Comparing Fukushima releases with Chernobyl
An Update for the 1st Anniversary

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1. Background

Immediately after the explosions at the Fukushima site I was interviewed by the BBC together with a nuclear expert, Prof Ian Fells (http://youtu.be/4S2qgTrqR6A). I said then that from what I could deduce just from seeing the videos of the explosions, it seemed that the pressure vessels were breached and that the releases would be comparable with or worse than Chernobyl. At that time, Fells and others (Grimston, Wakeford) were reassuring the world that the releases were not as bad as those at 3-Mile Island .

In the weeks that followed, a succession of nuclear industry apologists appeared on TV and Radio comparing Fukushima and Chernobyl. Even when eventually the IAEA conceded that the two were comparable, in that they were assigned the same highest number on the nuclear accident scale we were still being told, and still are being told, that the releases from Fukushima are about $1/10^{th}$ of the releases from Chernobyl. And in the weeks that followed I disappeared from the BBC as the Nuclear Industry Media Mafia rapidly took control but I was interviewed regularly by Russia Today and maintained my position that the affair was worse than Chernobyl.

This was patently obvious from all the data that was appearing. And this is important. The reason is that if, as is still maintained, the contamination is $1/10^{th}$ that from Chernobyl, it can be argued by those who say there were no health effects from Chernobyl, that there will be even less than no health effects from Fukushima. In fact, $1/10^{th}$ of no health effects. And that is exactly what is being argued by various nuclear industry apologists and controllers of information, notably Wolfgang Weiss ex IAEA and UNSCEAR and now it seems in charge of the WHO study of the health effects in Japan. But also many others, including John Boice in the USA and Lars Eric Holm in Sweden. So the time has come, one year after the event and after a great deal of measuring of radionuclides has occurred by many scientists, including me, to provide an update. This is made more simple by the recent publication by the Norwegian team of air modellers of Stohl et al whose paper has eventually been published (Stohl et al 2012).

But first let me describe my own findings, which I calculated on 31^{st} August 2011 and presented on the website of the Low Level Radiation Campaign. The reason I did this was because I had been asked, in the course of my discussions in the RADSAFE system of Health Physicists, to say how much radioactivity came out of Fukushima. I said about 10^{19} Bq. The RADSAFERS fell about laughing and the insult rate increased rapidly. Actually I have been banned from the RADSAFE list now as they are unable to deal with reality. But then at the time I went and made some calculations and became interested in the problem. There are two sides to the problems of comparing Chernobyl with Fukushima. There is not only the assessment of the releases from Fukushima, but there is also the assessment of the releases from Chernobyl.

2. My August 2011 calculations

I took various estimates of the releases from Chernobyl. It must be understood that the lies and evasions that occurred after Fukushima were only a repeat of the lies and evasions that occurred after Chernobyl. In fact the Fukushima lies and evasions were far worse. We must distinguish four periods in the assessment of releases from

Chernobyl. I show these below in Table 1 and Table 2 where a number of values are given from different sources for the Chernobyl releases. I also include my estimate of the total Caesium-137 inventory of the Chernobyl No 4 reactor, based on the inventory of a 1000MW reactor assuming burn up of fuel over 2 years and based on tables and information given in Eisenbud and Gesall 1998, the standard work.

Table 1. Requirements for distorting the levels of release from Chernobyl

Period	**Requirement**	**Result**
Immediately after accident	Soviets want to minimise release;	Releases talked down
Radioactivity measured in west	Everyone wants to minimise effects	Releases talked down
Unexpected increases in cancer and other effects	To keep the risk model intact, releases have to increase	Releases increased
Fukushima comparisons	Releases need to be high to make Fukushima low	Releases increased

Table 2 Various estimates of the Cs-137 releases from Chernobyl

Source	**Date**	**Estimate**
Sumner et al	1991	3.8 E+16
Savchenko UN	1995	3.8 E+16
Mould Institute of Physics	2000	3.8 E+16
Fairlie and Sumner, TORCH	2009	1.0 E+17
UNSCEAR	2011	8.5 E+16
Stohl et al	2012	8.5 E+16
This paper, based on Eisenbud /Gesell (total inventory)	2012	9.0 E+15

My August 2011 estimates were based on the total quantities released according the NISA in Japan. These were given for most of the radionuclide emissions by NISA and I show them in Table 3 where they are compared with the releases from Chernobyl according to various authorities. Results from Sumner et al, Savchenko et al and Mould agree with each other. There was a sudden sudden increase created by Fairlie and Sumner in 2009 and also more recently by UNSCEAR. These increases are difficult to understand since it is possible to calculate the fission product inventory of a nuclear reactor on the basis of the power in MW. Tables of fission inventory per MW are given in Eisenbud and Gesell 1998 and these can be used to predict the inventory of a 1000MW reactor (Chernobyl) and the contents of the three Fukushim Dai-ichi reactors 1-4 (rated at 3000MW on basis of data given in UNSCEAR 2000). I calculate the total inventory of the Chernobyl reactor and the Fukushima 1-4 reactors on the basis of these relationships and give the result in Table 4 (and in Table 2 for Cs137).

Table 3 Selected Radionuclides released from Fukushima (NISA) and Chernobyl according to various authorities

Nuclide	**Half life**	**Fuku. (NISA) 2011**	**Chern. Sumner 1991, (Mould) 2000**	**Chern. Fairlie Sumner 2009**	**Chern. UNS CEAR 2011**	**Fuku. Stohl et al 2012 NILU**
Kr85	10.7y	2.2E+17	3.3E+16			
Xe133	5.2d	1.1E+19	1.7E+18			1.53E+19
Cs134	2.1y	1.8E+16	1.9E+16			5.0 E+16
Cs137	30	1.5E+16	3.8E+16	1.0E+17	8.5E+16	3.7E+16
Sr89	50.5d	2.0E+15	8.0E+16			
Sr90	29.1y	1.4E+14	8.0E+15	1.0E+16		
Y90	64h	1.4E+14	8.0E+15	1.0E+16		
Ba140	12.7d	3.2E+15	1.6E+17			
La140	40h	3.2E+15	1.6E+17			
Te127m	109d	1.0E+15				
Te129m	33.6h	3.3E+15				
Te131m	30h	9.7E+13				
Te132	78h	7.6E+14	4.8E+16			
Ru103	39d	7.5E+9	1.2E+17			
Ru106	368d	2.1E+9	6.0E+16			
Zr95	64d	1.7E+13	1.5E+17			
Ce141	33d	1.8E+13	1.0E+17			
Ce144	284d	1.0E+13	8.9E+16			
Np239/ Pu239	24065 y	7.6E+13	4.2E+15			
Pu241/ Am241	14.4/ 432y	1.2E+12	5.0E+15			
Y91	58.5d	3.4E+12				
Cm242/ Pu238	162d	1.2E+11	7.8E+14			
I131	8d	1.6E+17	2.6E+17	1.8E+18		
I132	2.3h	4.7E+14				
Sb127	3.9d	6.4E+15				

Table 4 Calculating the total fission inventory of selected nuclides in Chernobyl and Fukushima 1-4 reactors only (no spent fuel) from the Power rating (fuel burnup) and assuming a running period of 2 y (from Eisenbud and Gesell 2000).

nuclide	**Half life**	**BP**	**BP chloride**	**Activity in fuel Chern**	**Activity in fuel Fuku**		
H3	**12.3y**	**Gas**		**1.6E+13**	**4.7E+14**		
Kr85	**10.7y**	**Gas**		**9.3E+14**	**2.8E+16**		
Sr89	51d	1384		8.9E+16	2.7E+18		
Sr90	28.9y	1384		6.7E+15	2.0E+17		
Y90	64h	3338		6.7E+15	2.0E+17		
Y91	58.8d	3338		1.2E+17	3.6E+18		
Mo99	66.6h	5560		1.5E+17	4.4E+18		
I131	**8.06d**	**gas**		**1.0E+17**	**3.1E+18**		
Xe133	**5.3d**	**gas**		**2.0E+17**	**6.0E+18**		
Cs134	**2.06y**	**678**		**2.3E+15**	**6.7E+16**		
Te132	**78h**	**gas**		**1.3E+17**	**3.8E+18**		
I133	**20.8h**	**gas**		**8.4E+17**	**2.4E+18**		
Cs136	**13d**	**678**		**2.7E+15**	**8.2E+16**		
Cs137	**30.2y**	**678**		**8.9E+15**	**2.7E+17**		
Ba140	13d	1640		1.7E+17	5.1E+18		
La140	40.2h	3457		1.8E+17	5.4E+18		
Ce144	284d	3426		1.3E+17	3.9E+18		
Pu239	24000y						
Pu238	86y		760				
U238	4E+9y		578				
U235	7E+8y						
Total all gas/ volatile				1.3 E+18	1.6E+19		

3. The Stohl et al 2012 findings

We are now in a position to use these data, and new findings of Stohl et al 2012 to make a more informed comparison of Chernobyl and Fukushima. The modelling of Stohl et al 2012 seems very careful, and the method they employ, which uses data from both ends of the problem, the atmospheric measurements together with theoretical quantification of the contents seems to make the best assessment yet of the emissions. They only look at two nuclides, Cs137 and Xe133. Their results give much higher releases for these two nuclides than earlier assessments. They conclude that the release from Fukushima of Xe133 was 1.5 x 10^{19}Bq and that of Cs137 was 3.67 x 10^{16}Bq. The authors then compare the Cs-137 emission with Chernobyl and conclude that on the basis of Cs137 the Fukushima releases were 43% of the Chernobyl releases. Although their source term calculation for Chernobyl is not given, we can conclude that they have put the Cs-137 release from Chernobyl at 8.5 x 10^{16} Bq. This

is the value given by UNSCEAR 2011 but it is clearly too high since it exceeds the theoretical value for the total inventory of 8.9 x 10^{15} by a whole order of magnitude, and it exceeds the value given by several earlier authorities (Table 1) of 3.8 x 10^{16} also. I propose that we can take this latter value of 3.8 x 10^{16} to be a conservative one, in which case, the Stohl et al result for Cs137 makes the releases from Fukushima and Chernobyl equal.

For Xe133, the Stohl et al 2012 result shows that the Fukushima releases exceeded Chernobyl by a factor of 9.The authors again over assess the X-133 releases from Chernobyl, but even so, argue that the Fukushima releases were more than twice those from Chernobyl for this nuclide.

4. Missing exposures

It is in any case difficult to understand the arguments that Fukushima releases were lower than Chernobyl purely from the fact that at Fukushima there are three exoploded reactors and at Chernobyl only one of the same size. The Stohl et al results make it clear that gaseous and low boiling point nuclides (highlighted in bold in the Table 4) will have been released: the total inventory of three reactors will have been discharged to the atmosphere. Since there were three pressure vessels of rating 1000MW each at Fukushima and one pressure vessel of the same rating at Chernobyl, that means for these volatile and gaseous nuclides there must have been approximately three times the releases. This was clear from quite early on, and it was why it was not difficult to conclude what Stohl et al 2012 eventually found. But in this examination of the total releases a large number of very dangerous nuclides have been ignored. If we examine the total inventory and the releases from Chernobyl given by the various authorities, we see that by far the greatest quantity of radioactivity exists as beta emitting nuclides which are not Cs-137 and Cs134 and I-131, the nuclides commonly referred to and measured. I list these in Table 5.

Table 5 Some measured and unmeasured missing beta emitter nuclides released from Fukushima (calculated from data in Eisenbud and Gesell 2000).

Nuclides	**Fukushima inventory (calc. from EG)**
Cs-134 + Cs-137	3.5 E+17
I-131	3.1E+18
Ba-140 + La140	1.05E+18
Ce-144	3.9E+18
Sr89 + Sr90	2.9 E+18
Te-132 + I132	6.0 E+18

5. Conclusions

On the basis of the most recent measurements and calculations, Fukushima releases exceeded those from Chernobyl by a factor of 9 for the noble gas Xe-133 and were approximately the same for Cs-137. Because the Fukushima reactors had a rated generating capacity of 3 times that of Chernobyl, the reactor inventory of fission products will be approximately three times that of Chernobyl. Since the measured Xe-

133 levels showed the entire inventory of this gas was released, it can be assumed that all of the inventory of the other fission product gases and volatile elements will also have been released. It follows that rated as an overall contamination process, Fukushima was about twice as serious as Chernobyl. In addition since the population density of the affected area was significantly greater than that of the Chernobyl affected territories, the total ill-health yield outcome will be significantly greater. Many dangerous beta emitters have not been measured and these represent in activity more than all the radio-Caesium activity and radio-Iodine activities combined.
My initial March 2011 estimates of the severity of the Fukushima catastrophe have thus been shown to be accurate.

References

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Summary

A comparison is made between the releases of radioactivity from Fukushima and Chernobyl. Using the most recent measurements and calculations made by Stohl et al 2012 it is clear that for the gas Xenon-133 the release from Fukushima was roughly 9 times greater than that from Chernobyl. For the commonly measured nuclide Cs-137, based on the most conservative data the releases were approximately comparable. It follows that the Fukushima catastrophe was more serious in terms of its releases of these two nuclides than Chernobyl. This is not surprising since there were three reactors breached at Fukushima to one at Chernobyl of equivalent capacity. However, much greater quantities of nuclides were released from Fukushima and were not measured. Total Fukushima releases exceeded 2 x 10^{19} Bq (20EBq) and were overall more than twice the releases from Chernobyl. The high population density of the area contaminated makes this a more serious issue for health than the Chernobyl releases. These findings support the early assessment I made in March and later in August 2011 on theoretical bases and the evidence I gave to the BBC.

Press Release
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Fukushima worse than Chernobyl for radioactive emissions

A report by Prof Chris Busby released today from Green Audit uses the most recent (March 1st 2012) data published by the Norwegian Institute for Air Research, Kjeller, Norway, to show that the Fukushima catastrophe released 9 times more of the radioactive gas Xe-133 to the atmosphere than Chernobyl accident did in 1986. Using the most authoritative and agreed estimated releases of the nuclide Caesium 137 only, he shows that the releases from Fukushima and Chernobyl are, in fact comparable. This gives the lie to the many statements in the media that the releases from Fukushima are 1/10th those from Chernobyl. Prof Busby's report also uses theoretical arguments and published data from standard works on radiation inventories of nuclear power plants to show that these estimates and findings are reasonable.

It follows that the Fukushima catastrophe was more serious in terms of its releases of these two nuclides than Chernobyl. *This is not surprising since there were three reactors breached at Fukushima to one at Chernobyl of equivalent capacity*, said Busby. Total Fukushima releases exceeded 2 x 1019 Bq (20EBq) and were overall more than twice the releases from Chernobyl. The high population density of the area contaminated makes this a more serious issue for health than the Chernobyl releases. These findings support the early assessment made by Prof Busby in March and later in August 2011 and the many statements he made to the BBC, ITV, and Russia Today and show that those many pro nuclear experts who talked don the seriousness of the catastrophe were wrong.

Busby draws attention to the fact that a large number of radionuclides were released which were not measured or listed, including the beta emitters Tritium, Barium 140 and Lanthanum 140, and including the alpha emitters Plutonium and Uanium none of which can be measured with normal equipment.

Busby said: *Of course what we are really interested in here is the health outcome, which in my opinion will be worse than Chernobyl's since the population density in the areas in Japan where these substances were dispersed is greater than Chernobyl. Those who mislead the public on this issue of health, who use the outdated and incorrect ICRP risk model, are worse than those who misled on the basis of the comparison with the releases since at least if we concede this, people can be evacuated and the health consequences will be reduced. All the evidence points to an error in the ICRP model of three orders of magnitude for internal exposures to the nuclides released by Fukushima, errors that have been conceded by their outgoing Scientific Secretary, Jack Valentin and errors that will be expressed in the population of Japan in t e next ten years in very real terms.*