Is there an inexpensive way to mitigate the risk of thyroid cancers associated with exposure to Iodine 131 after a nuclear accident?

Abstract:

On March 11, 2011, Japan was struck by an earthquake and tsunami, followed by a nuclear disaster at the Fukushima Daiichi Nuclear Power Plant. The total amount of radioactivity released into the atmosphere from the nuclear power plant was approximately one-tenth as much as was released during the Chernobyl disaster. Releases of Iodine 131 are of particular concern as evidence suggests they are responsible for increases in thyroid cancer incidence rates in Chernobyl. Identifying the main pathways of the uptake of Iodine 131 and effective ways to mitigate them could reduce the incidence rates of thyroid cancer following releases of radioactive Iodine. This would be of great benefit to those residing near any of the 430 nuclear power plants worldwide. It could also serve to reduce the strain on health services for decades after the event.

Introduction:

On March 11, 2011, Japan was struck by an earthquake and tsunami, followed by a nuclear disaster at the Fukushima Daiichi Nuclear Power Plant. The total amount of radioactivity released into the atmosphere from the damaged nuclear power plant was approximately one-tenth as much as was released during the Chernobyl disaster, prompting the International Atomic

Energy Association to classify the nuclear disaster as one of the most dangerous circumstances in the era of modern atomic energy - Level 7 on the International Nuclear and Radiological Event Scale (INES). [1]

The Japanese government declared a nuclear emergency, and local authorities issued instructions specifying that people within a 20 km zone around the Fukushima Daiichi nuclear power plant had to evacuate the area. In addition, people living between 20 and 30 km from the site were urged to evacuate on March 25. [3]

The radiation released consisted mainly of Tellurium 132 (half life 77hrs), Tellurium 131 (half life 24.8 min) and their respective progeny Iodine 132 (half life 2.26 hrs.), Iodine 131 (half life 8.05days) as well as Cesium 134 (half life 2.06yrs) and Cesium 137 (half life 30yrs). [2]

The radioactive isotope of particular concern immediately following a nuclear incident is Iodine 131 as the human thyroid has a unique ability to concentrate and bind radioactive Iodine, so that it receives a dose 500–1000 times higher than the rest of the body. [4] It has been proven that isotopes of Iodine are responsible for increased thyroid cancer rates in those exposed as a result of the nuclear disaster in Chernobyl in 1986. Iodine 131 can be introduced to the body by consuming foods or liquids with traces of radioactive Iodine in them, by inhaling radioactive particles, or by absorption through wounds in the skin. Water sources are often contaminated due to radioactive particles settling in catchment areas thereby providing a pathway for Iodine 131 to enter the body as citizens in a disaster area have no choice but to drink tainted water.

A need exists for an efficient means of preventing Iodine 131 from entering the body and being stored by the thyroid, and also treating affected water or finding an alternate supply in the aftermath of a nuclear incident.

To find a means of reducing the incident rate of thyroid cancer following a nuclear disaster would be of great benefit to anyone residing near any of the worlds' 430 commercial nuclear power stations operating in 31 countries. [5] It may also reduce the strain on health services by reducing the need for treatment of thyroid related illness for decades after the incident.

Thyroid Cancer following exposure to Iodine 131

Analysis of results after the Chernobyl incident showed not only a significant increase in incidence of thyroid cancer over time [3] (Figure 1), but also a strong link between age at exposure and the risk of later developing thyroid cancer. [4]

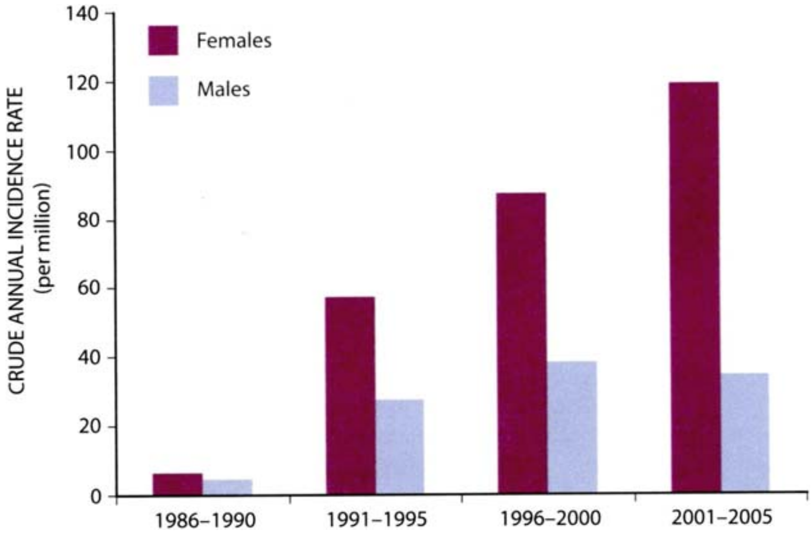

Figure 1. *Annual incidence rate per million of thyroid cancer following the Chernobyl accident in 1986. (Fushiki, 2012)*

As can be seen in Figure 2 there is a higher occurrence of thyroid cancers in those exposed at earlier stages of life.

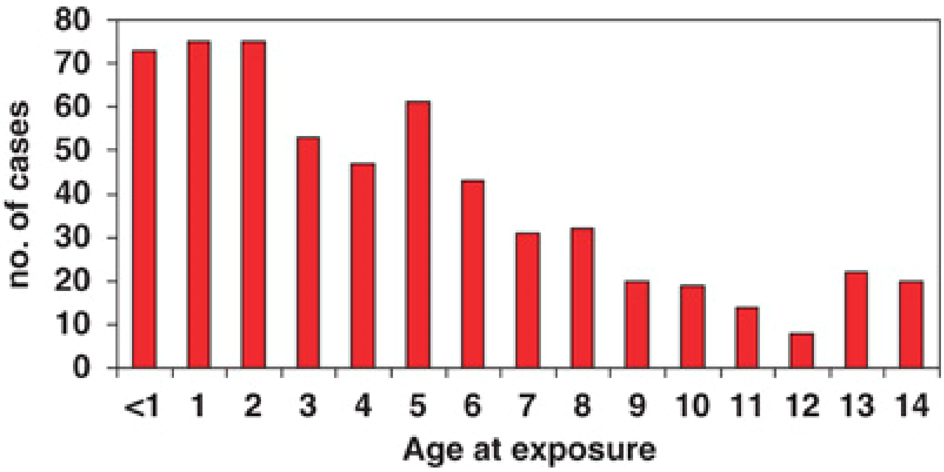

Figure 2 *Age at exposure and occurrence of thyroid cancer. All childhood cases observed in Belarus between 1987 and 1997 (Williams 2009)*

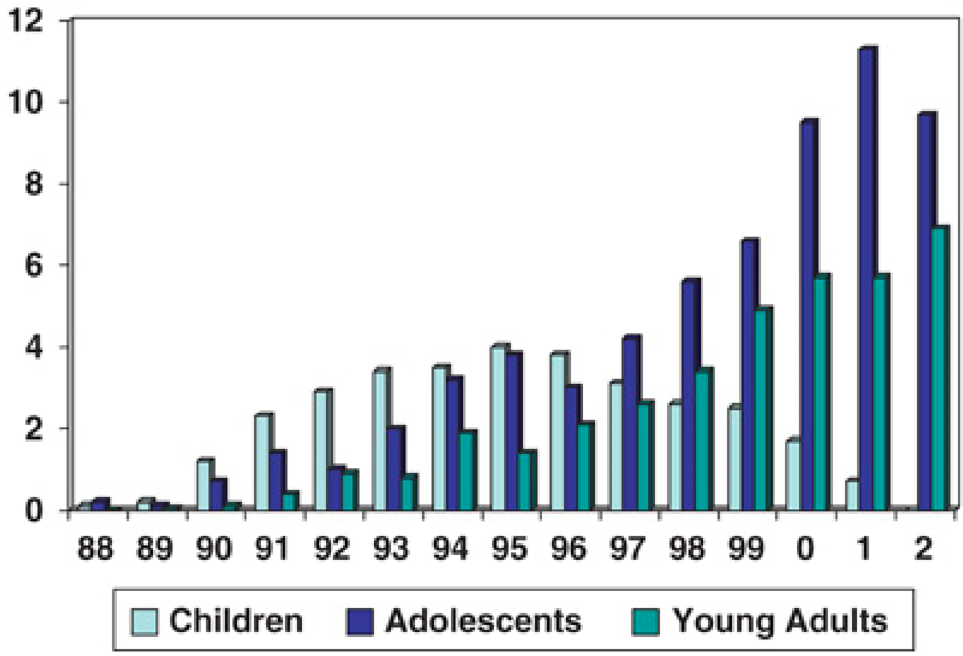

Figure 3 *Change in incidence (per 10^5) of thyroid cancer over time after the Chernobyl accident in 1986. Children aged <9, Adolescents aged 9 – 14, Young adults aged 14 – 19. (Williams 2009)*

Figure 3 shows the change in incidence rate (per 10^5) of thyroid cancer since the Chernobyl disaster in 1986. It indicates that as the number of cases concerning “Children” falls there is an increase in the number of cases concerning “Adolescents”. This graphically illustrates the link between age at exposure and the likelihood of developing thyroid cancer later in life. It also shows that there is a decreased risk for those exposed to Iodine 131 as adults. There are two possible reasons for this; 1) the main route through which radioactive Iodine was ingested after the Chernobyl nuclear incident was through milk – either cows milk or human breast milk. Both a Human breast and a cows udder contain a gland called the Mammary epithelium that concentrates Iodine. Milk forms a much higher proportion of the diet in young children than in adults. Therefore, children in effect have a higher chance of ingesting radioactive Iodine.[6] 2) the thyroid in young children tends to concentrate and bind iodine more effectively, as the thyroid grows relatively rapidly during the earlier stages of life. By the end of adolescence, the growth rate is very low, and during most of adult life, only one in every 1000 cells are in cycle at any one time making the thyroid mass relatively constant, meaning the thyroid is less likely to concentrate and bind Iodine.[7]

Possible Iodine 131 Mitigation Strategies

Potassium Iodide Tablets.

A stable form of Iodine (Potassium Iodide) can be used to flood the thyroid with non-harmful Iodine and therefore prevent the storage of harmful Iodine (Iodine 131). However, the timing of when the Potassium Iodide is administered has a large effect on how successful it is at blocking the uptake or storage of the harmful Iodine 131. [8]

This can be seen in Figure 4 where a “control” that has been administered no Potassium Iodide, is compared to one that has been administered Potassium Iodide, at various time intervals prior to being exposed to Iodine 131. The graph then models the activity of Iodine 131 at time intervals after the exposure, and therefore the protective effect of Potassium Iodide can be deducted.

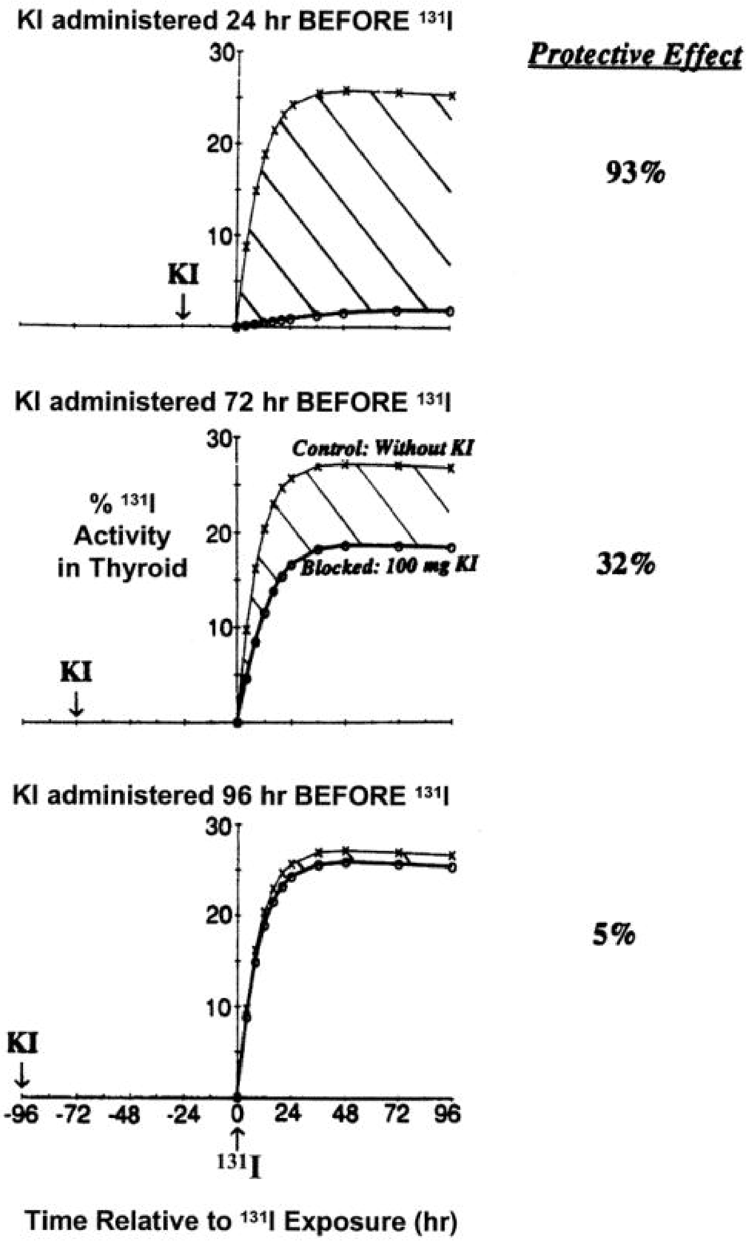

Figure 4 *The protective effect of administering Potassium Iodide at various times prior to exposure to Iodine 131. (Pat et al., 2000)*

In addition to the above figure, figure 5 shows further tests concluded that Potassium Iodide administered up to 48 hours ***before*** exposure to Iodine 131 can almost completely block thyroid uptake of Iodine 131 and therefore greatly reduce the amount of Iodine 131 that the thyroid absorbs.

Potassium Iodide administered 96 hours or more ***before*** exposure to Iodine 131 has no significant protective effect.

In contrast, Potassium Iodide administered just ***after*** exposure to Iodine 131 has a smaller and rapidly decreasing effect on the amount of Iodine 131 stored by the thyroid.

If Potassium Iodide is administered 16 h or later ***after*** exposure to Iodine 131, it will have little effect on the amount of Iodine 131 stored by the thyroid and therefore little or no protective effect in relation to developing thyroid cancer at a later stage.

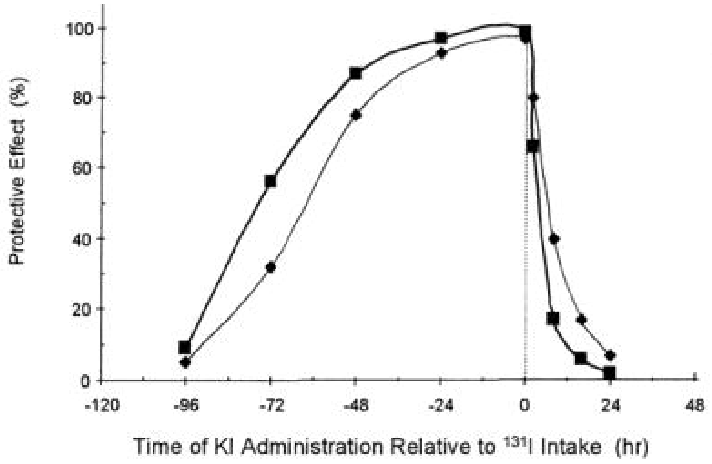

Figure 5 *Protective effect of administering Potassium Iodide at different times relative to Iodine 131 exposure at 0 hours. (Pat et al., 2000)*

The potential benefits of taking Potassium Iodide in the situation of a radioactive release also need to be compared to the possible side effects which include: Hypersensitivity reactions, gastric irritation, diarrhoea and Iodism (large doses).

There is also positive evidence of human fetal risk, but according to Medical Information Management Systems, the benefits from use in pregnant women may be acceptable despite the risk (e.g., if the drug is needed in a life-threatening situation or for a serious disease for which safer drugs cannot be used or are ineffective). [10] It will be difficult to gauge the effect that the administering of Potassium Iodide Tablets has had in relation to the Fukushima incident as they were given 2 days after the major release of radiation into the atmosphere from the Fukushima Daiichi Nuclear Power Plant. [13] The effective management of exposure to Iodine 131 through the use of Potassium Iodide Tablets relies heavily on the provision of correct information by authorities concerning the release of radionuclides to ensure the administering of tablets is performed in a timely fashion.

Milk Substitutes:

As Milk has been identified as a major pathway for children following an atmospheric exposure to Iodine 131, and that both human breasts and cows udders have a gland that in effect concentrates Iodine, formula style milk substitutes could be used in the event of a nuclear disaster. This does remove the possibility that Iodine 131 would be ingested via a natural milk pathway, however, care would need to be taken to ensure that the water used to create a formula style substitute was not contaminated as was the case with much of the water supply following the Fukushima accident. [9]

Uncontaminated Water:

Due to latent weather conditions at the time of venting radiation from the Fukushima Daiichi plant, high concentrations of Iodine 131 and other radionuclides were found on land surfaces and vegetation in the catchment areas for drinking water sources. Levels found were higher than 100Bq/L, which is the guidance level for infants. But considered safe for adults who have a guidance level of 300 Bq/L. [11]

Some individuals in Fukushimas' emergency response community recommended the boiling of tap water after the incident in order to remove harmful Iodine 131 and therefore make it safe to drink.

Tap water samples were collected on 27 March 2011 from the Chiba prefecture which is located approximately 220km's from the Fukushima Nuclear Power Plant as shown in Figure 6:

Figure 6 *Map of Japan showing where water samples were taken in relation to the Fukushima Nuclear Power Plant. (Tagami et al., 2011)*

The samples were then boiled for a period of 5 – 30 mins then cooled for analysis. The Iodine 131 concentrations were measured, then before and after boiling concentrations compared. It was found after plotting water concentration (volume before boiling/volume after boiling) against Iodine 131 concentration (I131 counts boiled water/ I131 counts initial water) (Figure 7) that there was no reduction in the concentration of Iodine 131 due to vapour loss as a result of boiling the water. It showed that in fact, by boiling the water, due to the vapour loss of the water, the concentration of Iodine 131 increased (Figure 8). As a result, to consume contaminated water that had been boiled, or indeed to make a milk substitute using the boiled water, you would increase your Iodine 131 intake.[2]

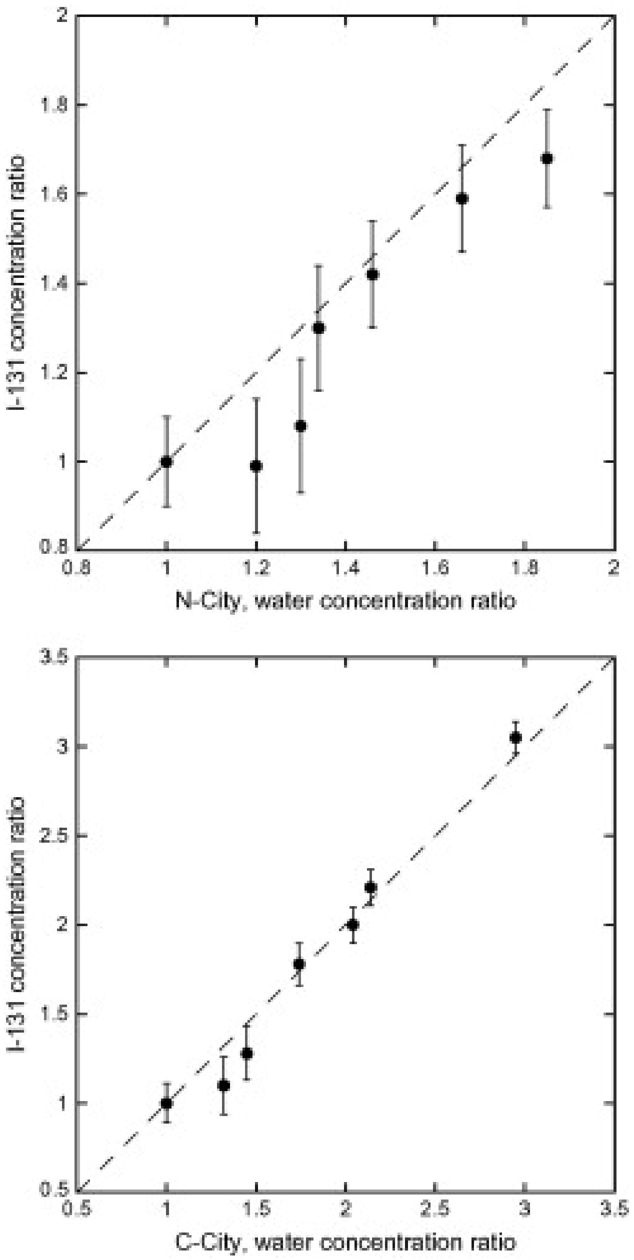

Figure 7 *Water concentration ratio plotted against Iodine 131 concentration ration after boiling tap water. (Tagami et al., 2011)*

	1 min	5 min	10 min
Run-1	1.03 ± 0.07	1.27 ± 0.04	
Run-2		1.02 ± 0.08	1.32 ± 0.10

Figure 8 *Comparison of I-131 concentration ratios after boiling tap water for 1, 5 and 10 min (initial water = 1). ± shows counting error. (Tagami et al., 2011)*

Two other methods of purification were also tested as part of this experiment. 1) Two commercially available water purifiers utilising activated carbon and hollow fiber membrane technology, and 2) a reverse osmosis filter. The experiment concluded that the reverse osmosis filter removed more than 95 % of harmful Iodine 131, while there was no clear reduction of Iodine 131 using the activated carbon water purifiers.

Some of the disadvantages of a reverse osmosis filter are that it treats, and yields, on average only 5 – 15% of the water going into the system.[12] Another disadvantage is the cost, however, they are gradually making their way into homes across the globe.

A second option for ensuring the integrity of drinking water would be to only drink from sealed bottles of water, which could be provided in emergency situations via military drops to those unable to reach an evacuation centre.

Conclusion:

In order to reduce the incidence of thyroid cancer after a nuclear disaster, there are many things to consider. Firstly, that those under the age of 18 have the highest incidence rate of thyroid cancer subsequent to being exposed to the radionuclide, Iodine 131, and as such are those least likely to be able to make the most effective decisions regarding their own welfare. Therefore it falls to those outside of this age bracket, and in fact, those least likely to be affected by exposure to Iodine 131, to make effective decisions and to take the most appropriate action in securing the future welfare of those not able. Evidence suggests that the administering of Potassium Iodide has been proven in tests to block almost the entire uptake of Iodine 131 by the thyroid if given up to 48hrs prior to being exposed to the harmful radionuclide. This can be an effective tool in reducing thyroid cancer rates but needs three parameters to be met to operate successfully as a best practice tool:

1. An effective education program designed to inform residents within a certain radius of any of the 430 Nuclear Power Plants in the world of the benefits of administering Potassium Iodide earlier rather than later, and the limited risks associated with repeat administration.
2. A store of Potassium Iodide in each home as is done in some countries such as France. [14]
3. A government with a culture based on delivering timely and accurate information as was often not the case with the Fukushima incident.

Research has shown that milk substitutes and formulas effectively stop the ingress of the radionuclide Iodine 131 via the milk pathway provided the water is not contaminated. It is suggested that these substitutes should be kept on hand in homes and used as a matter of course and included as part of the aforementioned education program.

Since Iodine 131 is short lived, if people had stopped giving locally supplied contaminated milk to children for a few months following the Chernobyl accident, it is likely that most of the increase in radiation-induced thyroid cancer would not have resulted. [15]

The availability of fresh uncontaminated drinking water in the home would negate a lot of the need to leave shelter and risk further contamination from other radionuclides. Evidence suggests that the most effective means of providing uncontaminated water is via reverse osmosis water purification devices. A best practice solution could be the implementation of these systems in homes within a certain radius of a Nuclear Power Plant.

The implementation of the aforementioned suggestions could provide tremendous benefit in managing the incidence of thyroid cancers after a nuclear accident. Decreasing the incidence of thyroid cancers would also serve to reduce the strain on health services for decades after an event.

Continued monitoring of the Fukushima situation is imperative to further the understanding of nuclear fallout and its affect on health, however, due to the delay in administering Potassium Iodide Tablets, the results should not be indicative of the effectiveness of this as an inexpensive means of mitigating the uptake and storing of Iodine 131 in the thyroid.

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