Does Fukushima radioactive fallout near Chernobyl levels?

Final version

Certain Mr. Wotawa from Austrian Met-Office claims Fukushima radioactive fallout nears Chernobyl levels and claims there was released 20-60% of Cs-137 when compared to Chernobyl, moreover allegedly just in one day. So it looks like the “fallout” nears the one of the Chernobyl at least in the media arena.

In this article I wish to point out that Mr. Wotawa's claims are overstatements possibly multiple orders of magnitude higher than the actual reality. This is especially embarrassing as he works for CTBTO (The Comprehensive Nuclear Test Ban Treaty Organization) where they should know something about nuclear physics or at least basic math. I unfortunately do not much wonder that a popular "science" journals in USA buys into such "ideas", because the sensationalism is still extremely high there.

At the beginning it would be good to clear what the Becquerel unit stands for (One Becquerel is defined as the activity of a quantity of radioactive material in which one nucleus decays per second).

I cite what Mr. Wotawa writes here at the official site of Austrian Met-Office this startling claims:

> ***Die geschätzten Quellterme für Jod-131 sind sehr konstant, nämlich 1.3x10^{17} Bq/Tag für die ersten beiden Tage (USA-Messungen) und 1.2x10^{17} Bq/Tag für den dritten Tag (Japan). Für Cäsium-137 lassen die USA-Messungen auf einen Quellterm von 5x10^{15} Bq schliessen, während in Japan sehr viel mehr Cäsium in der Luft war. An diesem Tag würde der Quellterm mit etwa 4x10^{16} Bq abgeschätzt werden.***
> ***Bei der Reaktorkatastrophe von Chernobyl war der gesamte Quellterm von Iod-131 1.76x10^{18} Bq, der von Cäsium-137 8.5x10^{16} Bq. Die für Fukuschima abgeschätzten Quellterme sind damit bei 20% des Chernobyl-Terms für Jod, und 20-60% des Chernobyl-Terms für Cäsium.***

I am citing both paragraphs in the German language to preserve it for the future generations - as a splendid example of the scientifically looking, but most probably startlingly incorrect conclusions presumably designed not just to get media attention and scare the traditional Austrian antinuclear activists, but whole the world.

A translation into English:

> *"The estimated source levels for Iodine-131 are very constant, namely 1.3x10^{17} Bq/day for this two first days and 1.2x10^{17} Bq/day for the third day (Japan). For the Cesium-137 close the USA-measurements from one source a level of 5x10^{15} Bq, while there was much more Cesium in the air in Japan. This day would the source levels be approx 4x10^{16} Bq".*
> *For the catastrophe of the Chernobyl reactor was the total source level of Iodine-131 10x10^{18} Bq and for the Cesium-137 8.5x10^{16} Bq. The estimated source levels for Fukushima are therefore around 20% Chernobyl levels for Iodine, and 20-60% of Chernobyl levels for Cesium."*

Especially the last "conclusion" sentence looks to me like really gross overstatement. Good to note Mr. Wotawa later raised the figure for Cs-137 even to 5x10^{16} Bq - even he was alerted it is highly dubious.

To explain: The Cs-137 nuclei has the half-life of 30.23 years. It is the most dangerous fission contaminant, because it has long half-life, yet it has very high gamma decay energy, it is quite

volatile if the temperatures are high enough, yet it has high affinity to soil. It is the most important long lasting contaminant in the Chernobyl zones, because it was literaly shot out the reactor by the nuclear excursion of 10t TNT equivalent and the rest literally boiled out of the wide open reactor at temperatures over 2000 °C caused by high fuel short half life radionuclide saturation producing high decay heat and by the burning graphite - which lifted it relatively high into the atmosphere, formed aerosol and was spread very far from the Chernobyl in a radioactive cloud. Cs-137 has another bad property that the living organisms especially the plants confuse it with the Potassium in their metabolism.

According to the IAEA report the total estimated release of the radioactive materials from Chernobyl disaster into the environment was $14x10^{18}$ Bq from which the Cs-137 was ~$8.5x10^{16}$ Bq in Chernobyl. Translated to weight (for idea how much it is) in grams using the equation:

$$\mathbf{W} = ((2 \times \mathbf{H} \times \mathbf{Sy}) \times \mathbf{Bcs}) / \mathbf{N}) \times \mathbf{Gcsm}$$

W – weight in grams, **H** – half-life, **Sy –** number of seconds in one year, **Bcs** – amount of Becquerels of the Cs-137, **N** – number of nuclei in one mole, **Gcsm –** number of grams in one mole of Cs-137

$$((2x30.23x365.25x24x60x60x85x10^{15})/6.02214179\times10^{23})x136.907= 36869 \text{ g of Cs-137}$$

This means the Chernobyl disaster emitted ~36.9 kilograms of Cs-137 into the environment according to the IAEA estimations.

Yet, Mr. Wotawa wants us to believe that almost half of this amount (17.4 kg) of Cs-137, was released into the environment at Fukushima in just one day.

17.4 kg of Cs-137 a day, especially such a cold day with such a slow wind? Everybody would have problems surviving even just hours in the immediate surroundings of the Fukushima plant if there were something like 17.4kg of Cs-137 (something like a content of ~800 gamma irradiators from Goiânia accident was dispersed there) released into the air in one day + many hundreds of kilograms of Xe-133, I-131, I-133, Te-129m, Te-132, Cs-134, Cs-136, Kr-85, Sr-89, Sr-90, Ru-103, Ru-106, Ba-140, Zr-95, Np-239, Mo-99, Ce-141, Ce-144... and many other fission products!

It is important to note that the gases and aerosols from the overheated but intact reactors in the intact containments were vented through the pressure suppression chamber water, and the residues of the Cs-137 (which is very soluble in water and its oxides even violently react with it) were so orders of magnitude lower in the vented steam than it would be if the reactor exploded wide open like in the Chernobyl. So it would be better for Mr. Wotawa to compare the Fukushima to Three Mile Island accident – as is done by those, who are not so zonked by their greatness – where it was also needed to vent the steam steam same way through pressure suppression chamber from the reactor with partially melted core. Which would be perhaps not so interesting for media, because nobody died there.

Now, what radiation levels would be around the Fukushima plant if there really was Mr. Wotawa's $4x10^{16}$Bq Cs-137 released during the third day? (March 14 - and if we completely omit the other days.) We have the wind speed measurements thanks to Tepco, so we can quite easily approximate the estimations and we do not need any black box simulations, such as those ZAMG now scared the USA with.

What would be the average level of the air radiation (in Becquerels) in a 500m diameter circle around the sources (the damaged reactor buildings) if we would buy into the Mr. Wotawa's Fukushima-Chernobyl comparison, and his emissions of $4x10^{16}$ Bq Cs-137 during the third day?

The average wind speed the day was very low - 1.2 m/s - which means that the wind in the given area would change the air (1.2*(24x60x60)/500) = <207.36 times (at maximum - in reality the wind direction changed during the day so it would be less) during the whole day. In the Chernobyl the total radioactive material dispersed was ~14x10^{18}Bq, out of which Cs-137 was ~8.5x10^{16} Bq, so the ratio of the Cs-137 decay activity in the total was 1/(14x10^{18}/8.5x10^{16}) = 1/165. If there would be 4x10^{16} Bq Cs-137 discharged during the one day (according to Mr. Wotawa) then the average concentration of just Cs-137 in the 500m circle diameter would be in the 2m above the ground (where the people usually are) more (Cs-137 is heavier than air) than:

$$(4x10^{16}/207.36)/(\pi x250^2 x2)) = 491 \text{ MBq/m}^3$$

The concentration would rise geometrically in the direction to the reactor buildings and in the close proximity to them we could expect dozens of GBq/m^3 in the air and because of accumulation a half of TBq/m^2 on the ground in form of extremely contaminated dust which would continuously recontaminate the air.

Not for the purpose of the comparison, but just to make the estimation complete - if we then would use the Chernobyl ratio to approximate the total radioactivity (the 165 times more): 65GBq/m^3 on average -at the whole 500m in diameter area. In fact again much more it would be at places closer to the reactor buildings, because all the solid radionuclides (all except Xe-133 and Kr-85 at the given temperatures) would deposit at the ground in the concentrations rising geometrically in the direction towards the sources (the reactor buildings - which are ~48x35m – more than 10 times smaller compared to our 500m in diameter circle). In close proximity to the buildings there could be then even dozen of TBq/m^3 of activity in the air and possibly hundreds of TBq/m^2 (!) on the ground - which would be indeed very comparable to the vicinity of the Chernobyl Unit4 immediately after the disaster, maybe even worse.

Nothing like that was measured at the Fukushima plant. The highest reported value so far in the contaminated water (presumably the one which the steam from the reactor was bubbled through and later leaked) was 20 Tbq/m^3 (not in the air around the plant!). It is quite a lot and it most probably means the water leaks from the containment(s) which need to be sealed. It is the same order of magnitude which would imply the Mr. Wotawa figures, but not in the air, which can be transported by wind, but contained in the water (note: in water the volume radioactivity concentrations are typically multiple orders of magnitude higher than in air, because the water is approx. 850 times denser than air), which is not spreading far, is relatively contained in the underground trench and can be pumped out, stored until the short half-life isotopes decay and then decontaminated, and which does not pose significant risk - if it will be properly handled - to anybody else than the workers at the plant. Important to note the company the workers injured worked for was not able to provide the two injured workers with the proper protective gear - which if used it would most probably prevent the injuries or at least considerably lower their severity.

According to IAEA document the equivalent dose in Sieverts/hour for Cs-137 ground contamination is:

$$1.6 \times 10^{-12} \frac{Sv/h}{Bq/m^2}$$

From the equation we can approximate that if there would be really a half of TBq/m^2 Cs-137 in the vicinity of the reactor buildings on the ground - as would suggest the Mr. Wotawa's figures - then the dose equivalent would need to be there constantly:

$$>((1.6\times10^{-12})\times(500\times10^{9})) = >800\text{mSv/h}$$

- just from the deposited Cs-137 - and possibly at least tens of times more from the total deposited radiation contamination there – resulting even in tens of Sieverts/hour of just the gamma radiation dose. -For example the I-131 has approx. 1/3 gamma decay energy of Cs-137, so the dose is lower accordingly, yet there would be just from the Mr. Wotawa's figures 30 times more I-131, so just this one of many fission products present would make the equivalent dose rise 10+fold. This would be immediately dangerous to life, making longer rescue efforts in relatively small group of people an effective suicide mission for the workers who would stay there more than just couple of minutes. But again, nothing like that was consistently measured there, the average was under 20 mSv/h, the highest short peak value reported by IAEA was 400 mSv/hour, yet to note a day later on March 15, and the values on the perimeter of the plant then even at the short peaks never surpassed the value of 12 mSv/hour.

One needs to note that this comparisons are approximations. Only what we can deduce from them unmistakably is that apparently the radiation didn't leaked into the environment in the vast amounts which would imply the Mr. Wotawa's figures.

Mr. Wotawa's figure for Cs-137 most likely originates from CTBTO measurements (- I was asking him for sources, but he never replied, so I unfortunately can't review them). The Cs-137 measurements at and around the Fukushima plant suggest that it's air release at Fukushima was about few dozens of grams/day (dozens of TBq). It is still quite a lot, but most of it would end very close to the Fukushima plant where it is conceivable it can be decontaminated and/or due to the prevailing wind direction would most probably anyway deposit in the open ocean where it disperses. The contamination of the Honshu inland soil would be dangerously high (>1Mbq/m^2) likely only at isolated spots where it was discharged from the most contaminated air by rain before it dispersed enough.

I think the likely orders of magnitude overstated conclusions of the CTBTO employee can serve as the example of the antinuclear exaggerations. I hope this article would at least little bit help to rectify them.

In fact – and I'm not the only one with similar opinion – the Fukushima chain of accidents caused by the almost unprecedented earthquake and tsunamis paradoxically shows the nuclear energy is relatively safe even in the most extreme situations – especially when we would take into account that the present nuclear technologies are even much more safer than the in 60ties projected Fukushima, definitely much safer than the hydrocarbon energy sources – which only the nuclear energy has the capacity to substitute for anyway – and that the future technologies of the 4th generation can be even much more safer than the present ones. Hopefully the reason will eventually prevail over the irrational fears fueled by the irresponsible scientists scaring the public - either as a result of fanaticism, pursuing an agenda or just a hubris.

The article was consulted with Mr. Ondrej Chvala PhD from Brookhaven National Laboratory