated how far radio-iodine could travel after release. Excess cases of childhood thyroid cancer have been observed more than 500 km from the site of the accident.

Why are children so much more at risk than adults?

There are two reasons, the first is that the thyroid is a small gland, weighing about 1 gm at birth and 20 grm for the adult. The thyroid avidly absorbs and retains iodine once iodine has reached the blood. The radiation dose is the energy absorbed per unit mass of tissue and, therefore, the dose per decay of ^{131}I in the thyroid will be higher the younger the child.

The second reason is that the child's thyroid is much more sensitive per unit of dose, to the carcinogenic effects of ionising radiation, than that of the adult. This is probably is due to the biological function of the thyroid in controlling growth. normal thyroid cells have little capacity to divide further after adulthood is reached.

Although inhaling iodine from the cloud can be an important source of ^{131}I in an accident much larger populations are generally at risk from ingesting ^{131}I in milk.
Since the child and adult intakes of milk are roughly equal, children get much higher doses to the thyroid as well as being much more sensitive to the effects of the exposure.

How should we respond to a nuclear accident?

Of course a nuclear accident is about much more than protecting children from radio-iodine, but as iodine is almost always going to be present in fallout from an operating reactor, it represents a typical 'microcosm' embedded in the much larger problem that an accident such a Chernobyl poses.

There are three important factors to consider, namely,
- What are the important routes of exposure
- What are the important factors in the exposed populations
- What means do we have at our disposal to minimise such exposures

What are the important routes of exposure?

This depends on location in relation to the source of the exposure and certain behavioural characteristics. Close to the source (say within 5 km) inhalation could be a serious hazard but it lasts only while the released radioactivity is in the air. At greater distances (say >20 km) ingestion will be the greater threat, particularly where fresh milk produced locally is consumed, because radioactivity deposited on pastures can enter the food chain. This threat lasts for a few months (in the case of iodine but many tens of years for radio-caesium) but radioactive decay and weathering of the pasture reduces the level of fallout with time.

What are the important factors in the potentially exposed populations?

Age is the most important factor because of the size of the thyroid. Gender is also a factor because of pregnancy (foetal thyroid activity starts at about 3 months post fertilisation) and lactation status. (Females are also about 3 times more sensitive to the carcinogenic effects of radiation on the thyroid).

How can such exposures be minimised ?

There are five potential countermeasures that can be taken to reduce the exposure of populations to radio-iodines. They are as follows :

- Evacuation
- Sheltering
- Food controls
- Agricultural controls
- Stable Iodine Prophylaxis

Rationale for implementing countermeasures

The ICRP recommends that countermeasures should only be introduced if they carry a net benefit in terms of the dose they can avert. This means that it is not only the effectiveness in averting dose, but also the risks entailed in taking the countermeasure that need to be considered. Thus, in effect, a cost benefit analysis has to be performed in respect of each countermeasure.

Countermeasure	Benefits	Risks and costs
Evacuation	Immediate removal from the threat	Accidents, exposure during the process, social disruption, policing etc.
Sheltering	Reduced exposure to inhalation hazard	More-or-less risk and cost free but social implications if prolonged
Agricultural controls	Reduces amount of radio-iodine entering the food chain	Risk free but stored fodder required while cattle are off pasture
Food controls	Reduces uptake of radio-iodine by the thyroid from ingestion	Few risks but milk has to be thrown away and there are administrative costs in redistribution of supplies
Stable Iodine Prophylaxis	Complete blocking of radio-iodine uptake for about 2 days if given at the right time.	No risk to children, some adults and neonates are at or potentially at, risk. Tablets have to be made stored and distributed.

Table 1. Comparison of the benefits of countermeasures with their risks and costs.

Evacuation should, therefore, be used close to the source and preferably before the exposure starts, i.e. as a pre-emptive action. It is essential for high-risk groups. Sheltering is appropriate also close in, but is less effective but can be used in conjunction with other measures, such as stable iodine prophylaxis. It may be preferable to evacuation if there is a risk of exposure during the evacuation. Agricultural controls are a good measure at all distances to reduce ingested doses if sufficient stored fodder is available. This may not be the case at all times of the year. Food controls are an effective measure at all distances to reduce ingested doses. Stable iodine prophylaxis is a good short-term measure close to the source of the exposure. At greater distances it can also be used for children for a few days only, while other measures are put in place.

It has to be recognised that all these countermeasures affect people

All these actions apply to people and they should understand what is being done and why. Parents may be separated from their children, specific instructions apply such as "children should take tablets but not adults", some milk supplies are safe to drink, some are not, etc., are some of the issues that may arise and cause concern and anxiety, in themselves public health detriments. Thus, public education is an important aspect of an effective response to an accident. Ideally it should be ongoing and not wait until the accident happens.

What has been learned about the optimum response?

- That to protect public health from even just radioactive iodine in the event of an accident involves a complex web of factors to be considered. That optimum response will be "case specific", depending on many factors that cannot be anticipated. Therefore, each accident has to be considered in its particular context.
- That public health expertise is essential in developing the case specific response.
- That the necessary administrative structures to coordinate the response are in place, regularly reviewed and tested with exercises.
- That public education is essential if the psychosocial effects are to be minimised.

Are these lessons applied in practice?

In some countries the answer is YES, but in many it is NO. Adequate preparedness requires a substantial investment in planning, exercising, expertise and public education, in a highly co-ordinated way, between many players.

However, the cost of not investing in this infrastructure can be great. In Ukraine since Chernobyl the costs incurred by the accident were at least $5.6 billion between 1992 and 2000. The collective dose to 2055 is estimated to be 6,000 person.Sv. That is $93,000/ person.Sv. The full cost, including 1986 to 1992 and costs still to come, may well be closer to $200,000/personSv

Iodine will not be the only problem

As stated earlier protection from radioactive iodine is a 'microcosm' of a much greater issue. We have seen the results of exposure to iodine after Chernobyl. It is far from certain that we have seen all effects that are to come, or indeed, that are present now, in the exposed populations.

Summary

Responding to reactor accidents in order to protect public health is a complex matter involving many disciplines, but most notably, public health expertise. The most effective response will be that tailored to the specific circumstances of the accident, carried out within a well-coordinated framework that is subject to regular review and exercising. As the threat of exposure to fallout does not respect national borders an international coordinating role has to be fulfilled.