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REVIEW

IMPLICATIONS OF TEPHRA (VOLCANIC ASH) FALL-OUT ON THE OPERATIONAL SAFETY OF THE SENDAI NUCLEAR POWER PLANT

CLIENT: **GREENPEACE GERMANY**

REPORT REF Nº **R3229-A1** - SUMMARY

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A DIFFICULTY ENCOUNTERED IN PREPARING THIS REVIEW HAS BEEN ACCESS TO DOCUMENTS AND DATA THAT ARE ONLY PUBLICLY ACCESSIBLE IN JAPANESE LANGUAGE VERSIONS. THIS MAINLY APPLIES TO DOCUMENTS, GUIDES AND SUBMISSIONS FROM THE NUCLEAR REGULATORY AUTHORITY (NRA) - THAT SAID, IT IS UNDERSTANDABLE THAT THE NRA IN PRESSING AHEAD WITH INTRODUCTION OF THE *NEW REGULATORY REQUIREMENTS* QUITE CORRECTLY PRIORITISED JAPANESE LANGUAGE VERSIONS. HOWEVER, THIS MAY HAVE GIVEN RISE TO TWO AREAS OF INCOMPLETENESS IN THE REVIEW: FIRST, THAT THE LITERATURE SURVEY MAY NOT HAVE BEEN COMPLETELY COMPREHENSIVE AND, SECOND, THE SHORT TIME AND LIMITED RESOURCES AVAILABLE FOR TRANSLATION HAVE NOT BEEN ENTIRELY SUFFICIENT TO TRAWL THROUGH THE JAPANESE LANGUAGE VERSIONS ACTUALLY IDENTIFIED AND ACCESSIBLE.

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EXECUTIVE SUMMARY

The Review comprises three aspects of the present nuclear safety measures relating to the functioning of the Sendai nuclear power plant (NPP) when subject to high levels of tephra ash fallout from an erupting volcanic event – the Review does not consider in any great depth other volcanic hazards, such as pyroclastic density flow, etc., nor how these hazards might act in combination with tephra fall to challenge the resilience of an operational NPP.

First, the Review seeks to describe the present regulatory constraints and requirements placed upon the Sendai NPP operator to adequately forecast the nature and risk of occurrence of the general volcanic hazard; second, the effectiveness of the screening process adopted to determine which volcanoes and to what extent these represent a hazard to the Sendai NPP; and, third, if the severity of the projected volcanic event complies with the 2013 revised *design-basis* requirements of the Nuclear Regulation Authority (NRA) and, in this regard, if the preparation and countermeasures at the Sendai NPP site are sufficient to protect the region from a significant radiological outcome in the event that nuclear plants are subject to a prolonged period of tephra fallout.

First inaugurated in 2012, the NRA issued draft guidelines in early 2013 for the assessment of, amongst other extreme natural phenomena, the risks and hazards of volcanic activity. The draft *New Safety Standards* for *Volcanic Assessment* adhered to the template of the recommendations of the International Atomic Energy Agency (IAEA), particularly in the adoption of a methodological evaluation process and, importantly, that the process overall was to determine and put in place the parameters of volcanic hazard-specific *design-bases* custom developed for each, specific nuclear power plant site.

However, the final *Assessment Guide of Volcanic Effects to the Nuclear Power Plan*, first issued as a draft revision in June 2013, lacks sufficient discipline and enforcement to ensure that operators, like Kyushu Electric at Sendai, rigidly adhere to sufficiently comprehensive risk and hazard evaluation procedures. For example, at the Sendai NPP the worse case tephra fall is not drawn from a probabilistically determined range of possibilities but it seems, and very much contrary to the recommended IAEA approach, from a single geologic event reckoned to have occurred some 12,800 years ago. Relying upon a single past event from the surviving geologic record, particularly if there is no surviving contemporaneous human account, is likely to be accompanied by uncertainty, particularly in that the gauge of potential, future volcanic activity could be underplayed if smaller, past volcanic events have been masked and missed from the geologic record, and/or if the physical record of a tephra fall event had been eroded or diffused over time

There are similar shortfalls in Kyushu Electric's promotion of the Volcano Explosivity Index (VEI) to screen out certain capable volcanoes, particularly in the assertion that more frequent VEI 3 to 6 magnitude events will have no adverse affect on the Sendai NPP, and that it is only the continental-scale VEI 7 event that would challenge the existing *defence-in-depth* resilience at Sendai. Essentially, VEI is a somewhat empirical measure of past and observed volcanic eruptions, taking into account the volume of the ejecta, plume cloud height and a number of qualitative observations, but it is not generally considered to be a portend of future eruption frequency nor, indeed, a yardstick of eruption magnitude nor of any particular effect (such a tephra fall).

Generally and, perhaps, more directly relating to the highly energetic volcanic hazards such a pyroclastic density flows and surges, is the over-reliance upon a single episode of relatively recent academic work that formulates a model whereby it is claimed possible to predict a forthcoming eruption – even if this monitoring methodology is reliable, the tolerance of the timescales available could be either too long (~tens to hundreds of years) to provoke action, or too short (weeks and months) in that there would be insufficient time to prepare and transfer the 400 to 1,000+tonnes or so of intensely radioactive fuel off the NPP site for safe and secure storage elsewhere in Japan.

However, this Review, confined to tephra fall, does not explore the very challenging, if not impossible, logistics of transferring such a large amount of intensely radioactive spent and short-cooled nuclear fuel.

The Review assesses the adequacy of the measures in place at Sendai NPP to cope with a prolonged tephra fall. Kyushu Electric assumes a maximum tephra deposited layer of 12 to 15cm depth which, in terms of superimposed wet ash loading on the various flat roofs and tanks dispersed around the NPP site, is within the roof design loadbearing limits – to manage this ash layer Kyushu Electric reckon that 30, two-man crews would clear the ash in 14 or so days. The Review considers this somewhat optimistic since, adopting UK physical labour rates for shifting water sodden, 'sticky' tephra would occupy around 30 days – if the tephra fall continued whilst the tephra layer was being cleared – a possibility not considered by Kyushu Electric - to keep abreast of a relatively moderate tephra fall rate of 1.3cm/hr about 40 or so two-man teams would be required to cover three-shift working.

On the basis of the 12,800 year geologic record of ash fall adopted by Kyushu Electric as the worse case, if by chance there occurred a change of wind direction from the north to an easterly, the geologic record of ash fall layer thickness in the vicinity of Sendai NPP increases to about 30cm that, if wet and accumulating uncleared, would exceed the roof superimposed limits by x1.18 and x1.4 of the spent fuel buildings serving reactors R1 and R2 respectively, thereby introducing the risk of roof damage and possible collapse over one or both of the spent fuel storage ponds.

It is generally acknowledged that as a result of prolonged tephra fall, the local electrical distribution grid and, particularly, exposed substation switchgear and transforming equipment, would be at risk of flashover and failure. Kyushu Electric assume that this would result in a loss of offsite power (LOOP) for 7 days during which Sendai NPP would be dependent upon the on-site emergency diesel generators and perhaps mobile-mounted generators if, that is, these could be brought onto the site via difficult to pass roads during the tephra fall. One aspect of maintaining diesel generator supplies is the need to change the engine aspiration and generator plant room filters to protect the mechanical sliding and rotating parts against seizure – for example, the US Columbia NPP tephra fall countermeasures include for a generator filter change completed every 2.3 hours of runtime and, similarly, for the plant room filters every 3.6 hours runtime. In comparison, the countermeasures detailed for the Sendai NPP do not include for any filter changes to the emergency diesel enclosure ventilation system, although the generator engine aspiration filters are reckoned, according to Kyushu Electric, to require replacement every 26.5 hours runtime (compared to 2.3 hours for Columbia) with the filter change operation occupying 8 personnel for about 2 hours. The Review expresses a number of reservations about the practicable applicability and source data deployed in the Kyushu Electric analysis.

Interestingly, the Kyushu Electric plans and countermeasures do not extent that much into the public sector areas away from the NPP site. Of course, tephra fall and deposition is likely to be widespread making road vehicle movement difficult, if not impassable, and with continuing tephra fall natural light could be very limited and, at night, if the local electricity power distribution system has failed, illumination of thoroughfares and buildings will be dependent upon stand-alone generator supplies. Moreover, buoyant, vesiculated pumice might be swept down the River Sendai, accumulating downstream to give rise to localized or, indeed, widespread flooding, all exacerbated by tephra blockage of drains and culverts. Also, there might be a high call on emergency services personnel to respond to other volcanic effects that might be more intense nearer the active volcanic vent(s).

In other words, in times of high volcanic activity, and for not readily defined periods thereafter, Sendai NPP might find itself competing for human and equipment resources that are equally or if not more so in demand elsewhere. It may be necessary for Sendai NPP personnel to venture out well beyond the NPP boundaries to maintain essential routes of manpower, equipment and fuel to the site, all of which could stretch the human resources necessary to maintain a stable and nuclear safe situation within the NPP site. Similarly, human resources contracted to attend the NPP site, both permanently employed and contracted labour, etc., may under conditions of duress prioritise their loyalties to family, to protect their homes and/or to evacuate to other less volcano affected areas of Kyushu or, indeed, elsewhere to greater Japan.

It is conceivable that in certain circumstances, Sendai NPP might find itself stranded and under-resourced, tipping into an intolerable and increasingly unstable situation. There is very little to

indicate in both the summarised Kyushu Electric and NRA assessments that this possibility has been recognized and prepared for. More so, the relatively small-scale exercises and rehearsals undertaken at Sendai to demonstrate Kyushu Electric's readiness and pre-planned countermeasures to manage tephra fall (involving the removal of a hundred or so meters of simulated tephra layer from a hardstanding surface on a clear, dry day) may not be at all representative of a real volcanic event in the region of Kyushu Island.

In summary: Although it has to be acknowledged that NRA's introduction of the 2013 *Volcanic Assessment Guide* is a significant step forward from the pre-Fukushima Daiichi era when no regulatory volcano evaluation procedures were in place, this first version of the *Guide* is a poor reflection on the methodological approach recommended by the IAEA. Moreover, the *Guide* does not instill sufficient discipline on the licensee to ensure that the volcanic hazards assessment is both comprehensive and meaningful, nor does it mandate the licensee to explore and establish NPP-specific *design-bases*, so much so that, instead, the outcome of the site assessment exercise is more akin to tinkering around the edges than that of addressing the fundamental resilience and *defence-in-depth* of the NPP and its site.

There is another weakness in the *Guide*, this being that it directs the operator to evaluate the affects of each volcanic effect separately in a mechanistic manner. However, the tephra fall subject of this Review is likely to have widespread and concurrent affects on a diverse range of activities and functions both on and off the NPP site – it is a *common-mode* initiator: it may cause machinery to seize; roofs may be damaged or collapse by ash overloading; off and on site electricity equipment may short-circuit and trip; transport routes to and from the NPP site may be impassable; NPP staff may be unable, or unwilling, to attend the site during the uncertainty of a volcanic eruption; and so on. Any one affect of ash fall may not, in itself and alone, be sufficient to bring the plant down, but when acting in combination and possibly chaotically, the plant's overall resilience may fail. Similarly, the affects of ash fall should also be considered in combination with the affects of other volcanic hazards, such as pyroclastic flow and surges.

This is the fundamental limitation of the NRA-Kyushu Electric approach, essentially being that it defines and addresses individual aspects of plant performance and resilience without considering the outcome of the whole.

The Kyushu Electric submission to the NRA, as summarized by the NRA, reveals that this first attempt by the new nuclear safety regulator to introduce a systemised and comprehensive volcanic effect NPP site evaluation may not have been entirely successful.

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