Decommissioning plans for the Fukushima Daiichi Nuclear Plant

Analysis of IAEA Mission Report and NDF Strategic Plan

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Fukushima Daiichi nuclear plant, October 2018, Aslund/Greenpeace

Introduction

The International Atomic Energy Agency submitted its fourth mission mission report on the 'On Mid-And-Long-Term Roadmap Towards The Decommissioning Of TEPCO's Fukushima Daiichi Nuclear Power Station' to the Japanese Government on 31 January 2019.[2] The report is based on an in country visit of IAEA officials and technical advisors conducted during the week of 5 November 2018. The IAEA submitted earlier reports in 2013, 2014, and 2015.

This Greenpeace analysis provides a critical review of some of the priority issues identified by the IAEA as well as the latest Technical Strategic Plan 2018 for Decommissioning of the Fukushima Daiichi published by the Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF) in November 2018.[3] This NDF plan provides much of the analysis underlying the IAEA report.

It is important to note that while the IAEA brings technical expertise to its assessment of issues at Fukushima Daiichi, the IAEA has a conflict of interests in its assessment. Specifically, it has a

1 Revised version of February 2019.

2 IAEA, "International Peer Review Mission On Mid-And-Long-Term Roadmap Towards The Decommissioning Of Tepco's Fukushima Daiichi Nuclear Power Station" 4th Mission Report, see http://www.meti.go.jp/press/2018/01/20190131008/20190131008-1.pdf

3 NDF, "Technical Strategic Plan 2018 for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company Holdings, Inc. Overview", November, 2018, Nuclear Damage Compensation and Decommissioning Facilitation Corporation, see http://www.dd.ndf.go.jp/en/strategic-plan/book/20170322_SP2016eFT.pdf

primary role in promoting the development and expansion of nuclear power globally. The Fukushima Daiichi nuclear disaster had a major impact on nuclear power operations in Japan and globally. As such, it is in the clear interests of the Japanese government to communicate to its domestic audience as well as internationally that major progress has been made in moving towards the decommissioning of the Fukushima Daiichi plant. The IAEA ever since 2011 has played a supporting role in its reporting of the Fukushima nuclear accident.

At the same time, the issues raised by the IAEA are clearly important to understand, and requires interpretation of the text in the report used, which in many cases, and understandably, is couched in diplomatic language. In decoding the report, it is can be clearly seen that the IAEA has major questions over the current TEPCO road map towards decommissioning, including as laid out in the NDF 2018 Technical Strategic Plan, but is very far from explicit. Given the scale of the challenges at the Fukushima Daiichi plant, the IAEA has chosen to miss an opportunity to raise fundamental problems with the current Strategic Plan for decommissioning of Fukushima Daiichi.

Analysis over recent years, including critical technical opinion from independent experts in Japan, as well as Greenpeace, has questioned the very premise of the decommissioning plan – specifically the proposed removal of the molten fuel. The experience of the molten core fuel at unit 4 reactor at Chernobyl, which remains in the reactor building where it relocated starting in 26 April 2011, is an indicator of the reality of post nuclear accident decommissioning timeframes. The current proposed decommissioning schedule at Chernobyl is to take place between 2045-2065, with the IAEA itself reporting in 2018 that it will be over the next 100 years.[4] In contrast, the latest Strategic Plan for Fukushima Daiichi decommissioning is that it is to be completed during 3-4 decades (2045-2055). This was set as early as 2015 when it was stated that, “fuel debris retrieval which is aimed to be completed within 10 years”.[5] On the current schedule this would be by 2031 – twenty years after the start of the Fukushima Daiichi accident. This is clearly not credible.

There are significant differences between the conditions at Chernobyl compared with Fukushima Daiichi. Most importantly are the hydrology conditions and water management at Fukushima Daiichi, and the complexity of the molten fuel dispersal in the three Fukushima Daiichi reactors, compared with the one Chernobyl-4 reactor.

While there is a pool of contaminated water at Chernobyl, this is as nothing when compared to the going large scale water crisis at Fukushima Daiichi, due in large part to the geology and location of the reactors. The water crisis is at the center of the long term management of the site. This raises the question – if the timeframe for removing the molten fuel lack all credibility – and therefore likely to remain a hazard for many years/decades and longer – what is being done to ‘solve the water crisis’ ? The priority clearly needs to be on water management, and preventing water accessing the areas of the reactors where it becomes highly contaminated. However, since April 2011 TEPCO has failed to address this issue effectively, such as the proposed Mabuchi plan of 2011 to build a more

4 Viktor Kuchinskiy, “Chernobyl NPP decommissioning efforts. Past, Present and Future.” Chernobyl NPP, Ukraine, see https://inis.iaea.org/collection/NCLCollectionStore/_Public/48/047/48047388.pdf

5 NDF, “Technical Strategic Plan 2015 for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company Towards Amendment of the Mid-and-Long-Term Roadmap in 2015”, see http://www.dd.ndf.go.jp/en/strategic-plan/book/20150624_Technology_strategy_plan_e.pdf

tried and tested 30-meter-deep Bentonite slurry wall, which was abandoned.[6] The plan, first raised publicly in April 2011,[7] and in consultation with U.S. Nuclear Regulatory Commission staff, was not developed in large part due to resistance from TEPCO, including an effort to avoid negative effects on market perception of the company.[8] Instead, several years passed and an ineffective ice barrier was installed. As former Minister Mabuchi explained,

"...technical officials within TEPCO vehemently opposed the solution because it was too similar to that used at Chernobyl, where a concrete sarcophagus was built over the damaged reactor. "TEPCO very much opposed this idea because to make such a cement coffin would be to admit the defeat of nuclear technology."[9]

This overview analysis is an attempt to highlight where the major challenges that exist at the Fukushima Daiichi plant, specifically the molten fuel / corium. The issues highlighted in the 2019 water crisis report from Greenpeace directly impact on the decommissioning plans at Fukushima Daiichi but are not generally not included in this report. Likewise, the plans and hazards for spent fuel removal from the pools of Units 1-3 are not included in this analysis.

By using the IAEA mission report and NDF 2018 Strategic Plan as the current state of knowledge, the briefing concludes that while progress is undoubtedly being made, the scale of the challenges are not being accurately communicated by the principal agencies responsible, in Japan this being TEPCO, the NDF, and government, and internationally by the IAEA. A review of the reality of the conditions at Fukushima Daiichi lead Greenpeace to conclude that the timeframe applied for the removal of molten fuel / corium at Fukushima Daiichi lacks all credibility and is not being informed by engineering or scientific knowledge but rather a political agenda set by the Government and a nuclear industry desperate to recover after March 2011.

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6 As described by Rob Gilhooly in Yoshida's Dilemma, "As early as June 2011, former Land, Infrastructure, Transport and Tourism Minister Sumio Mabuchi, who was drafted in by Prime Minister Kan to serve as a special advisor in charge of handling the Fukushima accident, proposed the construction of a four-sided, 30-meter-deep Bentonite slurry wall, "like a square bathtub" around the four reactors to prevent the groundwater water entering the site and mingling with contaminants. Initially, TEPCO balked at the estimated $1 billion plan, telling Mabuchi it would bankrupt them, but he eventually managed to persuade TEPCO vice-president Sakae Muto by highlighting the wide-reaching implications should no action be taken. In a memo to the government, TEPCO said such an announcement could cause the market to conclude that TEPCO was "moving a step closer toward insolvency." Mabuchi told a government panel investigating the accident that Muto believed "the market would be plunged into turmoil" if people thought that the utility had an additional $1 billion debt, pushing its liabilities further beyond its assets. Muto requested that TEPCO instead be allowed to announce that it would be researching the implementation of such a wall. The government acquiesced, but only after receiving a promise that construction of the wall would commence immediately after. On June 27, one day before TEPCO's AGM, Mabuchi was suddenly told his services were no longer required. What's more, the underground wall project was scrapped and kept secret for almost two-and-a-half years – see Rob Gilhooly, "Yoshida's Dilemma", One Man's Struggle to Avert Nuclear Catastrophe Fukushima – March 2011, Inkbeans Press, Murrieta, CA, USA, 2017.

7 AFP, "Underground walls could help stop radioactive leaks at Fukushima" 23 April 2011, see https://www.france24.com/en/20110423-operator-may-build-underground-walls-stem-radioactive-water-leaks

8 Mari Sato, "Japan balked at steps to control Fukushima water in 2011: memo", 13 September 2013, see https://www.reuters.com/article/us-japan-fukushima-water/japan-balked-at-steps-to-control-fukushima-water-in-2011-memo-idUSBRE98H14A20130918; and Chico Harlan, "For Tepco and Japan's Fukushima Daiichi nuclear plant, toxic water stymies clean up", Washington Post, 21 October 2013, see https://www.washingtonpost.com/world/for-tepco-and-japans-fukushima-daiichi-nuclear-plant-toxic-water-stymies-cleanup/2013/10/21/406f4d78-2cba-11e3-b141-298f46539716_story.html?utm_term=.10162cbaa9d1

9 Op.cit. Gilhooly 2017.

Overview and priority issues

The latest IAEA mission report "considers that significant progress has already been accomplished to move Fukushima Daiichi from an emergency situation to a stabilized situation. This should allow the focus of more resources for detailed planning and implementation of the decommissioning project of the whole site with considerations extended up to the completion of the decommissioning."

The coded language here is that TEPCO need to slow down and plan more. Given the official (and unrealistic) timeframe for decommissioning of 3-4 decades, this is indeed appropriate. However, the IAEA, if they were being transparent, would point out that the current schedule, in particular for removal of the 880 tons of molten nuclear reactor fuel in units 1-3 lacks all credibility.

"While fuel debris retrieval is one of the most important and challenging issues, such planning shall also address sustainability and long-term aspects such as radioactive waste management including the waste streams which will come from the decommissioning of the facilities on site. The implementation of the safe decommissioning of Fukushima Daiichi NPS is a unique complex case and expected to span several decades: the IAEA Review Team considers that it will therefore require sustained engagement with stakeholders, proper knowledge management, and benefit from broad international cooperation."

Its important that the IAEA is referring to nuclear waste arising from the Fukushima Daiichi plant, however, there is no plan for its secure, safe long term management – which reflects the overall nuclear waste situation in Japan with no progress on disposal sites.

Molten Fuel / Corium Status

"Shunichi Tanaka, the chairman of Japan's nuclear regulation authority, does not appear to share Tepco's optimism that it will stick to its decommissioning roadmap. "It is still early to talk in such an optimistic way," he says. "At the moment, we are still feeling around in the dark." 2017.[10]

The IAEA does not appear to share the same doubts over plans for Fukushima Daiichi as the former Chair of the Nuclear Regulation Authority (NRA).

The precise location, condition and amount of molten fuel (debris as described by TEPCO) in units 1-3 of the Fukushima Daiichi reactors remains uncertain. The Fukushima Daiichi molten fuel / corium has its own instabilities in term of criticality, radioactivity, decay heat, chemical properties, and geometric shape. TEPCO currently consider that fuel debris is controlled in a stable condition since the sub-critical state is confirmed, decay heat is controlled (cooled) by the circulated cooling system, hydrogen concentration is controlled by injection of nitrogen, and the measurement values of pressure and temperature remain stable.[11]

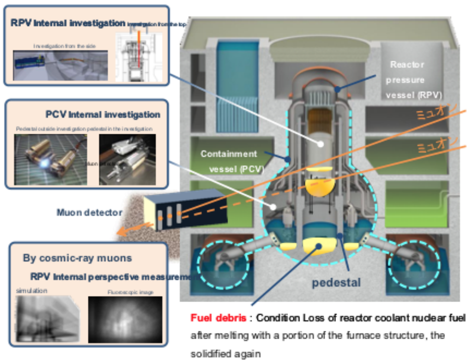
10 Justin McCurry, "Dying robots and failing hope: Fukushima clean-up falters six years after tsunami", The Guardian, 9 March 2017, see https://www.theguardian.com/world/2017/mar/09/fukushima-nuclear-cleanup-falters-six-years-after-tsunami

11 Technical Strategic Plan 2017 for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company Holdings, Inc.,, August 31, 2017 Nuclear Damage Compensation and Decommissioning Facilitation Corporation, see http://www.dd.ndf.go.jp/en/strategic-plan/book/20171005_SP2017eFT.pdf

As Table 1 below shows, the amount of molten fuel / corium at the three Fukushima Daiichi reactors is considered to be in the range of 880 tons, with a lower estimate of 609 tons and upper range of 1,141 tons. This compares with 150 tons at Three Mile Island unit 2 and 540 tons at Chernobyl unit 4.

Table 1 Estimated molten fuel in Fukushima Daiichi units 1-3

The International Research Institute for Nuclear Decommissioning (IRID) has overseen the modeling of the progression of the triple reactor meltdown at Fukushima Daiichi, as well as based on limited inspection of the reactors themselves.[12] This includes cosmic ray Muon scanning.[13] From this they have estimated the range of tonnage of molten material – known as corium (a combination of molten fuel, together with concrete, steel).



The estimate of total molten fuel/corium is based on simulations of the accident and observations with muons, among others. These calculations show that the total mass of corium is as follows:

• Unit 1 - between 232 and 357 tonnes, with a nominal value of 279 tonnes;

•Unit 2 - between 189 and 390 tonnes, with a nominal value of 237 tonnes;

•Unit 3 between 188 and 394 tonnes, with a nominal value of 364 tonnes. Unit 3 molten fuel contains 32 assemblies of plutonium MOX fuel, with 235kg of plutonium.

The reason that the corium content is higher than the original fuel 69 tons in reactor 1, and 94 tons in each of reactors 2 and 3 is that corium contains in addition to the original fuel, molten steel and concrete. Consequently the corium masses are 2.5 to 4 times more mass than the original fuel.

The sum of the nominal quantities of corium is 880 tons, with the lower range being 609 tons, and upper estimate being 1,141 tons. This nominal value of 880 tons is 3.4 times more than the original fuel in the three reactors.

It is estimated that for reactors 1 and 3, fuel and steel would account for about 30% of the mass each and concrete, 40%.For reactor 2, fuel and steel would make a total of 70% of the total mass, the rest being concrete.

TEPCO acknowledge that in the mid- to long-term, "the state of fuel debris may change over time, such as radioactive materials leaching from fuel debris as colloid or ions, and becoming granular or fragmented due to 4-29 oxidation or collapsing. If the volume of fuel debris in highly mobile forms increases due to leaching and/or granulation, the risk may rise for such form of fuel debris to flow

12 IRID, "Estimation of fuel debris distribution by the analysis and evaluation," Japan Atomic Energy Society Fuel Debris Research Committee, 4 October 2016, http://irid.or.jp/wp-content/uploads/2016/10/20161004.pdf (in Japanese)

13 The US DOE Los Alamos facility and Decision Sciences International Corporation, (DSIC) of California partnered with Toshiba Power Systems Company to use muon vision at the Fukushima Daiichi plant, see National Security Science, "Los Alamos's muon vision to the rescue"**,** December, 2016, see https://decisionsciences.com/fixing-fukushima/

into a circulated cooling system along with coolants, or **even released into the environment along with the flow of gas or coolant if a major loss of containment functions occurs.** Additionally, if granular and fragmented fuel debris with high mobility had high concentration of nuclear fuel materials, there will be an undeniable possibility of it accumulated at one place and causing local criticality.[14] On top of that, radioactivity of fuel debris is the cause of hydrogen generation by radiolysis of water. When a hydrogen concentration reaches a certain value, it gives rise to the possibility of hydrogen explosion. While currently the hydrogen concentration is constantly controlled by injection of nitrogen, in a mid- to long-term, the risk of losing control increases due to various factors such as deterioration and failure of equipment...fuel debris have not been fully investigated and still have some high uncertainties. Additionally, over time, the diffusibility of fuel debris may increase due to its instability and the reliability of containment functions may reduce, and the risk level of fuel debris may increase with time accordingly."[15] In January/March 2019 TEPCO plan to conduct two projects at the Fukushima Daiichi plant of significant implications for the future of decommissioning.

Robotic Inspection Unit 2 - Firstly, at unit 2, as of 13 February, TEPCO insert a robotic arm which was planned to come into direct contact with what TEPCO describe as molten material.[16] While no fuel was removed, TEPCO hope that this will provide more understanding of the condition of the fuel. Data from the test, such as the hardness of the debris and whether it is movable, will be used to develop equipment to remove and store the highly radioactive materials. Moving beyond initial inspection, TEPCO's next step will be to devise technology that is able to retrieve small samples of the molten fuel which will then be analyzed. It is unclear whether this will be conducted during 2019 or later.

Under TEPCO's road map for decommissioning the power plant revised in September 2017, the government and TEPCO are to decide on a reactor on which to start debris removal and determine how to carry out the procedure by March 2020. It looks increasingly likely that unit 2 will be the primary focus of removal efforts – due to more challenging conditions at units 1 and 3.[17] In addition, TEPCO is working on the evidence that a proportion of the molten fuel still remains inside the RPV of unit 2,[18] whereas their analysis concludes that the molten fuel in units 1&3 have passed

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14 If fuel debris has high concentration of nuclear fuel materials, has low concentration of neutron absorbers, and if the mixed ratio with reflector substances or coolants that serve as moderators accidentally reaches to a system that causes criticality, local and transient criticality events may occur.

15 Technical Strategic Plan 2017 for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company Holdings, Inc.,, August 31, 2017 Nuclear Damage Compensation and Decommissioning Facilitation Corporation, see http://www.dd.ndf.go.jp/en/strategic-plan/book/20171005_SP2017eFT.pdf

16 Chikako Kawahara, "1st contact made with melted nuclear fuel at Fukushima plant" Asahi Shimbun, 14 February 2019, see http://www.asahi.com/ajw/articles/AJ201902140041.html

17 Mainichi, "Gov't, TEPCO consider starting removal of debris from 2nd reactor at Fukushima nuke plant", 25 July 2018, see https://mainichi.jp/english/articles/20180725/p2a/00m/0na/002000c

18 In Unit 2, internal investigation of PCV was conducted in January 2018, continued from January and February 2017. It was confirmed that deposits, which seemed to be fuel debris, are accumulated in the bottom of pedestal, according to the result of analysis of the images obtained, as reported by NDF, "Technical Strategic Plan 2018 for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company Holdings, Inc. Overview", November, 2018 Nuclear Damage Compensation and Decommissioning Facilitation Corporation, see http://www.dd.ndf.go.jp/en/strategic-plan/book/20181109_SP2018eOV.pdf

through the bottom of the RPV and onto the concrete pedestal. Burn through into the pedestal as well some molten material outside the pedestal has been indicated by TEPCO as well.[19] However, the schedule of beginning actual removal which is scheduled to begin in 2021 lacks credibility. It is almost certain that these timeframes will be revised during the coming year – though any further delay will be resisted by the Government given the 2021 timeframe has been their target for the past five years. The 2019 IAEA mission report can be interpreted as signaling to the Japanese government/NDF and TEPCO to move more cautiously. While the IAEA do not explicitly state that the timeframe is unrealistic, they do signal that more preparation is required.

Reducing water injection unit 2 - A second operation, is the plan to reduce the amount of water pumped into the Reactor Pressure Vessel of unit 2.[20] This is premised on the inevitable decay heat of the molten fuel eight years after the meltdown. There appears to be a delay in this plan, originally scheduled for January 2019. As of 4 February 2019, TEPCO was injecting 72 cubic meters of water each day into each of the three destroyed Fukushima Daiichi reactors, including unit 2.[21] This compares with an average of 69.5 cubic meters since 3 January 2019.[22]

The aim of TEPCO is to reduce water injection at unit 2 by half, from 3.0 m^3/hour to 1.5 m^3/hour (35-36 cubic meters per day) then bring injection levels back up. The reactor temperature will then be monitored for seven days. In November TEPCO reported that the temperature in unit 2 at the bottom of the RPV (not molten fuel temperature) was 23 deg. C and are predicting a rise to 30 deg. C after the first test.[23] In March 2019 TEPCO had planned to stop all water injection at unit 2 for 7

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19 On 31st January 2017, TEPCO announced the results of a probe into Unit 2 – below the Reactor Pressure Vessel (RPV). Radiation levels were measured at 530 Sieverts (with a later measurement on 10th February of 650 Sv). A one meter hole was identified through the bottom grate below the RPV - the melt through hole is beside the Control Rod Drive exchanger and close to the center of the pedestal, which would be consistent with a burn through from the RPV into the sump pits in the containment structure below. The slow failure and small opening melted through the RPV likely allowed the molten fuel to burn down as it collected in the sump.

20 Osamu Tsukimori and Aaron Sheldrick, "Tepco said it would use the test results to better understand radioactive reactions during an emergency cooling halt." Reuters, 9 November 2018, see https://www.reuters.com/article/us-japan-disaster-nuclear-fukushima/fukushima-tests-to-help-assess-cooling-of-damaged-reactors-tepco-idUSKCN1NE0YW

21 TEPCO, "Situation of Storage and Treatment of Accumulated Water including Highly Concentrated Radioactive Materials at Fukushima Daiichi Nuclear Power Station (389th Release)" 4 February, 2019 Tokyo Electric Power Company Holdings, Inc., see https://www7.tepco.co.jp/wp-content/uploads/handouts_190204_02-e.pdf

22 TEPCO, "Situation of Storage and Treatment of Accumulated Water including Highly Concentrated Radioactive Materials at Fukushima Daiichi Nuclear Power Station (340th Release) 13 February, 2018 Tokyo Electric Power Company Holdings, Inc., see https://www7.tepco.co.jp/wp-content/uploads/180213e0101.pdf; TEPCO, "Situation of Storage and Treatment of Accumulated Water including Highly Concentrated Radioactive Materials at Fukushima Daiichi Nuclear Power Station (387th Release) 21 January, 2019 Tokyo Electric Power Company Holdings, Inc., see https://www7.tepco.co.jp/wp-content/uploads/handouts_190121_02-e.pdf; TEPCO, "Situation of Storage and Treatment of Accumulated Water including Highly Concentrated Radioactive Materials at Fukushima Daiichi Nuclear Power Station (386th Release) 15 January, 2019 Tokyo Electric Power Company Holdings, Inc., see https://www7.tepco.co.jp/wp-content/uploads/handouts_190115_02-e.pdf; and TEPCO, "Situation of Storage and Treatment of Accumulated Water including Highly Concentrated Radioactive Materials at Fukushima Daiichi Nuclear Power Station (385th Release) 9 January, 2019 Tokyo Electric Power Company Holdings, Inc., see https://www7.tepco.co.jp/wp-content/uploads/handouts_190109_02-e.pdf

23 TEPCO, "Checking the status of cooling of fuel debris at Fukushima Daiichi Nuclear Power Station Unit 2", 8 November, 2018 Tokyo Electric Power Company Holdings, Inc. Fukushima Daiichi D & D Engineering Company, see https://www7.tepco.co.jp/wp-content/uploads/handouts_181108_02-e.pdf

hours while monitoring for changes. TEPCO cites that they will abandon the injection stoppage at unit 2 if the temperature readings increase by 15 degrees. The temperature will be monitored using temperature gauges that were installed at the bottom of the reactor pressure vessel (RPV) and in the primary containment vessel (PCV) after the accident.[24]

TEPCO's thinking on this is that understanding the effect of reduced or no cooling has on the temperature of the molten fuel gives them assurance that in the event of prolonged loss of cooling, for example in the event of future seismic damage, they will know the number of hours they have before fuel temperature rise becomes critical. It is also however is potentially significant towards plans to reduce the accumulation of contaminated water, as well as determining options for accessing the molten fuel. In 2016 the Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF) reported that,

"With regard to the dry method, surface temperature of the fuel debris at the bottom of the D/W is estimated at 400 deg. C based on the assumption as follows: all fuel debris in Unit 1 fell inside the pedestal at the bottom of the D/W and located as disk shape, amount of decay heat in the target commencement period of fuel debris retrieval (2021), and condition of air cooling by natural convection. The temperature inside the fuel debris will be higher than surface."[25]

By 2018, the NDF was reporting that "Maintaining the cooling function: The decay heat of the fuel debris has been decreased dramatically since the core melt accidents. However, it may be necessary to keep the cooling function to prevent nuclides from shifting from the liquid phase to the gas phase due to thermal energy during the fuel debris retrieval work. At present, the cold shutdown state is maintained with keeping the temperature well below 100°C using cooling water. In addition, during the fuel debris retrieval work, it may be necessary to keep the temperature below the level at which the fuel debris retrieval device can continue to work without any problems for a long period of time." Again, the IAEA is not detailed in its analysis of this issue.

Molten Fuel / Corium Removal

The current strategic plan envisages molten fuel removal to begin 2021, with an estimated timeframe of 10 years to complete. The IAEA in 2013 noted optimistically that "it may take a further decade or more to accomplish."[26] In its latest 2019 mission report it has little to say on the reality of molten fuel/ corium removal other than,

"***Acknowledgment 16 (Fuel debris) -*** The IAEA Review Team also acknowledges significant progress is being achieved in clarification of the fuel debris distribution inside the reactor building of Units 1-3 since the 3rd Review Mission, and the step-by-step approach (from internal PCV

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24 Ibid.

25 NDF, "Technical Strategic Plan 2016 for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company Holdings, Inc", 13 July, 2016, Nuclear Damage Compensation and Decommissioning Facilitation Corporation, see http://www.dd.ndf.go.jp/en/strategic-plan/book/20170322_SP2016eFT.pdf

26 IAEA, "Report On Decommissioning And Remediation After A Nuclear Accident International Experts Meeting Vienna, 28 January–1 February 2013 Organized in connection with the implementation of the IAEA Action Plan on Nuclear Safety, see https://www.iaea.org/sites/default/files/decommissioning0913.pdf

investigation, fuel debris sampling and characterization, small scale retrieval to bulk retrieval) currently considered for the fuel debris retrieval."[27]

As of February 2019, no final decision has been made on which of the three reactors at Fukushima Daiichi will be prioritized for the start of efforts to remove molten fuel. That decision has been postponed during the last 2 years, and is currently scheduled to be made before end of FY2019 (in early 2020). The current strategic plan envisages that, "regarding the method of fuel debris retrieval for the first implementation unit to begin the operation, the fuel debris retrieval work for the first implementing unit will start within 2021 by determining the method of containing, transfer and storage (by FY2019) after due consideration of the results of the preliminary engineering work and R&D".[28] The NDF reported in November 2018 that molten fuel / corium is expected to be present in both the bottom of the primary containment vessel and the inside of the reactor pressure vessel of each unit, while acknowledging that "distribution varies among the units."[29] At that time, NDF proposed that, "The bottom of the primary containment vessel is most accessible and a certain amount of knowledge about it has already been accumulated through the investigation inside the primary containment vessel...There is a possibility that fuel debris retrieval could be started earlier".[30] The reality of experience with the two most serious reactor meltdowns prior to March 2011 highlights the folly of such claims.

The lessons from TMI and Chernobyl

The most relevant experiences of managing post accident molten fuel / corium are the 1979 Three Mile Island (TMI) unit 2 PWR reactor accident, and the 1986 Chernobyl unit 4 RBMK reactor accident. It has been noted that there are some similarities between the conditions of the molten fuel / corium in these two reactors and the situation at Fukushima Daiichi. As the NDF itself reported, "The stabilization for Unit-2 is most probable inside the vessel, that's why it means that the scenario of accident should be something like TMI-2 when molten materials of partially damaged core were stabilized inside the reactor vessel. And for Unit 1 and 3, the probable situation that corium is stabilized outside the vessel and from this point of view it is to some extent similar to Chernobyl-4 accident."[31]

27 Op.cit. IAEA January 2019.

28 NDF, "Technical Strategic Plan 2018 for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company Holdings, Inc. Overview", November, 2018, Nuclear Damage Compensation and Decommissioning Facilitation Corporation, see http://www.dd.ndf.go.jp/en/strategic-plan/book/20170322_SP2016eFT.pdf

29 NDF, "Technical Strategic Plan 2018 for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company Holdings, Inc. Overview", November, 2018, Nuclear Damage Compensation and Decommissioning Facilitation Corporation, see http://www.dd.ndf.go.jp/en/strategic-plan/book/20170322_SP2016eFT.pdf

30 NDF, "Technical Strategic Plan 2018 for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company Holdings, Inc. Overview", November, 2018, Nuclear Damage Compensation and Decommissioning Facilitation Corporation, see http://www.dd.ndf.go.jp/en/strategic-plan/book/20170322_SP2016eFT.pdf

31 Valery Strizhov, "The 1st International Forum on the Decommissioning of the Fukushima Daiichi Nuclear Power Station", Deputy Director, the Russian Academy of Sciences and Nuclear Safety Institute, Session IV Fuel Debris Retrieval ? C. A. Negin / CANegin&Associates, U.S. V. F. Strizhov / IBRAE, Russia, L. Szoke / Paks Nuclear Power Plant, Hungary K. Takamori / IRID T. Fukuda / NDF S. Koshizuka / The University of Tokyo, see http://ndf-forum.com/1st/common/data/pdf/presentation_t/en/Session-4.pdf

Three Mile Island – Although it is widely perceived that 'clean-up' of the TMI unit reactor was completed in the early 1990's[32] the actual situation is more complex, with final decommissioning scheduled for mid-21st century. The estimate on the amount of nuclear fuel that melted is in the range of 63 metric tons, with 19-20 tons dropping to the lower plenum of the RPV.[33] This is in contrast to the accident at Fukushima where most of the molten fuel has exited the RPVs. The resulting meltdown of the fuel at TMI led to a corium mass estimated at around 150 tons.[34] Of this, 100 tons of this corium was removed in the six years after the accident between 1985 and 1990.[35] An estimated 1000kg of molten fuel,[36] together with corium (material and parts of the reactor contaminated by this material) amounting to 50 tons remains inside the reactor.[37] The timeframe for decommissioning, including removal of this remaining fuel debris contaminated waste is actually scheduled for the period 2040-2053 (when the site license expires). Thus the timeframe for decommissioning TMI-2, since its partial meltdown in 1979, is in the range of 60-70+ years. The removed molten fuel was shipped to the Idaho National nuclear facility where it remains in storage. As in Japan, there remains no final disposal facility for high level waste in the United States.

Chernobyl – The 26 April 1986 meltdown at the Chernobyl unit 4 reactor led to the meltdown of the reactor core fuel of 190 tons. The resulting corium mass has been estimated at 540 tons.[38] To this extent, the volume of molten fuel/corium at Chernobyl is more comparable with the situation at the Fukushima Daiichi plant than that of TMI-2. However, there are significant differences in the geometry and configuration of corium debris and its location between Chernobyl and Fukushima.

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32 Associated Press, "14-Year Cleanup at Three Mile Island Concludes" New York Times, 15 August 1993, see https://www.nytimes.com/1993/08/15/us/14-year-cleanup-at-three-mile-island-concludes.html

33 Idaho National Laboratory, "TMI-2 Vessel Investigation Project Integration Report", April 1984, J. R. Wolf, J. L. Rempe, L. A. Stickler, G. E. Korth, D. R. Diercks, L. A. Neimark, D. W. Akers, B. K. Schuetz, T. L. Shearer, S. A. Chdvez, G. L. Thinnes, R. J. Witt, M. L. Corradini, J. A. Kos, NUREG/CR-6197 TMI V(93)EG10 EGG-2734, Idaho National Engineering Laboratory EG&G Idaho, Inc. Prepared for U.S. Nuclear Regulatory Commission, see https://inis.iaea.org/collection/NCLCollectionStore/_Public/25/052/25052631.pdf

34 Idaho National Laboratory, "TMI Unit 2 Technica! Information & Examination Program", Volume 6, Number 1 April 1986, see https://inldigitallibrary.inl.gov/TMI/EGG%20TMI%20Unit%202%20TI%20and%20EP%20Update%201986%20(7007743).pdf and GAO, "Nuclear Waste Shipping Damaged Fuel From Thr Mile Island to Idaho, Report to Congressional Requesters, August 1987, see https://www.gao.gov/assets/150/145542.pdf

35 John P. Clements, "Case Study Remediation of Three Mile Island Unit 2 in Preparation for Decommissioning", U.S. Nuclear Regulatory Commission, see https://www.nrc.gov/docs/ML1728/ML17289A047.pdf

36 "about 1000 kilograms of fuel there. It's all very fine material; 900 of it is in a reactor pressure vessel, the rest is distributed throughout the system." in Charles Negin, "The 1st International Forum on the Decommissioning of the Fukushima Daiichi Nuclear Power Station", C. A. Negin / CANegin&Associates, U.S., Session IV Fuel Debris Retrieval, C. A. Negin / CANegin&Associates, U.S. V. F. Strizhov / IBRAE, Russia, L. Szoke / Paks Nuclear Power Plant, Hungary K. Takamori / IRID T. Fukuda / NDF S. Koshizuka / The University of Tokyo, see http://ndf-forum.com/1st/common/data/pdf/presentation_t/en/Session-4.pdf

37 The contaminated material is primarily associated with systems and structures – see GPU Nuclear, "Three Mile lsland Nuclear Station, Unit 2 Docket No. 50-320. License No. DPR-73 Decommissioning Funding Status Report for the Three Mile lsland Nuclear Station". Unit 2, 27 March 2015 TMI-15-03, see https://www.nrc.gov/docs/ML1508/ML15086A337.pdf

38 Zbigniew Jaworowski, "Observations on the Chernobyl Disaster and LNT" 28 January 2010, see https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2889503/#b47-drp-08-148

For the Chernobyl accident, the accessibility of molten materials was relatively easy, because molten materials spread over different premises in the basement area under the reactor unit.

Table 2 - Nuclear Reactor Fuel Meltdown – TMI, Chernobyl and Fukushima Daiichi

Reactors	Start date of meltdown	Nuclear fuel (uranium) weight prior to accident	Estimated amount of molten fuel	Estimated amount of corium	Removal of corium timeframe	Decommissioning schedule timeframe	Costs
Three Mile Island unit 2	28 March 1979	93 tons	62 tons[39]	150 tons	1985-1990 (100 tons removed – 50 tons remaining - to be removed by 2053	2040-2053 (incl. Final removal of all molten fuel and contaminated material)	Fuel removal – US$ 973 million[40] – not including wider impact costs, decommissioning and final disposal costs.
Chernobyl unit 4	26 April 1986	190 tons[41]	190 tons	540 tons[42]	Over the next 100 years	Over the next 100 years	No overall estimate for decommissioning. Cost estimate of total accident costs, including economic impacts for 30 years to 2016 – US$800 billion.[43]
Fukushima Daiichi units 1-3	11 March 2011	Unit 1 – 69 tons[44] Unit 2 – 94 tons Unit 3 – 94 tons	69 tons 94 tons 94 tons	279 tons 237 tons 364 tons Total 880 Range between 609 and 1,141 tons	Ten years starting with removal in 2021 – to be completed by 2031.	3-4 decades	8 trillion yen (US$72 billion) official estimate (2016) revised from 2 trillion yen (US$18 billion) in 2013. In 2017 JCER estimate was 32 trillion yen (US$289 billion)[45]

39 Idaho National Laboratory, "TMI-2 Vessel Investigation Project Integration Report", April 1984, J. R. Wolf, J. L. Rempe, L. A. Stickler, G. E. Korth, D. R. Diercks, L. A. Neimark, D. W. Akers, B. K. Schuetz, T. L. Shearer, S. A. Chdvez, G. L. Thinnes, R. J. Witt, M. L. Corradini, J. A. Kos, NUREG/CR-6197 TMI V(93)EG10 EGG-2734, Idaho National Engineering Laboratory EG&G Idaho, Inc. Prepared for U.S. Nuclear Regulatory Commission, see https://inis.iaea.org/collection/NCLCollectionStore/_Public/25/052/25052631.pdf

40 World Nuclear Association, "Three Mile Island Accident" 2012, seehttp://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/three-mile-island-accident.aspx

41 Lars-Erik De Geer, Christer Persson & Henning Rodhe (2018) "A Nuclear Jet at Chernobyl Around 21:23:45 UTC on April 25, 1986," Nuclear Technology, 201:1, 11-22, DOI: see 10.1080/00295450.2017.1384269

42 Zbigniew Jaworowski,"Observations on the Chernobyl Disaster and LNT" 28 January 2010, see https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2889503/#b47-drp-08-148

43 Jonathan M. Samet and Flora L. Thornton and Joann Seo ,"The Financial Costs of the Chernobyl Nuclear Power Plant Disaster: A Review of the Literature", Distinguished Professor and Chair Department of Preventive Medicine Keck School of Medicine of USC Director, USC Institute for Global Health Project Specialist Department of Preventive Medicine Keck School of Medicine of USC (April 21, 2016), see https://www.greencross.ch/wp-content/uploads/uploads/media/2016_chernobyl_costs_report.pdf

44 TEPCO, "Overview of facility of Fukushima Daiichi Nuclear Power Station", see http://www.tepco.co.jp/en/nu/fukushima-np/outline_f1/index-e.html

45 Japan Center for Economic Research, "Accident Cleanup Costs May Rise to ¥50-70 Trillion - It's Time to Examine legal liquidation of TEPCO - Higher Transparency is Needed for the Reasons to Maintaining Nuclear Power", Tatsuo Kobayashi, Principal Economist, Professor Tatsujiro Suzuki, Specially Appointed Fellow (Director of Nagasaki University Research Center for Nuclear Weapons Abolition), Kazumasa Iwata, JCER President, see http://www.jcer.or.jp/eng/research/policy.html

As Table 2 indicates, the scale of the challenges at Fukushima Daiichi are of a different order of magnitude when compared to the 1979 TMI accident and even Chernobyl. In the case of TMI, current decommissioning of the reactor is scheduled to be completed as much as 70 years after the accident began. TMI was a one reactor, partial fuel melt accident and with 150 tons total of molten fuel / corium.

For Fukushima, molten fuel / corium accessibility is much more difficult than at Chernobyl due to Primary Containment Vessel (PCV) integrity and flooding and there is more of it. Again, as with TMI, the meltdown at Chernobyl-unit 4 was one reactor, compared to three at Fukushima Daiichi and with an estimated 880 tons (with a range from 609-1,141 tons). In contrast to the softly softly approach in the IAEA 2019 mission report to the Japanese government, the IAEA was more open in its critical assessment of the major challenges with decommissioning of Chernobyl.

A recent 2018 assessment from the IAEA, highlighted the challenge at Chernobyl for removal of molten fuel/corium, which stated, that it, "should be performed during next 100 years".[46]

Table 3 - IAEA prospective for post Chernobyl Shelter after 30 years of recovery: status, challenges and future safety - November 2018 "[47]

*** No technology & methodology for FCM (fuel contaminated material)/ RAW removal;**
*** No program for removal**
*** Lack of data about physical, chemical and other characteristics of current status of FCM and their destruction**
*** Challenging planning' of activity for removal of FCM and RAW**
*** High radiation exposure doses for workers and high "collective dose"**
*** Robotic technics' to be used and technical possibilities to remove FCM /RAW**
*** Physical 'accessibility' to places / premises of old SO with FCM / RAW**
*** Influence of 'fuel dust'**
*** Scope of 'project of removal"**
and finally, "is it possible to remove all FCM / RAW?"

All of these challenges remain in 2019 – 33 years after the start of the Chernobyl disaster.

And yet only 8 years into the Fukushima Daiichi disaster, the IAEA remains effectively silent on many of the same technical challenges that exist at the TEPCO plant – even though the reality at the plant remains an even greater challenge than that at Chernobyl.

There are clearly massive economic disparities between the economies of the Ukraine and Japan, and therefore the option to fund Fukushima Daiichi decommissioning should be available over the

46 Tetiana Kilochytska and Vladimir Michal, "IAEA prospective for post Chernobyl Shelter after 30 years of recovery: status, challenges and future safety", IAEA publications and projects considering 'post accidentInternational Atomic Energy Agency, International Scientific and Practical Conference "Transformation of the Shelter Object into Ecologically Safe System: Experience, Challenges and Solutions" 27-28 November 2018, Ukraine, see http://sof2018.dazv.gov.ua/presentations/pdf/kilochytska.pdf

47 Ibid.

coming decades – though it is a major problem for TEPCO.[48] However, on timescales alone, the current plan to remove all molten fuel from the three Fukushima Daiichi reactors is delusional.

Nuclear Fuel Burn Up and Radiological Risks

An important distinction between the radiological hazard at Chernobyl and Fukushima is the so called fuel burn up. Reactor operators have over recent decades sought to extend the period between refueling their reactors. This is driven by economics – the longer the uranium fuel remains in the reactor, the more electricity generation for a given quantity of uranium fuel. The consequence of this is that the fuel has a higher burn up rate - the thermal energy (heat) generated per unit mass of fuel. This is referred to as GigaWatt days ton Heavy Metal (GWd/tHM). One of the factors that permits higher burn up is a higher enrichment concentration of U-235 in the original fuel. For Chernobyl this was not an option as it was a natural uranium fueled reactor – with no enrichment, relying on the naturally occurring U-235 in the original uranium. This is one principal reason why the uranium fuel core was a massive 190 tons. But it is also means that the burn up rate for the fuel was low in comparison with the majority of nuclear reactors worldwide. Chernobyl unit 4 average fuel burn was 10.9GWd/tHM.[49] By contrast the nuclear fuel at the three Fukushima Daiichi reactor were operating at much higher burn up.[50] The reactors had been shutdown for maintenance in 2010, and had only resumed operation between September and November.[51] Consequently, the reactors had not achieved their GWd/tHM license limit by 11 March 2011. In the case of unit 1 the average fuel burn up was 25.8GWd/tHM, unit 2 was 23.1GWd/tHM and unit 3 was 21.8GWd/tHM.[52] In previous refueling cycles, TEPCO were operating the three reactors from between 11 and 14 months, which would have resulted in fuel burn up rates in the range of 40GWd/tHM. The risks of operating higher fuel burn up in terms of operational reactor safety have been long documented, including for plutonium MOX fuel, 32 assemblies of which were only loaded into Fukushima Daiichi unit 3 in September 2010.[53] Thus, the radiological conditions of the estimated 880 tons of

48 Shaun Burnie, "TEPCO's Atomic Illusion", Greenpeace Germany, 23 June 2017.

49 Volodymyr M. Pavlovych, "Nuclear Fuel in the Destroyed 4th Unit of Chernobyl NPP", Institute for Nuclear Research of the National Academy of Science of Ukraine, see http://www.rri.kyoto-u.ac.jp/NSRG/reports/kr79/kr79pdf/Pavlovych.pdf

50 A. Toba, "Burnup Extension Plan Of BWR Fuel And Its impact on the Fuel Cycle in Japan", Tokyo Electric Power Company, Inc., Tokyo, Japan, in Impact of High Burnup Uranium Oxide and Mixed Uranium– Plutonium Oxide Water Reactor Fuel on Spent Fuel Management, IAEA Nuclear Energy Series No. NF-T-3.8, International Atomic Energy Agency, Vienna, 2011, see https://inis.iaea.org/collection/NCLCollectionStore/_Public/24/045/24045337.pdf

51 Until 11 March 2011, Unit 1 had been operating for 165 days from 2010/9/27, Unit 2 had been operating for 113 days from 2010/11/18 and unit 3 had been operating for 169 days from 2010/9/23, see https://www.jstage.jst.go.jp/article/taesj/advpub/0/advpub_J11.040/_article

52 Kenji Nishihara, Isao Yamagishi, Kenichiro Yasuda, Kenichiro Ishimori, Kiwamu Tanaka, Takehiko Kuno, Satoshi Inada & Yuichi Gotoh (2015) Radionuclide release to stagnant water in the Fukushima-1 nuclear power plant1, Journal of Nuclear Science and Technology, 52:3, 301-307, DOI: 10.1080/00223131.2014.946455, see https://www.jstage.jst.go.jp/article/taesj/advpub/0/advpub_J11.040/_article

53 F Barnaby and S Burnie, "MOX Production Standards And Quality Control At Belgonucleaire And The Implications For Reactor Safety In Fukushima-1-3 Submission To The Fukushima District Court, Fukushima City, Japan", Oxford Research Group and Greenpeace International, December 26th, 2000, see http://www.fukuleaks.org/edanoleaks/Scribble_Japan_Earthquake/pdfs/moxqcsweden.pdf

molten corium fuel at Fukushima Daiichi was far more severe than the molten fuel at Chernobyl, and would have been even more severe if the accident had occurred towards the end of its cycle which would have been in summer/autumn 2011.

The burn up rate for the Fukushima Daiichi fuel is a critical factor in terms of the radiological threat, heat generation and consequences. The composition, heat output and radioactivity per ton of heavy metal of the molten fuel is entirely dependent upon the burn-up. As the radioactive elements in the molten fuel decay, they produce heat. As the abundance of these elements decreases with time, so does the heat production. For spent fuel routinely discharged from reactors, between four days and one year after discharge, the heat output decreases by roughly a factor of ten. Ten years after discharge, it is down by roughly a further factor of ten. By 100 years after discharge, it is down by another factor of five. The complexity is that in each of the reactor units at Fukushima the fuel is not in its original form inside fuel assemblies but in molten corium masses, therefore heat decay is not as easy to predict. Equally, the radioactive lethality is different. Under normal circumstances for about the first 100 years, spent fuel emits gamma radiation at a dose rate greater than 1 sievert per hour, which would be lethal to about 50% of adults (LD50) in three to four hours. Clearly, the conditions at Fukushima Daiichi are far from normal.

To illustrate the differences in the radiological inventory between Chernobyl and Fukushima Daiichi, let us focus on two radionuclides – Cesium (Cs-134 and Cs-137) and Strontium (Sr-90). As fission products, the burn up of the fuel is a major determinant of the total inventory of these radionuclides in the reactor fuel. In the case of Chernobyl unit 4, the total estimated cesium inventory as of 26 April 1986, and specifically Cs-134 and Cs-137, was 180 and 280 PBq respectively, for a total of 460PBq.[54] In the case of the reactors at Fukushima Daiichi, the total Cesium inventory was 1,419PBq. For Strontium-90, the Chernobyl unit 4, the inventory was 200PBq compared with 520PBq for the three Fukushima Daiichi reactors.[55]

Table 4 – Cesium and Strontium-90 inventories – Chernobyl-unit4 and Fukushima Daiichi units 1-3

Reactor	Cesium 134	Cesium 137	Total Cesium	Strontium 90	Total Strontium 90
Chernobyl unit 4	180PBq	280PBq	460PBq	200PBq	200PBq
Fukushima Daiichi 1	190PBq	203PBq	1,419PBq	150PBq	520 PBq
Fukushima Daiichi 2	277PBq	256PBq		190PBq	
Fukushima Daiichi 3	252PBq	241PBq		180PBq	

54 OECD, “Chernobyl: Assessment of Radiological and Health Impact 2002 Update of Chernobyl: Ten Years On Chapter II The release, dispersion and deposition of radionuclides”, see https://www.oecd-nea.org/rp/chernobyl/c02.html

55 Kenji Nishihara, Isao Yamagishi, Kenichiro Yasuda, Kenichiro Ishimori, Kiwamu Tanaka, Takehiko Kuno, Satoshi Inada & Yuichi Gotoh (2015) Radionuclide release to stagnant water in the Fukushima-1 nuclear power plant1,Journal of Nuclear Science and Technology, 52:3, 301-307, DOI:10.1080/00223131.2014.946455; and Estimation of In-plant Source Term Release Behaviors from Fukushima Daiichi Reactor Cores by ForwardMethod and Comparison with Reverse Method Tae-Woon Kim1,*, Bo-Wook Rhee2, Jin-Ho Song2, Sung-Il Kim2, Kwang-Soon Ha21 Risk and Environmental Safety Research Division, Korea Atomic Energy Research Institute, Daejeon, Korea; 2 Thermal Hydraulics and Severe Accident Research Division, Korea Atomic Energy Research Institute, Daejeon, Korea, Journal of Radiation Protection and Research 2017;42(2):114-129 https://doi.org/10.14407/jrpr.2017.42.2.114

Clearly, the radiological threat from Chernobyl, 33 years after the accident, is severe. However, the Fukushima Daiichi inventory is 2.5 times greater in the case of Cs-137 and 2.6 times greater for Sr-90 than that at Chernobyl. None of this is addressed by the IAEA in their 2019 mission report.

For much of the first 100 years, the radioactivity of the molten corium fuel at Fukushima Daiichi will be dominated by the fission products—by two 30-year half-life fission products, Sr-90 and Cs-137, after the first ten years. After a few hundred years, the total radioactivity is dominated by the transuranics: plutonium, americium, neptunium, and curium. These have half lives ranging from 18 years (Curium 244) and 24,100 years (Plutonium 239).The primary threat to public health would be water contamination and ingestion of the long-lived radioisotopes. It takes several hundred thousand years for the ingestion radio-toxicity of nuclear fuel to become less than that of the natural uranium (including its associated decay products) from which it was derived. The long-term hazards from the radio-toxicity of the 880 tons of molten corium at Fukushima Daiichi require that it be isolated from environment for at least hundreds of thousands of years – currently it is not.

Reasons for IAEA near silence on Fukushima Daiichi challenges

The IAEA is absolutely right to highlight the explicit challenges at Chernobyl, including the timeframe of 100 years and lack of technology. But there is no justification for it failing to address the same issues in its 2019 mission report on Fukushima Daiichi. The answer as to why is more obvious: to do so would expose the overall fallacy of the current plan for Fukushima Daiichi. Further, it would undermine the overall narrative of the Japanese government that they have a plan, a timetable for the decommissioning. The international politics of nuclear power are in this case, clear. Under Director General Yukiya Amano, a 37 year career diplomat of the Japanese foreign ministry prior to his appointment to the IAEA,[56] the agency knows that exposing Japan's plans for Fukushima as not credible, it is just not done. Not least, as telling the people of Japan of the actual challenges at the site would set back Japanese government policy for the restart of nuclear power. It is also not in the interests of the IAEA as it advocates the global expansion of nuclear power.

The closest the IAEA comes to saying that there should be some revision in the decommissioning schedule, is when it reports that,

"**Advisory Point 6** ...The IAEA Review Team advises TEPCO to consider implementation of international good practice approaches to technology maturation and deployment as well as development of contingency plans to accommodate any schedule delays... (and) ***Advisory Point 19 (Fuel debris) -*** Whilst significant progress has been achieved in estimation of the fuel debris distribution inside the reactor building of Units 1-3, there is recognition that more must be done. The IAEA Review Team supports continuing efforts to more precisely understand the fuel debris distribution inside each unit, the associated level and distribution of radiation encountered...The IAEA Review Team advises that before the commencement of the fuel debris retrieval activities, there should be a clear implementation plan defined to safely manage the retrieved material. TEPCO should ensure that appropriate containers and storage capacity are available before starting the fuel debris retrieval. Sufficient characterization (e.g. estimation of criticality, hydrogen emission, neutron activity, thermal condition, parameters of neutron-multiplying medium, etc.) of

56 IAEA, Biography of Director General Yukiya Amano, see https://www.iaea.org/about/dg/biography

the fuel debris environment will support successful safe debris retrieval and design of related facilities and equipment including containers and any treatment and storage facilities."[57]

Given the complexity and need for extreme caution in proceeding with inspections, this could be read as saying the IAEA does not think a 2021 timeframe is credible – but given the politics of this issue - they are unlikely to be so explicit – at least in public.

Accessing the reactors

After several years of consideration, the NDF reported in 2018 that a combination of methods will be used to access the Fukushima Daiichi reactors. Their assumption is that access will be made "to the bottom of the primary containment vessel from the side and that access is made to the inside of the reactor pressure vessel from the upper part of the vessel."[58] At least on current information, it is likely to be unit 2 that is prioritized.

Unlikely as it is that retrieval will begin in 2021, it is at that point that major hazards arise. As IRID engineer Kenro Takamori has noted,[59] "As for risk management in retrieval of fuel debris, when you touch the fuel debris there is a risk of re-criticality, so development of evaluation technology in that area is also necessary. And at the same time it will be an effort over 40 years in order to ensure safety. Seismic assessment over 40 years' time; how the structural integrity will be maintained. If not, then what are the areas for reinforcement and what the ultimate state that has to be anticipated? We also will be conducting evaluation in those areas as well. We have investigated technologies related to fuel debris retrieval based on comprehensive evaluation of element technologies. However, there is still ongoing development of the methodology; many ideas and options. And right now no detailed plans are being developed, especially we have to ensure safety so the criticality management systems, the circulation feed water cooling system, purification system, those are necessary. Many of the safety and functional requirements will also have to be identified before we are actually able to retrieve the debris. Also, in the designing process we would have to design it into the process; safety, risk management, and also cost, and the time required. So in the design stage we will also take into consideration these various factors."

These are all issues that remain largely unresolved. As Toshihiko Fukuda of the NDF has explained there are three main issues -

"First point is the distribution of the fuel debris, in the reactor core regions, bottom of the RPV, bottom of the PCV, is it inside or outside of the pedestal, how much fuel debris do we have at each location? And also does any high risk fuel debris exist or present? From criticality perspectives, for example, is there any stub-like fuel? And lastly, the state of the damaged equipment. For example,

57 Op.cit. IAEA January 2019.

58 NDF, "Technical Strategic Plan 2018 for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company Holdings, Inc. Overview", November, 2018, Nuclear Damage Compensation and Decommissioning Facilitation Corporation, see http://www.dd.ndf.go.jp/en/strategic-plan/book/20181109_SP2018eOV.pdf

59 Kenro Takamori, "The 1st International Forum on the Decommissioning of the Fukushima Daiichi Nuclear Power Station", Deputy Director, the Russian Academy of Sciences and Nuclear Safety Institute, Session IV Fuel Debris Retrieval, C. A. Negin / CANegin&Associates, U.S. V. F. Strizhov / IBRAE, Russia, L. Szoke / Paks Nuclear Power Plant, Hungary K. Takamori / IRID T. Fukuda / NDF S. Koshizuka / The University of Tokyo, see http://ndf-forum.com/1st/common/data/pdf/presentation_t/en/Session-4.pdf

there are so-called MCCI products made of fuel debris interacted with concrete at the bottom of the PCV, and the status of the pedestal."[60]

TEPCO is making progress in understanding some of these issues, but is a long way from reaching an understanding that would permit commencement of molten fuel / corium removal.

Nuclear waste management

The IAEA mission report is far more explicit in expressing its doubts about current enormous nuclear waste management plans at the Fukushima Daiichi plant. The Fukushima Daiichi plant site is de-facto a nuclear waste generating and storage facility – though it was never designed to be. The range of waste forms, conditions and hazards are not possible to go into detail in this briefing. But for example, to highlight the challenges. While the contaminated water issue rightly is a major focus of attention, the processing of the many radionuclides is on a daily basis generating complex waste forms and in volume. As the IAEA explains,

"The current volume of post-accident waste is reported to be in excess of 400,000 m3 and more than 4,000 vessels and the volume is projected to increase to 770,000 m3 and more than 7,000 vessels in ten years without additional countermeasures. However, with implementation of currently planned measures such as volume reduction, recycling and incineration the volume of stored waste could be significantly reduced to the order of 250,000 m3."[61]

TEPCO's roadmap and NDF 2018 Strategic Plan specifies that the prospects of a processing/disposal method and technology related to its safety should be made clear by around FY2021. However, the IAEA notes that, "some of the waste processing technologies that are being adopted have ***a significant risk*** of schedule slippage. Delays could be experienced in many ways including in the design process, in research and development, in procurement, in factory acceptance testing, in construction and in installation and commissioning. In addition, treatment rates could be lower than planned due to unforeseen difficulties. In this respect, further ***review of the schedule appears warranted*** for the installation and commissioning activities."

In terms of final disposal, there are no options for offsite disposal of the vast nuclear waste volumes already generated at the Fukushima Daiichi site, never mind the even greater volumes to be generated over the coming decades. These waste forms pose a major safety hazard to workers on the site, as well as risking off-site contamination. Something experienced during 2013 when offsite radioactive releases were significant.

Offsite risks from decommissioning

The on-going risks to the environment, and therefore public safety, from the Fukushima Daiichi plant was highlighted by the accidental releases that occurred in August 2013. This is at variance from the government's response to the United Nations Special Rapporteurs in 2017. In 2013, air monitoring stations north of the plant, including Minami Soma, an area that was less contaminated

60 Toshihiko Fukuda, "The 1st International Forum on the Decommissioning of the Fukushima Daiichi Nuclear Power Station", Deputy Director, the Russian Academy of Sciences and Nuclear Safety Institute, Session IV Fuel Debris Retrieval, C. A. Negin / CANegin&Associates, U.S. V. F. Strizhov / IBRAE, Russia, L. Szoke / Paks Nuclear Power Plant, Hungary K. Takamori / IRID T. Fukuda / NDF S. Koshizuka / The University of Tokyo, see http://ndf-forum.com/1st/common/data/pdf/presentation_t/en/Session-4.pdf

61 Op.cit. IAEA January 2019.

than other areas in 2011, suddenly reported Cs-137 activity levels that were 30-fold above the background. Scientists reported in 2015 that the most likely reason was debris removal operations at the site conducted on 19th August, 2013.[62] On the same day, TEPCO reported that “an alarm indicating high radioactivity level went off at the continuous dust monitor installed in front of the Main Anti-earthquake Building.”[63] TEPCO began in August 2013 debris removal in the Unit 4 spent fuel pool area,[64] and worker dose data at the site for the period in July had shown higher than normal levels,[65] which of course is a major concern outside the specifics of this event in 2013.

The study on the offside contamination based on 21 soil samples, included, “One soil sample in the center of the simulated plume exhibited a high 90Srcontamination (78±8 Bq kg-1) as well as a high Sr-90/Cs-137 ratio (0.04); both phenomena have usually been observed only in very close vicinity around the FDNPP. We estimate that through the resuspension of highly contaminated particles in the course of these earthmoving operations, a gross Cs-137 activity of ca.2.8×1011Bq has been released.”[66]

In Minami Soma, as the authors reported, “typical background values in these filter stations ranged from 0.04 to 0.95 mBq m–3; on August 19, 2013, however, 26.3 mBq m–3 have been measured. The sampling location in Minami Soma was approximately 20km from the nuclear plant. Prior to the Fukushima nuclear accident, Cs-137 concentrations were in the range of μBq m–3 or less, mainly due to the fallout of atmospheric releases... (and) in soil samples...noticeable 90Sr contaminations (˜20 and ˜270Bq kg) were also detected in the south direction about 15 km,” from the Fukushima Daiichi plant. “These results emphasize the importance of radionuclides monitoring beyond the Namie district.”[67]

The study revealed, “significant intermittent releases of airborne radionuclides in August 2013, long after the initial releases caused by the Fukushima nuclear accident in spring 2011...Finally, this study evidences that significant secondary releases of radionuclides by resuspension processes and

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62 Environmental Science, “Post-accident sporadic releases of airborne radionuclides from the Fukushima Daiichi nuclear power plant site”, Georg Steinhauser, Tamon Niisoe, Kouji H Harada, Katsumi Shozugawa, Stephanie Schneider, Hans Arno Synal, Clemens Walther, Marcus Christl, Kenji Nanba, Hirohiko Ishikawa, and Akio Koizumi, Environ. Sci. Technol, 8 October 2015, see https://pubs.acs.org/doi/abs/10.1021/acs.est.5b03155

63 TEPCO, “Alarm Went Off at the Dust Monitor Installed in Front of the Main Antiearthquake Building at Fukushima Daiichi Nuclear Power Station”, August 19, 2013 Tokyo Electric Power Company, https://www4.tepco.co.jp/en/nu/fukushima-np/handouts/2013/images/handouts_130819_03-e.pdf

64 TEPCO, “Launch of Debris Removal and Transfer of Launch of Debris Removal and Transfer of Equipments inside the Reactor Well, Reactor Pressure Equipments inside the Reactor Well, Reactor Pressure Vessel, Vessel, and Spent Fuel Pool of Unit 4 and Spent Fuel Pool of Unit 4 at Fukushima Daiichi Nuclear Power Station at Fukushima Daiichi Nuclear Power Station” Tokyo Electric Power Company August 26, 2013, see https://www4.tepco.co.jp/en/nu/fukushima-np/handouts/2013/images/handouts_130826_07-e.pdf

65 TEPCO, “Exposure Dose Evaluation of the Workers at Fukushima Daiichi Nuclear Power Station,” Press Releases 2013, Press Release, 30Aug 2013, see http://www.tepco.co.jp/en/press/corp-com/release/2013/1230162_5130.html

66 Ibid. Twenty-one soil samples were taken on September 7, 2014 in the Minami Soma area (Figure S1) and investigated for γ-emitting radionuclides (134Cs, 137Cs), as well as for 90Sr and Pu.

67 Environmental Science, “Post-accident sporadic releases of airborne radionuclides from the Fukushima Daiichi nuclear power plant site”, Georg Steinhauser, Tamon Niisoe, Kouji H Harada, Katsumi Shozugawa, Stephanie Schneider, Hans Arno Synal, Clemens Walther, Marcus Christl, Kenji Nanba, Hirohiko Ishikawa, and Akio Koizumi, Environ. Sci. Technol, 8 October 2015, see https://pubs.acs.org/doi/abs/10.1021/acs.est.5b03155

eolian transport of contaminated particles are conceivable scenarios in the future. Most importantly, the ongoing decommissioning and dismantling activities of the crippled Fukushima reactors, thereby, pose an imminent health threat for future decades. A resuspension of highly contaminated particles from the FDNPP site not only involves the risk of a massive radio-cesium dispersion; these particles are likely to carry an even more hazardous load such as less volatile, bone-seeking90Sr or actinides (including plutonium)." Importantly, the potential releases of plutonium and strontium (and in the case of 2013 actual) have particular relevance for public health, including dose assessments. (see below)

Whereas the Japanese government communication to the people of Japan, including Fukushima, and the wider international community, that the plant is under control, the evidence demonstrates otherwise, including that there have been significant off-site releases of radioactivity from the site. As former Prime Minister Koizumi put it in 2016, "When [Abe] said the situation was under control, he was lying," Koizumi told reporters in Tokyo. "It is not under control."[68]

Given the many decades and longer that work will be required to continue at the Fukushima Daiichi plant, the potential for significant further off-site releases, including to the terrestrial and marine environment, the risks are self evident.

Radionuclide hazards

Strontium

While the Fukushima Daiichi accident released large amounts of radioactivity into the environment, the majority of the major hazardous radionuclides remains at the site. One in particular is of particular concern – Strontium-90 (Sr-90)

While Sr-90 releases to the environment from the Fukushima Daiichi plant were a small fraction of the overall releases in 2011, that does not mean there is no strontium threat in Fukushima. Sr-90, which has a half life of 28.8 years, is a bone seeking fission product isotope which if inhaled or ingested poses a far higher risk to human health than the equivalent activity of cesium-137.

The government of Japan, in its response to United Nations Special Rapporteur Grover in May 2013[69] stated that "The Special Rapporteur recommends estimating the internal dose of radioactive strontium (Sr-90), which emits beta-radiation, by urinalysis because it is difficult to measure beta-radiation by WBC. Because contamination of Sr-90 is much less than that of radioactive cesium from the Fukushima nuclear accident, it is reasonable to focus on the internal dose of cesium. The concentration of 90Sr was between 1/19,000 and 1/600 of that of radioactive cesium in the monthly fallout measured by the Ministry of Education, Culture, Sports, Science and Technology (MEXT).[70] Thus, there is no strong incentive to measure concentration of Sr-90 in urine for the health management of the residents." and in its "Correction of errors" section it stated that,"Concentration

68 The Guardian, "Former Japan PM accuses Abe of lying over Fukushima pledge", Justin McCurry, 7 September 2016, see https://www.theguardian.com/environment/2016/sep/07/former-japan-pm-junichiro-koizumi-accuses-abe-lying-over-fukushima-pledge

69 Op.cit. Grover. (2 May 2013)

70 Analysis of strontium-90 in the monthly fallout of each prefecture (http://radioactivity.nsr.go.jp/ja/contents/6000/5808/24/194_Sr_0724.pdf (in Japanese)

of strontium-90 is also monitored in food and water. The level of Sr-90 concentration is controlled in food and water. Thus it is not necessary to measure concentration of Sr-90 by urine tests."[71] The problems with this misleading reassurance are two fold.

Firstly, it ignores the significant, if not unprecedented, threat posed by 90Sr from what remains at the plant. For this we need to understand the amount that was in the reactor cores at the time of the accident, the so-called reactor core inventory. And secondly it fails to address the significantly higher risks from Sr-90 in comparison to Cs-137, including dose estimates to the population.

The inventory of Sr-90 in the three operation reactors in March 2011, as well as in the recently removed fuel core from unit 4 have been calculated at 5.2E + 17 in Bq.[72] This is 520 PBq. The releases in 2011, during the initial phases of the accident, to the atmosphere have been estimated to have been 0.14 PBq.[73] The Sr-90 volume in the molten fuel / corium is an enormous hazard, including for on going water contamination.

This 520 PBq amount does not include the amount of Sr-90 released to the marine environment as well as what has been collected and processed in the water management program since 2011. The calculations are that in the range of 1-3% of the Sr-90 in the cores was diluted in water.[74] This is an enormous amount of Sr-90 when one thinks that the atmospheric release was 0.026% of the inventory, but also highlights the scale of the remaining threat in the molten fuel / corium, with 97-98% of the Sr-90 remaining.

While Sr-90 releases from the Fukushima Daiichi were a fraction of that released from the Chernobyl accident, that does not mean there is an absence of risk to the people of Fukushima from what has already been released.

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71 "Correction of errors from the Government of Japan on the Report of the Special Rapporteur on the right of everyone to the enjoyment of the highest attainable standard of physical and mental health", Anand Grover, A/HRC/23/41/Add.5/Rev.1, Report of the Special Rapporteur of the Special Rapporteur on the right of everyone to the enjoyment of the highest attainable standard of physical and mental health, Anand Grover Addendum Mission to Japan: comments by the State on the report of the Special Rapporteur," A/HRC/23/41/Add.5/Rev.1, 27 May 2013.

72 Journal of Nuclear Science and Technology "Radionuclide release to stagnant water in the Fukushima-1 nuclear power plant1", Kenji Nishihara, Isao Yamagishi, Kenichiro Yasuda, Kenichiro Ishimori, Kiwamu Tanaka, Takehiko Kuno, Satoshi Inada & Yuichi Gotoh (2015) , 52:3, 301-307, DOI: 10.1080/00223131.2014.946455, see https://doi.org/10.1080/00223131.2014.946455

73 Nature, "Strontium-90 activity concentration in soil samples from the exclusion zone of the Fukushima daiichi nuclear power plant", Sarata Kumar Sahoo1, Norbert Kavasi1, Atsuyuki Sorimachi2,3, HidekiArae1,ShinjiTokonami3, JerzyWojciech Mietelski4, Edyta Łokas4 & SatoshiYoshida1, Project for Environmental Dynamics and Radiation Effects, National Institute of Radiological Sciences, 4-9-1 Anagawa, Inage-ku, Chiba 263-8555, Japan. 2 Department of Radiation Physics and Chemistry, Fukushima Medical University, 1 Hikarigaoka, Fukushima, Fukushima 960-1295, Japan. 3 Institute of Radiation Emergency Medicine, Hirosaki University, 66-1 Hon-cho, Hirosaki City, Aomori 036-8564, Japan. 4Department of Nuclear Physical Chemistry, Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Radzikowskiego 152, Poland. 6 April 2016, see https://www.nature.com/articles/srep23925.pdf

74 Op.cit. Journal of Nuclear Science and Technology.

An under reported study published in 2015[75], highlighted the uncertainties of the governments current future dose estimation, specifically for internal exposure. A key finding of the study is that the correlation between 90Sr and 137Cs may soon no longer follow the assumption of Japanese authorities, which is based on a maximum 90Sr/137Cs activity ratio of 0.1 or even 0.003 in food. In other words, the authorities estimate the amount of 90Sr in samples, including food (particularly forest foods) based on the ratio the found in the early phases of the accident and first year or so. If the ratio changes the dose calculations can become less reliable.

But as Merz et al report, “Background data from Japan suggested that after several years following the release into the environment, the 90Sr/137Cs activity ratio observed in food rises significantly (most of the samples showing a ratio > 2).”As the authors concluded as a result of their study, “This calls for an adaption of the current policy and also increased monitoring efforts with respect to 90Sr” and that “The diminution of the regulatory limit (90Sr/137Cs = 0.003) as of April 2012 was an adaption into the wrong direction. The Japanese authorities are urged to reimplement the “old” limit (90Sr/137Cs = 0.1), which probably will have to be raised further in the future. This observation fosters the need for continuous monitoring of both 137Cs and 90Sr; otherwise the 90Sr content of food will soon be underestimated.”

There clearly needs to be far more investigations in the strontium releases from the Fukushima Daiichi plant, including those from 2011, and in the intervening years. The risk that government dose models for Fukushima citizens could be significantly underestimated as a resulting of the evolution of Sr-90 in the environment of Fukushima prefecture is of major concern to Greenpeace.

Water management

Update to Greenpeace Fukushima Daiichi water report January 2019. There is general agreement that the management of contaminated water, including groundwater migration onto the site, is one of the major challenges at the Fukushima Daiichi site. There are no prospects in the coming few years that TEPCO will bring this issue under control to prevent further increase of contaminated water, nor secure the governments preferred option of Pacific Ocean discharge.[76] TEPCO or the government will therefore fail to meet their 2020 target of reducing to zero the accumulation of contaminated water through groundwater migration. Therefore for the foreseeable future securing additional tanks storage capacity remains the only option for TEPCO, while continuing to try and improve its water processing systems.

As of 7 February 2019, there were 996,353 cubic meters of processed water in storage tanks at the Fukushima Daiichi plant – this was an increase of 1,520 cubic meters from the week before.[77] In

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75 Environmental Science & Technology, “Analysis of Japanese Radionuclide Monitoring Data of Food Before and After the Fukushima Nuclear Accident”, Stefan Merz,† Katsumi Shozugawa,*,‡ and Georg Steinhauser*,§,⊥†Atominstitut, Vienna University of Technology, Stadionallee 2, 1020 Vienna, Austria‡Graduate School of Arts and Sciences, The University of Tokyo, Meguro-ku, Tokyo 153-8902, Japan§Environmental and Radiological Health Sciences, Colorado State University, Fort Collins, Colorado 80523, United States ⊥Institute of Environmental Radioactivity, Fukushima University, Fukushima 960-1296, Japan, published by the American Chemical Society, 2015, see https://pubs.acs.org/doi/abs/10.1021/es5057648

76 Greenpeace, “TEPCO WATER CRISIS”, Greenpeace Germany Briefing, 22 January 2019, see http://greenpeace.jp/wp-content/uploads/2019/01/TEPCO_Water_Crisis.pdf

77 TEPCO, “Storage and treatment of high level radioactive accumulated water (as of February 7, 2019)”, Situation of Storage and Treatment of Accumulated Water including Highly Concentrated Radioactive Materials at Fukushima

terms of storage tank capacity it was 1,040,100 cubic meters, an increase of 4,000 cubic meters from the week before. At this rate of accumulation, processed water will surpass 1 million cubic meters in late February 2019 for the first time. In addition to this processed water (water that has passed through the ALPS and other water treatment facilities), a further 119,357 cubic meters of strontium treated water was in storage tanks as of 7 January 2019 (an increase of 130 cubic meters in one week).

The IAEA in its 2019 report to the Japanese government warned that, "with the current capacity of 970,000 m3, can only be a temporary measure while a more sustainable solution is needed." What it did not provide details on is the potential additional capacity with the installation of new steel tanks which in the week to 7 February increased by 4,000 cubic meters (4 tanks). Inevitably, TEPCO will need to continue to increase tank capacity during the coming years. Even if the Government finally takes a decision to discharge water into the Pacific, it will likely not be for several years, and potentially longer if all water has to be processed for a second time through the ALPS (approximately 6 years).

New tank capacity

If water continues to accumulate at the same rate as in the year from 8 February 2018 when it was 850,660 cubic meters[78] – an increase of 120,000 cubic meters - it would require an additional 120 storage tanks per annum. In the year to February 2019, TEPCO installed an additional 163 tanks (163,000 cubic meters) of capacity. Of course the water accumulation fluctuates, particularly during heavy rain and during the typhoon season, with the winter to December 2018 being particularly low in rainfall, with weekly accumulation in the past as high as 4000 cubic meters. The IAEA notes that site capacity constraints limit the total tank storage available is constrained to 1.37 million cubic meters, "meaning that the storage of ALPS treated water is expected to reach full capacity within the coming three to four years."[79] The physical constraints of the site (the southern half of the site is largely occupied by the tanks, the northern half of the site is needed for waste storage and processing facilities) leave little room for additional tanks beyond 1.37 million m3.

The IAEA and Pacific Discharge

The IAEA was one of the earlier proponents (2015) of the option to discharge processed water with high radioactive tritium content.[80] In its latest mission report to the Japanese government, the IAEA acknowledges that public confidence in TEPCO has been undermined by the disclosures in 2018 that water processing had failed to remove radionuclides such as strontium, and which TEPCO been less than transparent in reporting. It acknowledges that the five options under consideration for

Daiichi Nuclear Power Station (389th Release), see https://www7.tepco.co.jp/wp-content/uploads/handouts_190204_02-e.pdf

78 TEPCO, "Situation of Storage and Treatment of Accumulated Water including Highly Concentrated Radioactive Materials at Fukushima Daiichi Nuclear Power Station (339th Release)", 5 February, 2018, see https://www7.tepco.co.jp/wp-content/uploads/180205e0101.pdf

79 Op.cit. IAEA January 2019.

80 IAEA, "Mission Report IAEA International Peer Review Mission On Mid-And-Long-Term Roadmap Towards The Decommissioning Of Tepco's Fukushima Daiichi Nuclear Power Station Units 1-4 (Third Mission)", Tokyo and Fukushima Prefecture, Japan, 9 – 17 February 2015 see https://www.iaea.org/sites/default/files/missionreport130515.pdf

dealing with the contaminated water,[81] including ocean discharge, will require, “a communication plan ensuring a proactive and timely dissemination of information to stakeholders and general public are necessary.”

The IAEA Review Team commends TEPCO for implementing the full set of the countermeasures against the groundwater ingress into the damaged facilities and against leakage of contaminated water from the buildings and from the site, thus contributing to reduction in the generation of contaminated water and to the protection of the workers, public and the environment, and the management of the site boundary dose.

“Despite the improvements in addressing the root causes contributing to the generation of contaminated water, the IAEA Review Team continues to identify water management as critical to the sustainability of decommissioning activities, in particular the resolution of the disposition path for the ALPS (Advanced Liquid Processing System) treated water containing tritium and other radionuclides in tanks. With the volume of ALPS treated water expected to reach the planned tank capacity of 1.37 million m3 within the coming three to four years, and considering current site facility plan for space allocations, and that further treatment and control of the stored water before disposition would be needed for implementation of any of the five solutions considered by the Japanese Government (as TEPCO expressed at the Sub-committee on handling of ALPS treated water, October 1, 2018), a decision on the disposition path should be taken urgently engaging all stakeholders.”

Interestingly the Japanese government sets a maximum dose rate at the site boundary of the Fukushima Daiichi plant of 1mSv/y. “Government Regulations for Storing Contaminated Water in Tanks(Effective dose of 1mSv/year [or less] at site borders). While commendable, this is not consistent with its policy applied to wider Fukushima contaminated areas is to permit annual public exposure up to 20mSv/y.

The Nuclear Regulation Authority requires that additional doses (additional doses newly given off by the power station facility that exclude naturally occurring radiation) posed on site borders from rubble and contaminated water stored at the power station site must be under 1mSv/year. This “effective dose at site borders” is used as a safety management standard when storing contaminated water in tanks on site.[82] Measures appear to being applied to minimize exposure to workers at the Fukushima Daiichi site, while up to 20mSv/y is permitted for Fukushima citizens, including women and children.

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81 The five options, decided in 2016, are: * geosphere injection (no pre-treatment/ post-dilution/ post-separation); * offshore release (post-dilution/ post-separation) * vapor release (no pre-treatment/ post-dilution/ post-separation)* hydrogen release (no pre-treatment/ post-separation) and, * underground burial (no pre-treatment); see METI, “Tritiated Water Task Force Report”, June 2016 Tritiated Water Task Force” June 2016, see http://www.meti.go.jp/english/earthquake/nuclear/decommissioning/pdf/20160915_01a.pdf; and CNIC, “The Fukushima Daiichi Nuclear Accident: Current State of Contaminated Water Treatment Issues and Citizens’ Reactions”, 2 October 2018, see http://www.cnic.jp/english/?p=4219

82 TEPCO, “Treated water portal site”, February 2019, see http://www.tepco.co.jp/en/decommission/progress/watertreatment/index-e.html