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United Nations system-wide study on the implications of the accident at the Fukushima Daiichi nuclear power plant

Report of the Secretary-General

Summary

The present report contains the results of the United Nations system-wide study on the implications of the accident at the Fukushima Daiichi nuclear power plant. The report has been prepared for the High-level Meeting on Nuclear Safety and Security, to be held on 22 September during the sixty-sixth session of the General Assembly. The study contains three sections. The first section focuses on specific issues pertaining to peaceful uses of nuclear energy and nuclear safety. It addresses International Atomic Energy Agency (IAEA) safeguards, peaceful nuclear energy applications, agriculture and food security, the environment, health, sustainable development and financing. The second section, which focuses on nuclear safety and security, addresses the role of the IAEA it that area, as well as natural disasters, climate change and the nexus between nuclear safety and security. The third section focuses on the international emergency response framework in the event of nuclear accidents and addresses the adequacy of disaster preparedness measures, the cooperation between international organizations and the development of new monitoring and scientific capabilities.

In each area of focus, the study seeks to identify and discuss specific issues that may be relevant to the consideration of Governments; assess the implications of the Fukushima accident and the impact of major nuclear accidents; discuss trends and developments; and provide recommendations.

The study comprises contributions and inputs from 16 United Nations entities, specialized agencies and related organizations, including the Department of Economic and Social Affairs; the Food and Agriculture Organization of the United Nations; the International Atomic Energy Agency; the International Civil Aviation Organization; the International Maritime Organization; the Office for the Coordination of Humanitarian Affairs; the Pan American Health Organization; the

Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization; the United Nations Children's Fund; the United Nations Development Programme; the United Nations Environment Programme; the United Nations International Strategy for Disaster Risk Reduction; the United Nations Office for Disarmament Affairs; the United Nations Scientific Committee on the Effects of Atomic Radiation; the World Health Organization; and the World Meteorological Organization.

Contents

I. Introduction

1. On 19 April 2011, in his speech at the Kyiv Summit on the Safe and Innovative Use of Nuclear Energy, the Secretary-General noted that, in the light of expectations for the continued growth in nuclear power, ensuring maximum nuclear safety has assumed great significance. He also highlighted the need for the international community to undertake a global rethink of nuclear energy and safety issues. While acknowledging that each State has the right to define its national energy policy, he stressed that our common objective should be to deepen our understanding of the entire range of issues relating to development of nuclear energy and its safety, transcending national borders. Going forward, the effects of a nuclear plant disaster, from prevention to clean-up, should be more fully reflected in the assessment of how to ensure the peaceful uses of nuclear energy and maximum safety. In that connection, the Secretary-General proposed five concrete measures, including a United Nations system-wide study on the implications of the accident at the Fukushima Daiichi nuclear power plant, to be undertaken by the relevant United Nations entities as well as by the specialized agencies and related organizations and to be prepared for the High-level Meeting on Nuclear Safety and Security, to be held on 22 September during the sixty-sixth session of the General Assembly.

2. The Secretary-General consulted with the heads of international organizations prior to the formal launch of the study. Given its central role in the development of nuclear safety standards and nuclear security guidance, as well as its efforts to promote peaceful nuclear applications and safety in all its aspects, the International Atomic Energy Agency (IAEA) functioned as the lead coordinating entity for the aspects of the report that fall exclusively within its statutory areas of responsibility. The opportunity to provide input to the study was also brought to the attention of other United Nations entities, some of which contributed accordingly.

3. The other primary contributors to the report included such entities as the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization; the Department of Economic and Social Affairs; the Food and Agricultural Organization of the United Nations (FAO); the Office for Disarmament Affairs; the Office for the Coordination of Humanitarian Affairs; the United Nations Children’s Fund (UNICEF); the United Nations Development Programme (UNDP); the United Nations Environment Programme (UNEP); the United Nations International Strategy for Disaster Risk Reduction; the World Health Organization (WHO); and the World Meteorological Organization (WMO). Other entities that contributed to the report and supplied inputs to the primary contributors were the International Civil Aviation Organization (ICAO), the International Maritime Organization (IMO), the Pan American Health Organization (PAHO) and the United Nations Scientific Committee on the Effects of Atomic Radiations. The United Nations System Chief Executives Board for Coordination, in its capacity as adviser to the study, provided support and background information.

4. Although the primary contributors sought to consult and collaborate with other relevant entities, with a view to providing a joint submission, as far as this may have been feasible, the views expressed in each of the sections represent those of the primary contributors, as specified, and do not necessarily represent the views of any other entity. Additional inputs received from the contributing entities are reproduced in the annex to the present report.

II. Observations

5. The accident at the Fukushima Daiichi nuclear power plant has compelled the international community to consider whether everything is being done to ensure nuclear safety. The Secretary-General welcomes the recent and planned activities aimed at strengthening nuclear safety and security as well as disaster preparedness, such as the Fifth Review Meeting of the Contracting Parties to the Convention on Nuclear Safety and the third session of the Global Platform for Disaster Risk Reduction. The Secretary-General particularly welcomes the outcome of the IAEA Ministerial Conference on Nuclear Safety and the development by the IAEA Director General of an action plan to strengthen nuclear safety, including through the consideration of the development and application of international and legally binding norms. The Secretary-General hopes that the plan will form a basis for international efforts to improve nuclear safety. The Secretary-General also welcomes the intention of Japan, in cooperation with IAEA, to convene a high-level meeting in late 2012 aimed at following up on and sustaining political momentum and accountability on the matter.

6. Decisions on the development and use of nuclear energy and the application of IAEA safety standards are the sole responsibility of individual Governments. Nevertheless, major nuclear accidents and emergencies respect no borders and their consequences can be grave, as shown in the accidents at the Fukushima Daiichi and Chernobyl nuclear power plants. The international impact of major nuclear accidents and emergencies is a matter of global concern and public interest that must be discussed. Openness and transparency with respect to issues pertaining to nuclear energy and the implications of nuclear accidents and emergencies are critically important to maintain public trust. In that regard, the United Nations, in close cooperation with the specialized agencies and related organizations, has an important role to play.

7. The Secretary-General recognizes the central role of the IAEA in the development of nuclear safety standards and the promotion of the highest level of nuclear safety, in accordance with its mandate. The Fukushima accident has given rise to concerns regarding the adequacy of international safety standards and conventions, the global emergency preparedness and response system and the effectiveness of national regulatory bodies. Those concerns underscore the need for greater international cooperation, openness and transparency as the international community intensifies its efforts to strengthen nuclear safety regimes.

8. The Fukushima accident has highlighted the importance of enhanced hazard assessments that focus on credible scenarios involving natural disasters that can affect nuclear energy installations. Furthermore, the possible effects of climate change, such as rising sea levels, or severe weather conditions will also have an effect on the nuclear safety of active nuclear power plants. Such effects will therefore need to be taken into account in designing, siting and operating nuclear power plants. The low greenhouse gas emissions of nuclear power, however, may help to reduce the risks associated with climate change.

9. The Secretary-General notes that the Fukushima accident also has implications for nuclear security and the prevention of intentional attacks on nuclear energy installations and nuclear materials, either in use, storage or transit, which can give rise to radiation emergencies. The Secretary-General hopes that the high-level

meeting on nuclear safety and security can serve as a bridge to the 2012 Nuclear Security Summit, to be held in Seoul.

10. The international response to the Fukushima accident demonstrated the value of the Inter-Agency Committee on Radiological and Nuclear Emergencies and the operation of the Joint Radiation Emergency Management Plan of the International Organizations, based upon the central coordinating role of IAEA. In the weeks following the accident, efforts were initiated within the Inter-Agency Committee and by the Secretary-General to review existing arrangements, particularly in the area of information-sharing, and to make necessary improvements.

11. At the national level, the accident has underscored the need to ensure that Government policies with respect to emergency response and risk assessments and risk reduction measures are transparent and responsive to public risk perceptions. The potential for multifaceted emergencies to become regional and international matters of concern should be studied further, as the understanding of disaster risk information and risk reduction measures, as well as the timely and accurate provision of information, play a crucial role in decisions regarding public sector development and investment. In order to support the decision-making process, it is critical to ensure that the general public is kept informed about risks and risk management options.

12. In responding to the Fukushima accident, well-developed scientific and monitoring capabilities were employed, especially by IAEA, WHO and WMO, in accordance with pre-existing arrangements. In addition, the global monitoring network maintained by the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization proved its relevance in nuclear emergencies and, together with the existing UNEP capabilities, could be utilized to supplement the capabilities of the organizations that play a central role in responding to radiation emergencies.

13. Notwithstanding the contribution that safe and scientifically sound nuclear technologies make to the agriculture and food production industries, in the event of a major nuclear accident, human exposure to radioactive contamination may come through food and water, which can have a considerable negative impact on national and international food trade. The impact on trade can arise not only in affected areas owing to imposed food restrictions, but also in unaffected areas owing to public fears, resulting in limitations to market access and negative effects on rural development and economic growth. In the light of the potential long-term health effects that increased radiation exposure can cause, including to populations across national boundaries, strengthening the cooperation and coordination among the relevant entities is an important objective.

14. Although public and private entities seeking to develop nuclear power generally consider costs associated with the entire life cycle of commercial nuclear installations, the environmental, social and economic consequences of major accidents must also be considered and included in decision-making processes to identify and consider such costs. While some States have taken the decision not to pursue or to phase-out nuclear energy, other States remain committed to developing or acquiring nuclear power. Disaster risk analyses must therefore ensure that nuclear plants are built and operated safely and able to withstand any possible threat that could give rise to a radiation emergency.

15. The Secretary-General commends the recommendations in the present report to the attention of Governments for their consideration.

III. Information received from United Nations entities, specialized agencies and related organizations

A. Specific issues pertaining to peaceful uses of nuclear energy and nuclear safety

1. International Atomic Energy Agency safeguards and peaceful uses of nuclear energy[1]

16. Providing access to energy for the 2.4 billion people currently living in energy poverty is an important precondition for progress towards achieving the Millennium Development Goals. All energy sources and technologies will be required to meet that enormous challenge. Nuclear power has been and will remain a significant contributor to meeting global energy needs.

17. As of July 2011, some 440 nuclear power reactors were operating in 29 countries, with 65 new reactors under construction. Interest in nuclear power, although impacted by the accident at the Fukushima Daiichi nuclear power plant, remains high. Of the countries without nuclear power that before the accident had strongly indicated their intentions to proceed with nuclear power programmes, only a few have cancelled or revised their plans, but most have not.

18. Nuclear science and technology can also be used to develop nuclear weapons. Compliance with international legal instruments, such as the Treaty on the Non-Proliferation of Nuclear Weapons, other bilateral and multilateral non-proliferation agreements[2] and safeguards agreements with the IAEA, is therefore an essential element of the responsible use of nuclear power.

19. IAEA was established in 1957 to help States ensure that nuclear energy would serve peace and development. Through the implementation of its safeguards, the Agency provides assurances to the international community that nuclear material and other specified items placed under the safeguards are not diverted from peaceful uses.

20. Safeguards are implemented under agreements concluded by the IAEA with States and regional inspectorates. Those agreements are of three main types: (a) comprehensive safeguards agreements,[3] which cover all of the nuclear material in each non-nuclear-weapon State party to the Treaty on the Non-proliferation of Nuclear Weapons; (b) voluntary offer safeguards agreements,[4] which cover some or all of the civilian nuclear activities in the nuclear weapon States parties to the Nuclear Non-Proliferation Treaty; and (c) item-specific safeguards agreements with

[1] This section was prepared by the International Atomic Energy Agency (IAEA).

[2] The Treaty for the Prohibition of Nuclear Weapons in Latin America and the Caribbean (Tlatelolco Treaty); the South Pacific Nuclear Free Zone Treaty (Rarotonga Treaty); the Argentine-Brazilian Declaration of Common Nuclear Policy of 28 November 1990; the Treaty on the Southeast Asia Nuclear Weapon-Free Zone (Bangkok Treaty); the African Nuclear-Weapon-Free Zone Treaty (Pelindaba Treaty); and the Treaty on a Nuclear Weapon-Free Zone in Central Asia (Semipalatinsk Treaty).

[3] Based on IAEA document INFCIRC/153 (Corrected).

[4] Ibid.

other States.[5] A State in which any one of those agreements is in force may also conclude an additional protocol[6] providing for broader access to information and locations, thereby strengthening the effectiveness and efficiency of IAEA safeguards.

2. Agriculture and food security[7]

Relevance of nuclear technologies

21. Safe and scientifically sound nuclear technologies, such as isotope measurements and tracing, mutagenesis, radiation applied for food decontamination, vaccine production and pest control, are valuable tools for agriculture and food production. Such technologies substantially contribute to food security. Those technologies are highly accurate, sensitive, specific and precise and can increase crop and livestock productivity, contribute to comprehensive animal disease control, insect pest control, food safety and quality strategies, and help to conserve natural resources.

22. Nuclear techniques are therefore of socio-economic importance and provide value-added solutions to ensure food availability, accessibility and affordability. Examples include improved crop varieties; effective soil and water management and more efficient fertilizer use; improvements to crop and livestock production systems; enhanced animal disease diagnoses and control; traceability of contaminants in food; improved shelf-life and safety of food; and the environmentally friendly control of insect pests.

23. Those technologies are uniquely provided by FAO and IAEA through the Joint FAO/IAEA Programme on Nuclear Techniques in Food and Agriculture, by means of research, training and technical and policy advice in the area of food and agriculture.

24. Peaceful uses of nuclear and related techniques for food and agriculture have contributed tremendously to food security and sustainable agricultural development all over the world.

Implications of the Fukushima accident and the impact of major nuclear accidents

25. After a nuclear accident or radiological emergency involving the release of radioactive material into the environment, there will be serious radioactive contamination of water, agriculture, aquaculture, fisheries and forestry productions as well as wildlife, thus posing a serious threat to veterinary and public health, food security and trade, with direct implications on the livelihoods of people.

26. Immediately following its release (and as long as the contamination continues), radioactive material falling from the air or carried in rainwater or snow can deposit on the surface of agricultural products or animal feed and consequently contaminate milk and meat. Consuming food contaminated with radioactive material will increase the amount of radioactivity a person is exposed to and could increase health risks.

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[5] Based on IAEA document INFCIRC/66/Rev.2.

[6] Based on the Model Additional Protocol published in IAEA document INFCIRC/540 (Corrected).

[7] This section was prepared by the Food and Agricultural Organization of the United Nations.

27. Over time, radioactivity can build up within food, as radionuclides are transferred from contaminated soils into crops or animals. Radionuclides can also be directly deposited from the air or washed off into rivers, lakes and the sea where fish and seafood could take up the radionuclides.

28. Contaminated areas may not be able to grow crops or support livestock grazing as a result of the persistence of radionuclides such as caesium 137 for decades. Special procedures should be followed to decontaminate animals and/or their products before consumption, for example. Medium- to long-term restrictions on agricultural production and fishery activities may have to be kept in place in specifically defined areas where radioactive contamination persists. After the Chernobyl nuclear accident in 1986, agricultural productions and practices were affected within hundreds and even thousands of kilometres from the accident site, and in the close proximity of the Chernobyl nuclear power plant, where high levels of contamination still persists, normal agricultural production is still not permitted.

29. The effects of radioactive contamination can also have an impact on the agroecosystem balance and, in particular, plant pollination by insects, plant biodiversity and the biological status of the soil micro-organisms and earthworms that play an essential role in soil nutrient and organic matter cycling. As some fungi and plants are able to absorb and accumulate high amounts of radionuclides, they can pose a biosecurity risk to grazing wildlife, increasing the build-up of radionuclide contamination throughout the food chain. Even to the present day, 25 years after the Chernobyl incident, wild boars in Germany can still be found to be contaminated with radioactive caesium.

30. Another serious implication related to a nuclear accident is the impact on the national and international food trade, which arises not only from imposed food restrictions in certain areas, but also from consumers' reluctance to consume some foods because of public fears of radioactive contamination. This may result in limitations to market access and market losses by affected countries, leading to negative impacts on rural development and economic growth.

31. The full impact of the radioactivity released in Japan remains to be fully assessed, but the health risks posed by radioactive contamination are well documented.

Trends and developments

32. Food monitoring data confirm that food contamination mechanisms are changing, that is, from the deposition of radionuclides on the surface of field crops, such as spinach, to root uptake through the soil or the growing medium, such as bamboo shoots and shiitake mushrooms. Stabilization and minimization of soil contamination is going to play an essential role to avoid the transfer of radionuclides through wind and soil erosion to other land and water bodies, including its release to plants and animals.

33. FAO is working in close collaboration with its partners in providing the technical assistance and policy advice in response to the request from Member States in the areas of:

- Contamination detection and monitoring
- Remediation strategies and approaches

- Agricultural countermeasure development
- Science-based food trade policy
- Capacity-building for preparedness and response in food and agriculture to nuclear emergencies

Recommendations

34. In order to strengthen preparedness and response planning and capacity to nuclear and radiological emergencies and minimize their impact on food and agriculture, and improve recovery, coordinated actions in the following areas would be strongly recommended:

- Facilitate coordinated support to national, regional and international food and agriculture response planning to nuclear emergency
- Increase technical assistance and policy advice for Member countries and organize regional/international simulations including all food and agriculture elements of emergency response and recovery activities
- Strengthen international and national capacity development in food and agriculture monitoring and agriculture remediations
- Review and improve the legal framework and cooperative mechanisms for inter-agency collaboration

3. Health[8]

Specific issues relevant for consideration by Governments

35. The health impact of peaceful use of nuclear energy represents an issue of paramount importance. Policymakers and decision makers should ensure that the highest levels of safety are applied at existing and future nuclear installations. The health and well-being of populations should be a central concern and a priority in the discussions and decisions on energy strategies. Health, environment and economic implications should be considered as a whole for any strategy that Governments may decide to choose.

Implications of the Fukushima accident and the impact of major nuclear accidents

36. Radioactive material may be released into the environment during an emergency at a nuclear power plant, the radionuclides of main concern to human health being iodine and caesium. The internal or external occupational exposure of rescuers, first responders and nuclear power plant workers is likely to occur during the emergency response phase and may result in radiation doses high enough to cause acute health effects such as skin burns, internal contamination or acute radiation syndrome. The general population is not likely to be exposed to doses high enough to cause acute effects, but may be exposed to low doses that could result in increased risk of long-term effects such as cancer. Consumption of contaminated food and/or water may also contribute to overall radiation exposure. If radioactive iodine enters the body through inhalation or ingestion and if no countermeasure is taken, it will concentrate in the thyroid gland, increasing the risk of thyroid cancer,

[8] This section was prepared by the World Health Organization.

particularly in children, as was witnessed in those populations affected by the accident in Chernobyl.

37. In the case of the Fukushima accident, by the end of May 2011, nearly 8,000 workers were employed at the Fukushima Daiichi power plant, 30 of whom were reported to have been exposed to a cumulated radiation dose higher than 100 mSv. Radiation-related fatalities have not been reported. Public health measures were quickly implemented, residents in the vicinity of the site were evacuated in a timely manner and potassium iodide tablets were given to the affected population. Evacuated residents were screened and decontaminated when needed. Food and drinking water contamination has been monitored and appropriate restrictions applied when necessary. Physical and prolonged stress among the evacuees has had significant health impacts. The disruption in their lives, breakdown of social contacts, long detention at evacuation sites with little privacy and crowded conditions, and sharp changes in their social environment have all contributed to grave stress, causing mental trauma.

38. Similar to the case in Chernobyl, the Fukushima accident has resulted in significant anxiety in the general population, which may be aggravated by factors such as mistrust of authorities.

Trends and developments

39. Public exposure to radiation has declined significantly due to technological and safety improvements. However, Japan's experience demonstrated that nuclear accidents can still occur and, when combined with natural disasters, such accidents have the potential to transcend boundaries, making international instruments[9] useful in addressing such situations and requiring the coordination and cooperation of multiple stakeholders.

40. The development of coherent norms and standards at both the regional and the global level is crucial to ensure governance in the field of radiation safety. The 1996 International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources represented an unprecedented international effort towards the global harmonization of standards in all aspects of radiation protection for patients, workers and members of the public.

Recommendations

41. The health and well-being of populations should be a central concern and a priority in the discussions on future energy strategies.

42. Member States should consider strengthening national preparedness systems and cross-sector coordination.

43. National criteria for interventions after nuclear emergencies need to be consistent with international recommendations, and decisions concerning response interventions need to be made in a transparent and coordinated manner.

44. Continued monitoring and efficient public communication of risks and the possible health effects of the Fukushima accident are essential, and the involvement

[9] The "Emergency Conventions", including the 2005 International Health Regulations, the 1986 Convention on Early Notification of a Nuclear Accident and the 1986 Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency.

of international organizations is important to ensure the transparency and credibility of the assessments and interventions implemented by national authorities.

4. Environment[10]

Specific issues relevant for consideration by Governments regarding planning and design of nuclear facilities (including the risk management framework)

45. In deciding on whether to include nuclear energy in their energy mix, countries should undertake a rigorous environmental impact assessment that includes not only a comparison of the environmental benefits of replacing fossil-fired power plants and the routine environmental issues of operation and construction, but also an analysis of the likelihood, magnitude and environmental consequences of severe accidents with nuclear power compared with its alternatives.

46. Economic calculations to compare different energy supply options are complex. Full life cycle costs, particularly the health and environmental costs of routine releases, waste disposal costs and the costs that would be incurred in the event of an accident are often not included in such analyses. Internalizing those costs is necessary.

47. In countries where a nuclear power industry is being introduced or in regions where nuclear power is already deployed, institutional capacities to assess, regulate and model environmental impacts, as well as the ability to respond to environmental issues in an emergency situation, should be assessed and strengthened, if necessary.

Specific issues relevant for consideration by Governments regarding operating nuclear facilities and the operational phase

48. There are a range of environmental impacts associated with the operation of nuclear power installations, not all of which are radioactive in nature.

49. During routine operation, nuclear installations release small amounts of radioactive substances into the atmosphere and water bodies.[11] The continuous monitoring of such discharges and the ongoing monitoring of the environment to understand the impacts on the biota and ecosystem should be integral to the operation of nuclear power plants.

50. The management of spent nuclear fuel and possibility of radiation leakages should be monitored until facilities are finally decommissioned.

Specific issues relevant for consideration by Governments regarding decommissioning

51. There is no single universally agreed approach to the safe decommissioning of nuclear facilities, including the final disposal of spent nuclear fuels.

52. Environmental risk assessments of the various options should be undertaken prior to finalizing decommissioning plans. Those assessments should cover the site of the power plant itself, the transportation of highly radioactive wastes and the final storage/disposal of such materials.

[10] This section was prepared by the United Nations Environment Programme.

[11] United Nations Scientific Committee on the Effects of Atomic Radiation, *Sources and effects of ionizing radiation* (2010 edition), scientific annex B, "Exposures of the public and workers from various sources of radiation".

Implications of the Fukushima accident and the impact of major nuclear accidents

53. In the aftermath of the Fukushima Daiichi accident, the effects of long-lived radioactive material in the local environment will be an issue of concern for many years to come. Large-scale releases of radioactive substances into the environment such as those caused by the Chernobyl and Fukushima accidents can result in significant environmental impacts. Radioactive substances that are released into the air are deposited on the ground and onto the biota. Radioactive contamination can last for years or decades and decontamination is very expensive.

54. In areas farther away, agricultural production and fishing may need to be temporarily suspended. Environmental impacts due to radiation may cause significant economic damages by forcing a cessation of economic activities in the affected area.

55. Such environmental impacts may not only cause the temporary suspension of economic activities due to actual contamination, but may also lead to rumours and an erosion of confidence that harms local industries and tourism. Perceptions of contamination occurring when consumers avoid foodstuffs they rightly or wrongly believe to be contaminated exacerbate losses. Such damage of reputation may cause even greater financial losses for those industries.

56. In the first few weeks following the Chernobyl accident, the neighbouring non-human biota was also affected by the massive accidental release of radionuclides. Radiation caused numerous acute adverse effects up to a distance of several tens of kilometres. While the cessation of human activities from the exclusion zone altered the balance in the ecosystem and allowed the infestation of pests, it also resulted an increase in the population of wild animals and bird species.[12]

Trends and development

57. The Fukushima accident showed that the design basis accident[13] of that plant had been too modest. In hindsight, the severe accident risks, particularly with regard to the environment, had been underestimated.

Recommendations

58. Scientific understanding of the relation between the levels of radioactive material in the environment and the potential effects on the biota residing in that environment needs to be further improved.

59. In the event of accidents, effective decontamination and remediation methods for affected soil need to be investigated and implemented.

60. Safety standards for the planning, design, operation, decommissioning and emergency response procedures of nuclear power plants must include environmental protection measures.

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[12] Ibid. (scientific annexes C, D and E).

[13] A design basis accident is a postulated accident that a nuclear facility must be designed and built to withstand without loss to the systems, structures and components necessary to assure public health and safety.

61. Improved capacity-building in Member States, including in ministries for the environment, is required in order to more effectively oversee the environmental risk management of the nuclear power industry.

62. Countries that are not members of the IAEA can be affected by accidents in neighbouring countries and need a minimum level of institutional capacity, particularly in environmental monitoring.

63. Institutional capacity-building and the systematization of methodologies are essential to ensuring that long-term energy plans integrate environmental considerations in their options analyses.

5. Sustainable development and financing[14]

64. From a sustainable development perspective, one of the most salient issues is energy access. Currently, 1.4 billion people, mainly in rural areas of sub-Saharan Africa and South Asia, have no access to electricity, and billions more are energy constrained. The average electricity use in those regions is substantially below 10 per cent of that in high income economies (180-750 kWh per person per year, compared with 7,500-18,000 kWh per person per year). Without expansion in access to electricity, it will be impossible to achieve the Millennium Development Goals, particularly on eradicating extreme poverty by 2015.[15]

65. While future developments concerning nuclear energy will depend on progress in safety and affordability, that form of energy has been of interest to developing countries for a number of reasons. In 2001, the Commission on Sustainable Development concluded that the decision on the use of nuclear energy rested with individual countries according to their needs, capacities and goals. A total of 7 of the 29 countries that produce nuclear energy are developing countries. Most developing countries planning new nuclear programmes have not announced changes after Fukushima.

66. The human impacts from the Fukushima accident, which caused hundreds of billions of dollars of property damage, have also focused attention on risk management. Some have called for a global phase-out or moratorium, while others have called for stricter regulations, enhanced safety measures and insurance mechanisms.

67. In the absence of a moratorium, disaster risk analyses will need to ensure that nuclear plants are built in safe areas and are able to withstand the worst threats possible. Nearly half of all reactors in operation and under construction are in countries with high seismic risks. Nuclear plants are also often built on the coast to use sea water for cooling.

68. The bottom line for developing countries is the final cost of energy, including baseload costs and those relating to additional safety measures, waste disposal, disaster insurance, decommissioning and regulatory systems. In a 2010 study by the Organization for Economic Cooperation and Development, it was noted that "Nuclear's strength is its capability to deliver significant amounts of very low

[14] This section was prepared by the Department for Economic and Social Affairs and the United Nations Development Programme.

[15] Organization for Economic Cooperation and Development, International Energy Agency, *World Energy Outlook 2010*, p. 56.

carbon baseload electricity at costs stable over time; it has to manage, however, high amounts of capital at risk and its long lead times for construction”.[16] Notwithstanding the stability of those baseload costs, final costs had been rising even prior to Fukushima as additional elements were factored into the cost of capital. A comparison of estimates from studies published in 2010 and 2011 with those published from 2003 to 2005 reveals a quadrupling (in nominal terms) of “overnight capital costs” of nuclear plants ($5-10 versus $1.2-2.6 per Watt) in contrast to a decline in the costs of renewable technologies,[17] which could raise the final cost of nuclear energy well above $100 per megawatt hour.

69. In the past, major advances in access to electricity occurred in countries when the cost per megawatt hour of electricity was less than 3 per cent of per capita income. Since the majority of those in need of energy live in countries where annual per capita incomes are under $1,000, the need is for technological options in the range of $30-50 per megawatt hour.

70. To help countries to evaluate the potential contribution of nuclear energy to sustainable development, an in-depth assessment of the net cost impact of the following is needed:

- *Potential for cost reduction*. For developing countries, the key challenge is to bring down energy costs to levels that are compatible with their per capita incomes. That requires an independent assessment of cost trends in all available technologies[18]
- *Emissions*. International agreements or national policies that mobilize climate or other environmental financing will, in principle, lower the costs of all technologies, including nuclear power, that have an advantage over fossil fuel alternatives with respect to greenhouse gas emissions and local pollutants
- *Proliferation*. The potential consequences from nuclear proliferation are a matter of major concern in the international community. Developing countries will need technical assistance to enhance their institutional capacities in order to enable them to manage the risk of proliferation effectively. IAEA has been very active in providing such assistance
- *Waste disposal*. There are uncertainties and risks related to radioactive waste disposal. Currently there is no large-scale permanent repository site for the storage of spent nuclear fuel, although Finland and Sweden are constructing such repositories
- *Local impacts of mining*. There are concerns regarding the impact of mining fissionable material on local communities and ecosystems

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[16] International Energy Agency/Nuclear Energy Agency, *Projected costs of generating electricity, 2010 Edition* (2010), p. 21.

[17] For estimates of costs from 2010 to 2011, see United States Energy Information Administration, “Updated capital cost estimates for electricity generation plants” (2010), p. 8; and International Institute for Applied Systems Analysis, *Global Energy Assessment* (2011). For estimates from studies published from 2003 to 2005, see IAEA, “Nuclear Power and Sustainable Development” (Vienna, 2006), p. 10. For investment cost of renewable energy (photovoltaics, offshore wind) and nuclear energy as a function of cumulative installed capacity, See International Institute for Applied Systems Analysis, *Global Energy Assessment* (2011).

[18] DESA “A global green new deal for climate, energy and development” (New York, 2009).

- *Insurance against disasters*. After Fukushima, uncertainties have emerged about the cost of insurance against major disasters. Innovative insurance mechanisms will need to be developed to reduce that uncertainty
- *Local impacts of nuclear energy policy and disasters on the safety and well-being of communities*. Twenty-five years after the Chernobyl accident, the affected communities are still dealing with the stigma and lack of economic opportunities and information on the consequences of the disaster

71. Governments and private investors face tough challenges on financing nuclear energy, especially in developing countries. Major international financial support would be necessary to build nuclear plants and develop institutional, regulatory, enforcement and infrastructure capacities. The challenges are even greater as energy investments continue to be affected by uncertainties in the global economy. Financing issues include:

- *Sharing risks among investors and Governments*. With cost uncertainties, heightened public concern and changing energy policy environments, it is extremely challenging to secure private financiers for nuclear energy without significant risk-sharing by the public sector. The solution may be to develop innovative financial instruments to cover uncertainties related to natural or man-made disasters, decommissioning costs and the final disposal of radioactive waste
- *Ensuring a level playing field for different technology options*. A level playing field is needed in order to enhance investments and develop markets for efficient energy systems. Reforming subsidies and incentive schemes will be critical for fair competition among all options
- *Reflecting external costs in investment models*. Currently, many technologies that reduce greenhouse gas emissions or have other social or environmental benefits are not able to claim such a cost advantage. The internationalization of external costs will need to include environmental and societal costs, including risks, in order to facilitate truly informed decision-making for sustainable development

B. Nuclear safety and security

1. Role of the International Atomic Energy Agency in nuclear safety and security[19]

Specific issues relevant for consideration by Governments

72. IAEA is an independent intergovernmental, science and technology-based organization in the United Nations system that serves as the global focal point for nuclear cooperation. Nuclear safety and security have a common purpose, which is to protect people and the environment from the harmful effects of ionizing radiation. The central role of IAEA with respect to nuclear safety and security is set out in its Statute and enshrined in decisions and resolutions of its policymaking organs. IAEA develops nuclear safety standards and, based on those standards, promotes the achievement and maintenance of high levels of safety in nuclear energy applications. It also offers specific review services to determine how the standards

[19] This section was prepared by IAEA.

are being applied. Guidance on public and occupational radiation protection for a wide range of exposure situations, including nuclear emergencies, is provided in the IAEA International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources and related documents.

73. IAEA supports global efforts to make nuclear and other radioactive material secure through the provision of guidance documents and services and helps States to establish comprehensive national nuclear security regimes. It works to provide a strong, sustainable and visible global nuclear safety and security framework.

Implications of the Fukushima accident and the impact of major nuclear accidents

74. The Fukushima Daiichi accident had an adverse impact on public perceptions of the safety of nuclear power throughout the world. In particular, the accident and international response raised questions concerning the adequacy of international safety standards and conventions and the extent of adherence to them, the global emergency preparedness and response system and the effectiveness of national regulatory bodies. Some countries re-examined their plans to introduce or expand nuclear power programmes or extend the operating life of existing nuclear plants. The following areas may be affected by the Fukushima Daiichi accident:

- Science and technology, including safety engineering, design against onsite and external natural hazards, mitigation and recovery systems and radiation protection in severe accidents
- Managerial, human, organizational and national infrastructure, including emergency preparedness and response, severe accident management, regulatory frameworks, technical support organizations and national resources
- Public communication, transparency and international cooperation

Trends and developments

75. Over the past two decades, there has been a clear trend towards strengthening nuclear safety regimes. International cooperation has increased and countries considering the introduction of nuclear power programmes have been encouraged to apply IAEA safety standards and relevant international instruments. Other developments have included increased regional harmonization and cooperation, steadily improving safety performance indicators, an increase in the number of countries considering embarking on nuclear power programmes, the extension of the service lives of existing plants, greater openness and transparency and increased synergy between safety and security. There has also been an increasing number of requests for IAEA expert peer review services in areas such as regulation, operational safety, emergency preparedness and security, as well as a greater focus on issues such as safety management and leadership.

76. The trend towards longer service lives of nuclear plants brings its own challenges, such as ensuring that safety margins remain adequate. The extension of the lives of existing nuclear plants and the expansion of nuclear power programmes are also placing an increasing strain upon the limited human resources available to design, construct, maintain and operate nuclear facilities.

77. A preliminary assessment of the Fukushima Daiichi accident has already identified plant design, international response arrangements and implementation of

international safety standards as areas where further development is needed. A continuing trend towards increasing international cooperation, openness and transparency will undoubtedly assist countries in responding effectively and learning the necessary lessons from the Fukushima Daiichi accident.

Recommendations

78. In the Ministerial Declaration adopted at the IAEA Ministerial Conference on Nuclear Safety, held in Vienna in June 2011,[20] a number of measures were set out to improve nuclear safety and a firm commitment was expressed to ensure that those measures are actually implemented. The importance was reiterated of universal adherence to the relevant international instruments on nuclear safety, as well as the need for their effective implementation and continuous review. The importance was also emphasized of enhanced national and international measures to ensure the most robust levels of nuclear safety, based on IAEA safety standards. It was stated that safety standards should be continuously strengthened and implemented as broadly and effectively as possible. The Ministers attending the Conference committed themselves to increasing bilateral, regional and international cooperation to that effect.

79. The Ministers expressed their commitment to strengthening the central role of IAEA in promoting international cooperation in order to enhance global nuclear safety and in coordinating efforts to strengthen global nuclear safety by providing expertise and advice and promoting nuclear safety culture worldwide. The Ministers also expressed their commitment to further strengthening the authority, competence and resources of national regulatory authorities.

2. Natural disasters[21]

Specific issues relevant for consideration by Governments

80. Cooperation between international organizations concerning natural disasters has grown, especially in areas such as prediction and response. For example, WMO has assisted IAEA in its efforts to define natural phenomenon hazards as part of the development of related IAEA nuclear safety standards.

Implications of the Fukushima accident and the impact of major nuclear accidents

81. The Fukushima Daiichi accident was caused by a natural disaster of unprecedented severity: a major earthquake that triggered a huge tsunami. The accident highlighted the importance of performing hazard assessments that focus on credible, if unlikely and infrequent, scenarios that can challenge structures, systems and components. That is more significant for nuclear installations with multiple reactors.

Trends and developments

82. The increase in the number of hazards considered to be potentially damaging to nuclear power plants has been recognized in nuclear safety assessments for many years. It has led to the re-examination of the levels of protection against natural disasters such as seismic events and tsunamis. Increased levels of protection have

[20] See IAEA document INFCIRC/821.
[21] This section was prepared by IAEA.

been called for and enhancements have been made in early warning systems for tsunamis and other hazards. Better methods for dealing with uncertainties have also been developed.

Recommendations

83. The levels of hazards, or combinations of interrelated hazards, need to be evaluated in order to include less frequent events and allow adequate consideration for uncertainties. Based on IAEA safety standards, those hazard levels should be considered in the safety assessments of nuclear power plants and the necessary preventive and mitigation measures should be implemented.

84. In the case of Fukushima Daiichi, offsite response to the events at the site could not be relied upon due to lost communication channels and damage to access routes. A key feature of any plant recovery plan should accommodate the need for the plant accident management team to be able to operate without dependency on offsite resources. The fragility of the supporting infrastructure should be considered in any planning of emergency response to such disasters.

85. Demand for improved access to risk information has grown steadily through the years. Risk information in the immediate aftermath of a nuclear emergency is vital for effective response, not only for technical specialists, but also to guide the immediate actions of humanitarian agencies, national and local governments and the general public.

3. Climate change[22]

Specific issues relevant for consideration by Governments

86. There are two ways in which climate change affects the comparison between the benefits and risks of nuclear power and the benefits and risks of its alternatives.

87. First, the possible effects of climate change, such as rising sea levels or more extreme storms and droughts, should be taken into account in designing, siting and operating nuclear power plants. A forthcoming IAEA Safety Guide on Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations will provide guidance. If climate change is not taken into account in the construction of any given nuclear power plant, then the future risks of that plant may be higher than in today’s climate.

88. Second, one of the benefits of nuclear power is its very low greenhouse gas emissions, which help reduce all risks associated with climate change.

89. Nuclear plant operators have accumulated substantial experience of working in diverse climates and severe weather conditions. Weather-related incidents at nuclear power installations have never exceeded level 3 on the seven-point International Nuclear and Radiological Event Scale. There is also substantial experience concerning tsunamis, for which there has only been one accident above level 3: the Fukushima accident. Tsunamis are not weather-related, but, all other things being equal, risks from tsunamis would increase with rising sea levels as a result of climate change. However, existing planning and engineering techniques can significantly reduce or eliminate the vulnerability of nuclear power plants to climate, weather and tsunami hazards.

[22] This section was prepared by IAEA.

Implications of the Fukushima accident and the impact of major nuclear accidents

90. The principal lesson of the Fukushima accident is that assumptions made concerning which types of accident were possible or likely were too modest. Those assumptions should be reviewed for all existing and planned reactors, and the possible effects of climate change should be taken into account. The emerging Global Framework for Climate Services of the World Meteorological Organization[23] may be particularly useful in providing the necessary climate information.

Trends and developments

91. The important potential effects of climate change identified in the forthcoming IAEA Safety Guide on Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations include the following:

- Rising sea levels will affect some coastal nuclear power plants; plants on rivers may also be vulnerable to flooding due to increased rainfall or changes in snow-melt
- More intense high winds, storms and lightning could increase the risk of grid disruptions
- Extreme heat and drought could disrupt water cooling systems
- Ice due to extreme cold could disrupt the intake of cooling water
- Forest fires and wildfires could disrupt both grid connections and access to nuclear power plants by personnel and emergency responders
- Debris caused by storms and floods could disrupt the intake of cooling water

Recommendations

92. Risks for nuclear power plants associated with climate change and extreme weather events are not insurmountable. Know-how and technologies are available to significantly reduce or eliminate climate-related risks and should be applied as described in the forthcoming IAEA Safety Guide on Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations.

4. Nexus between nuclear safety and security[24]

Specific issues relevant for consideration by Governments

93. The most important document in the IAEA Safety Standard series, Safety Fundamentals,[25] states that "safety measures and security measures must be designed and implemented in an integrated manner so that security measures do not compromise safety and safety measures do not compromise security".

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[23] World Meteorological Organization (WMO), *Climate Knowledge for Action: A Global Framework for Climate Services — Empowering the Most Vulnerable* (2011), available from http://www.wmo.int/hlt-gfcs/downloads/HLT_book_full.pdf.

[24] This section was prepared by IAEA. Nuclear security has been defined by the IAEA Advisory Group on Nuclear Security as: "The prevention and detection of and response to theft, sabotage, unauthorized access, illegal transfer or other malicious acts involving nuclear material, other radioactive substances or their associated facilities". See IAEA document GOV/2009/54-GC(53)/18.

[25] See http://www-pub.iaea.org/MTCD/publications/PDF/Pub1273_web.pdf, para. 1.10.

94. The Fukushima Daiichi accident also has implications for nuclear security. There are several common characteristics shared by accidents and sabotage, such as reduced effectiveness of remaining systems, including through the loss of power, communications, computer, safety and physical protection systems; and the loss of key operating, safety and security personnel.

Implications of the Fukushima accident and the impact of major nuclear accidents

95. In the light of the Fukushima Daiichi accident, States should review their nuclear security framework in order to ensure that they are properly prepared to respond to the consequences of a severe nuclear accident.

Trends and developments

96. The international nuclear security framework has been strengthened over the past 10 years in response to increased concerns about the risk of a malicious act involving nuclear material, facilities or transport. New security-related instruments such as the Convention on the Physical Protection of Nuclear Material and its Amendment have been supplemented by recommendations and guidance documents produced by IAEA as part of its *Nuclear Security* series.

97. IAEA has enhanced its support to States to help them establish sustainable nuclear security regimes by implementing nuclear security plans. The aims of IAEA have been shared by groups of States, such as the Global Initiative to Combat Nuclear Terrorism, or industry, through the World Institute for Nuclear Security. There has been greater awareness among States of the need for such regimes and for State systems to involve non-traditional actors.

98. IAEA has received an increasing number of requests for expert peer review services in areas such as legislation, regulation and physical protection of facilities.

Recommendations

99. In order to properly address nuclear security, the international community should promote universal adherence to and implementation of relevant international legal instruments. Other steps should include the detailed technical examination by States of their assumptions about the nature of potential threats and the adequacy of existing security measures. Response plans should be revised to deal with worst-case scenarios that go beyond previous assumptions. Such plans should also be rigorously tested through both table-top and practical exercises.

100. In cooperation with other stakeholders, IAEA should continue to help States to establish effective, comprehensive and sustainable national nuclear security regimes. IAEA support will include peer reviews and assessment services, human resource development programmes and, where appropriate, physical protection upgrades. Coordination efforts between IAEA and other United Nations entities, such as the Office on Drugs and Crime and the Counter Terrorism Implementation Task Force, should continue to be increased, with expanded exchanges of information at the working level, improved communication between the entities and avoidance of duplication.

101. In addition to IAEA assistance, States should ensure the effective use of resources and coherent approaches with other stakeholders within the United Nations system.

C. International emergency response framework in case of nuclear accidents

1. Cooperation between international organizations[26]

Specific issues relevant for consideration by Governments

102. The established system for nuclear and radiological emergencies is based on the central coordinating role of IAEA and the Inter-Agency Committee on Radiological and Nuclear Emergencies.[27] The scope of activities covered by the Inter-Agency Committee is based on two treaties: the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of Nuclear Accident or Radiological Emergency. In addition, the 2005 International Health Regulations represent a legally binding global agreement by States to protect public health by preventing, detecting, assessing and responding to any public health emergency of international concern.

103. The Joint Radiation Emergency Management Plan of the International Organizations, the maintenance of which is one of the primary functions of the Inter-Agency Committee, identifies the inter-agency framework for radiation emergency preparedness and response, provides a practical mechanism for coordination and clarifies the roles and capabilities of the participating international organizations.

104. The Inter-Agency Committee also provides an opportunity to conduct periodic exercises. IAEA conducts regular communication drills and Conventions Exercises (ConvEx) at three levels of complexity, the most complex being ConvEx-3 exercises,[28] which cover the response in the early phase of a severe nuclear emergency.[29]

Implications of the Fukushima accident and the impact of major nuclear accidents

105. After the Fukushima Daiichi accident, the Inter-Agency Committee demonstrated the value of an institutionalized inter-agency coordination mechanism. Immediately after the accident, IAEA, through its Incident and Emergency Centre, notified all relevant international organizations and activated the Joint Plan. On 15 March 2011, the first coordination meeting of the Inter-Agency Committee was conducted by video conference. A further 10 coordination meetings were held until the end of June. The objective of the meetings was to reach a common understanding of the situation, exchange information and consider and coordinate

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[26] This section was prepared by IAEA.

[27] Established following the Chernobyl accident and comprising 15 member organizations: UNEP, Office for the Coordination of Humanitarian Affairs, Office for Outer Space Affairs, Scientific Committee on the Effects of Atomic Radiation, FAO, IAEA, ICAO, IMO, European Commission, European Police Office, International Criminal Police Organization-International Criminal Police Organization, OECD/Nuclear Energy Agency, Pan American Health Organization, WHO and WMO.

[28] The exercise is conducted every three to five years to test the response of States and international organizations to a severe nuclear or radiological emergency, including information exchange, provision of assistance and coordination of public information.

[29] The Inter-Agency Committee also conducts table-top exercises at its regular meetings, using various scenarios to review arrangements in the Joint Radiation Emergency Management Plan of the International Organizations.

response activities, including communication with the public with one voice. Emerging tasks were taken up by specific organizations. For some issues, ad hoc task groups were established.[30]

106. Following IAEA notification,[31] WHO Headquarters, the organization's Western Pacific Regional Office, its centre in Kobe, Japan, and its Radiation Emergency Medical Preparedness and Assistance Network[32] became active. WHO immediately notified all its member States in the region through National Focal Points for the International Health Regulations. A WHO field mission was undertaken by the organization's Western-Pacific Regional Office to the areas affected by the earthquake and tsunami to assess public health needs.

107. WHO closely monitored the public health risk of populations in and outside of Japan. Technical briefing notes related to food safety and regular updates on food monitoring results were developed by FAO and WHO and provided to member States through the International Food Safety Authorities Network.

108. PAHO activated its Emergency Operations Centre and deployed experts to respond to its member States, National Focal Points for the International Health Regulations and to media queries regarding implications for the American Region, mainly regarding travel and import of food and products.[33]

109. WMO emergency arrangements were activated on 11 March following a request from IAEA for emergency support. All eight WMO Regional Specialized Meteorological Centres, including the three primary Centres in the Asia region (Beijing, Tokyo and Obninsk, Russian Federation), were requested to provide charts estimating the possible spread of airborne radioactive material from the accident site.[34] Throughout, WMO also collaborated very closely with the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization, WHO, ICAO and IMO.

110. The Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization kept its State parties aware of the developing situation with six

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[30] For example, because of the importance of addressing concerns about air and maritime transport during a nuclear emergency, and supplementing its involvement in the Joint Radiation Emergency Management Plan, the International Civil Aviation Organization coordinated the work of an ad hoc transport task force that brought together a number of United Nations agencies (including itself and IAEA, IMO, WHO, WMO, WTO and ILO) and private trade associations.

[31] Under the Convention on the Early Notification of a Nuclear Accident, the Ministry of Health, Labour and Welfare of Japan notified WHO through the International Health Regulations National Focal Point within a few hours of the event.

[32] See http://www.who.int/ionizing_radiation/a_e/rempan/en/.

[33] PAHO also used the opportunity to advise its member States to review their radiological/nuclear emergency plans and expand bibliographic databases.

[34] The requests were repeated daily until 18 April 2011, and thereafter reduced to three times a week, in around-the-clock operations through 24 May 2011, when IAEA requested the termination of the WMO emergency support. Some WMO centres also collaborated with the IAEA Incident and Emergency Centre to develop a best-estimate emission sequence from the beginning of the nuclear emergency, using high-resolution atmospheric transport and dispersion modelling results, and comparing them with radionuclide monitoring data. The emission sequence was then used by several meteorological centres to re-compute best-estimated dispersion and deposition patterns in high spatial resolution.

technical briefings from 15 March 2011.[35] The Preparatory Commission and IAEA started in-depth cooperation on 21 March 2011. Subsequently, the Preparatory Commission had special briefings on the situation for organizations using Preparatory Commission data (WMO, WHO, IAEA and the United Nations Office for Disarmament Affairs). From 11 April 2011 onwards, the Preparatory Commission also participated in the coordination video conferences of the Inter-Agency Committee, at the invitation of IAEA.

Trends and developments

111. The Inter-Agency Committee and the Joint Plan represent a well-established inter-agency mechanism that can provide coordination and facilitate clarity regarding the roles and capabilities of different international organizations in radiation emergency preparedness and response. However, neither the Inter-Agency Committee nor the Joint Plan supersede the work of each individual organization.

112. Some areas where existing arrangements need to be improved have already been identified, such as expanding the role of IAEA role in receiving and disseminating information and better addressing the huge public demand for information through one-voice messages. However, improvements in emergency response will require a commitment to increased preparedness, including through training and exercises, and an acknowledgement that nuclear emergencies can happen again.

113. The Fukushima accident also highlighted the need for the global harmonization and universal implementation of nuclear safety standards.

Recommendations

114. A rigorous and objective evaluation should be conducted of the strengths and weaknesses of the current inter-agency arrangements. Consideration should also be given to formalizing the practical arrangements in the Joint Plan, including deployment of joint inter-agency field missions.

115. The involvement of relevant United Nations entities and related governmental organizations should be enhanced and increased, in particular monitoring and humanitarian organizations, within the Inter-Agency Committee and the Joint Plan. There should also be regular advocacy for the Joint Plan within organizations, including training key personnel and senior officials in response and coordination mechanisms and ensuring a clear understanding of the organizations' roles.

116. Operational procedures should be developed for coordinating the preparation and timely dissemination of public information on nuclear emergencies for international audiences as a critical preparedness and response activity.

117. The level of preparedness should be regularly tested by conducting United Nations system-wide emergency exercises based on the existing Conventions Exercises regime, with possible extensions to field monitoring exercises.

118. The value should be noted of the ad-hoc technical working groups established for the Fukushima Daiichi accident. Consideration should also be given to

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[35] The Preparatory Commission operates the International Monitoring System, a global monitoring network that currently includes more than 60 highly sensitive stations for measuring radionuclides.

establishing Inter-Agency Committee working groups for sector-specific topical areas.

2. Adequacy of disaster preparedness measures[36]

Specific issues relevant to the consideration for Governments

119. Commensurate with their respective functions, roles and responsibilities, United Nations entities and related organizations establish and maintain emergency preparedness programmes.

120. Effective local, national, regional and global preparedness and response cooperation capabilities and arrangements are essential in order to minimize the impacts of nuclear and radiological incidents and emergencies. Such arrangements are also fundamental to the mitigation and response to disasters caused by natural hazards. As the Fukushima incident illustrated, disasters can have sequential and collateral impacts that we have yet to imagine and plan for, not only for nuclear facilities but also for industrial complexes, weapons storage depots and major infrastructure such as hydroelectric dams, bridges and highways. Those considerations must motivate new efforts for integrated and innovative planning for preparedness and response.

121. IAEA is upgrading safety standards, guidance and practical tools in the area of emergency preparedness and response, utilizing the lessons learned from responses to past radiation emergencies and from the exercises that have been carried out. IAEA is helping its member States to enhance their own preparedness, including strengthening national emergency plans that are consistent with international requirements. To that end, it is carrying out appraisal missions and international, regional and national training events using standardized training materials. It is extremely important to strengthen the link between the nuclear response system and the humanitarian coordination system, through such mechanisms as the Inter-Agency Standing Committee and the cluster approach.

122. International and regional organizations have a broad experience of cooperation, including civil-military cooperation, in preparing for and responding to natural hazards. That experience has been established by engaging with a large number of countries. However, it now needs to be broadened by drawing upon the experience of IAEA and the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization. Equally, IAEA can benefit from the wide resource base and expertise of the emergency response and preparedness community.

Implications of the Fukushima accident and the impact of major nuclear accidents

123. The implications of the Fukushima accident can be grouped into key areas:

- Building codes work and are helpful only if consistently applied and consciously used in high-risk areas as a priority
- Public education, awareness-raising and training drills work. At the same time, people’s perception of risk changes over time and thus must be constantly

[36] This section was prepared by the Office for the Coordination of Humanitarian Affairs and the United Nations International Strategy for Disaster Risk Reduction.

re-assessed in order to ensure a high degree of receptivity for early warning and risk information. Risk perception and preparedness is a social issue and must be better understood by planners and political decision makers

- Early warning systems work and should be consistently applied. Multiple instruments must be used for informed decision-making

- National risk management systems must be "all-of-government" and integrated. Institutional coordination and knowledge gaps present the major risk that crisis managers and leaders are not properly informed about the nature and implications of the crises they are called upon to manage

- Public trust is critical in risk and crisis management. That asset is built on credible information being easily available, consistent and reliable. Public trust in decision makers is all the more important in crises where there is a strong fear of the unknown fuelled by catastrophic projections in media

- Safety and security information needs to be cross-referenced and combined, and coupled with integrated multi-hazard early warning mechanisms across systems (such as those for civil protection, military or scientific purposes) and stakeholders (for example, communities, State apparatus and the private sector)

124. Many elements of disaster preparedness worked well, particularly in Japan, in dealing with such a multi-faceted emergency. It is clear that the impact of a large-scale event with off-site consequences rapidly becomes a matter of regional and global concern. As the accident occurred on Japan's east coast, it was largely isolated, and the major releases of radioactive materials were to the air and ocean. If the same event had occurred in an area in greater proximity to other countries, the implications for neighbours could have been serious. It is important to share reliable information in a timely manner with all of the relevant national and international actors and to ensure that the affected population is effectively informed.

Trends and developments

125. For all countries, there is a need to ensure that emergency response systems are adequate and forward-thinking. Many response arrangements currently assume that there will not be a need to respond to more than one nuclear accident or other emergency concurrently. Vulnerable countries need to carefully review emergency response arrangements for challenges related to extreme weather events and other natural hazards, such as earthquakes, that may trigger an accident and therefore impact the response. Universal implementation of the IAEA Safety Standards on emergency preparedness and response[37] at the national level is improving preparedness and response, facilitating emergency communication and contributing to the harmonization of national criteria for protective and other actions.

126. The implications of future natural hazards triggering sequential and collateral disasters necessitates that the United Nations response system, along with IAEA and others such as the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization, enhance cooperation to better support countries and regional efforts to increase preparedness capacity.

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[37] Jointly sponsored by FAO, ILO, OECD/NEA, PAHO, Office for the Coordination of Humanitarian Affairs and WHO.

Recommendations

127. There is a need for an inclusive and consolidated response system. The different response mechanisms should be linked and mainstreamed and an appropriate governance framework for coordination should be developed.

128. Disaster-prone countries, areas of substantial industrial and technological activity and regions where increased use of nuclear energy is expected, need to integrate preparedness measures for technological disasters into their emergency preparedness to respond to multi-hazards.

129. Relevant United Nations entities and related organizations are encouraged to enhance training programmes and to participate in relevant international exercises. Training and emergency response exercises are a key component of a good emergency preparedness programme and provide a powerful tool for verifying and improving the quality of emergency arrangements and capabilities.

130. The emergency preparedness and response framework should be strengthened by enhancing legal instruments and encouraging States to become parties to relevant conventions, through the universal implementation of the IAEA Safety Standards and through enhanced cooperation among States and international organizations.

131. The public must be provided with reliable information by authorities in a timely and sustained manner. Decision makers need to be able to base their decisions on clear and actionable information provided by multi-hazard information sources. The role of civil society organizations in providing information and explaining risk to the public must be emphasized.

132. Close cooperation and coordination among the relevant intergovernmental and non-governmental organizations on nuclear, industrial and technological safety and related matters should be encouraged.

133. There is a need to improve national, regional and international emergency preparedness and response to nuclear accidents and industrial and technological emergencies. That should include the possible creation of rapid reaction capacity, the strengthening of existing systems and the development of training in the field of crisis management.

134. Closer cooperation between IAEA and United Nations emergency response organizations is needed in order to ensure enhanced integration of preparedness and response capacities.

135. All United Nations humanitarian organizations should be involved in the Joint Radiation Emergency Management Plan of the International Organizations.

136. There is a need for high-level attention to and advocacy for the linkages between technological safety and security, environmental emergencies and humanitarian affairs.

3. Development of new monitoring and scientific capabilities[38]

Specific issues relevant for consideration by Governments

137. IAEA has capabilities for assessing nuclear emergencies and their radiological consequences. The IAEA Environment Laboratories in Seibersdorf, Austria, and in Monaco specialize in evaluating terrestrial and marine environmental samples, respectively. They coordinate the Analytical Laboratories for Measuring Environmental Radioactivity network and the Marine Information System database. The IAEA Radiation Monitoring and Protection Services Laboratories provide routine and ad hoc monitoring for IAEA staff, external experts and trainees in line with IAEA health and safety measures. The IAEA Safeguards Analytical Laboratories (which include the Environmental Sample Laboratory and the Nuclear Material Laboratory in Seibersdorf and the On-Site Laboratory in Rokkasho, Japan) maintain the Network of Analytical Laboratories.

138. The WHO International Health Regulations mechanism reinforces capacities for monitoring global public health risks during radiation emergencies. That is especially relevant to scenarios of unknown disease outbreaks, which may be due to a malicious act, in which case health authorities may be the first point of notification.

139. The existing capabilities of UNEP of disaster response teams are integrated into the system of the Office for the Coordination of Humanitarian Affairs and should be enhanced in order to address radiation emergencies. Capability should be developed to rapidly assess impacts on the wider environment, including for land, water and air, and their humanitarian and socio-economic implications.

140. The Comprehensive Nuclear-Test-Ban Treaty Organization global monitoring network of radionuclide stations is also important in nuclear emergencies. That kind of network may be used to assess the conditions causing the release at the source location, in order to provide information on the global radiological situation[39] and to predict when radioactivity might be detected at other stations.[40]

141. WMO provides the authoritative scientific voice on the state and behaviour of the Earth's atmosphere. Its operations include around-the-clock monitoring, data and information exchange, the provision of forecasts and warnings, and services to the general public, disaster management organizations, international organizations and other sectors.[41]

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[38] This section was prepared by IAEA.

[39] The Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization provides results and data for its States parties as soon as they are available; the system is also supported by a human review to ensure the quality of the results.

[40] Detections made by the network help to validate the atmospheric modelling. The Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization also provides assistance to disaster relief by providing data for tsunami warning systems. In that case, the data are provided in accordance with cooperation arrangements with tsunami warning centres recognized by the United Nations Educational, Scientific and Cultural Organization.

[41] Operational arrangements include functions of the Regional Specialized Meteorological Centres with specialization in atmospheric transport and dispersion modelling and are maintained in cooperation with IAEA. Routine exercises are conducted. Numerical weather prediction models provide input to atmospheric transport and dispersion models that are used for assessing (for example, analyses and hindcasts) and predicting the atmospheric movement, dispersion and deposition of airborne radioactive material.

Implications of the Fukushima accident and the impact of major nuclear accidents

142. After the Fukushima Daiichi accident, IAEA sent four radiological monitoring teams to Japan to help validate the results of more extensive measurements made by the Japanese authorities. The IAEA Environment Laboratories in Monaco reviewed all information regarding the marine environment and liaised with a number of centres to establish models to simulate the dispersion of radioactive material released into the ocean. The IAEA Environment Laboratories in Seibersdorf received samples taken in Japan during IAEA missions for analysis. The IAEA Radiation Monitoring and Protection Services Laboratories provided radiation protection services and advice to all IAEA, WHO and FAO staff travelling to Japan.

143. A comprehensive effort was made to ensure the operational capability of the Comprehensive Nuclear-Test-Ban Treaty Organization radionuclide monitoring network and timely analysis of the results. Before the first detections were made in the monitoring network (15 March 2011),[42] atmospheric transport and dispersion modelling was used to predict the expected time and date of detections in the network.

Trends and developments

144. Real-time online radiation monitoring systems are planned or already operational in many States, particularly those with nuclear power or which are adjacent to countries with nuclear power. While the purposes for establishing such systems may vary, the data are important for response to radioactive atmospheric releases.[43]

145. Comprehensive Nuclear-Test-Ban Treaty Organization data proved to be useful as a global surveillance system. The Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization could provide automatic warnings in case detected radioactive material contained unexpected radionuclides or abnormal concentrations of radionuclides. To provide rapid response, arrangements between the Preparatory Commission and other organizations are critical.[44]

146. Meteorological data, analyses, predictions, related information and their timely exchange among WMO members are the focus of WMO operational systems. Numerical weather prediction systems[45] integrate data and relevant environmental information and are an essential tool for analysing, assessing and predicting the

[42] During the course of the release, more than 40 radionuclide stations detected released radionuclides.

[43] An IAEA project on the development of a world-wide emergency radiation monitoring system is under way.

[44] The Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization did not participate in the Inter-Agency Committee for Radiological Nuclear Emergencies prior to the Fukushima Daiichi accident.

[45] High resolution numerical weather prediction models and atmospheric transport models, already widely available, can be used to improve atmospheric transport estimates; however, their use in emergency response should be carefully implemented based on realistic best-available estimates of the amount of radioactive material released. Radionuclide monitoring data should be used to calibrate the simulations, to improve assessments and predictions. In addition, since atmospheric washout is essential to the deposition of airborne radioactive material, precipitation data and high-resolution analyses are crucial.

state of the atmosphere, including the transport, dispersion and deposition of airborne materials.[46] Data requirements for improved predictions are continuously reviewed and addressed, for example in the ever-expanding use of data from satellite-based monitoring systems.

Recommendations

147. IAEA should establish a global radiation monitoring platform to display real-time data on radioactive releases and integrate data from international and national monitoring and early warning systems. The Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization should be requested to provide its expertise and radionuclide data for that purpose. The integrated monitoring platform would not supersede national radiation monitoring programmes but would bring additional benefits to all States and international organizations.

148. Consideration should be given to developing arrangements and tools for collating and interpreting environmental monitoring data (air, soil and water) and information derived from meteorological, hydrological and other computational models to assess their short- and long-term implications for public health and the environment.

149. IAEA should consider establishing a worldwide network of analytical laboratories, based on the existing Analytical Laboratories for Measuring Environmental Radioactivity and other national and regional networks, to analyse radionuclides in environmental and food samples.

[46] The possible impacts of an atmospheric release depend on the emission characteristics and environmental conditions. During an emergency, actual emissions at the source and monitoring data, of both the radioactivity and atmospheric parameters, are essential inputs for atmospheric transport modelling simulations, for assessing possible impacts and in turn for competent authorities to use when determining suitable protective actions.

Annex

Additional information received from United Nations entities, specialized agencies and related organizations

[English only]

1. In addition to their inputs to the thematic sections of the present report (see section III), replies containing additional information were received from the Preparatory Commission of the Comprehensive Nuclear-Test-Ban Treaty Organization and the World Meteorological Organization.

Preparatory Commission of the Comprehensive Nuclear-Test-Ban Treaty Organization

Development of new monitoring and scientific capabilities

Role of the Comprehensive Nuclear-Test-Ban Treaty Organization network following the 11 March 2011 earthquake

2. The events following the magnitude 8.9 earthquake on 11 March 2011 triggered all the verification systems designed to ensure compliance with the Comprehensive Nuclear-Test-Ban Treaty. It proved again that the Preparatory Commission International Monitoring System and transboundary data and data products produced by its International Data Centre have wide-ranging civil and scientific applications of direct relevance to disaster reduction and mitigation:

- The earthquake and several thousand aftershocks were conclusively detected by the International Monitoring System seismic stations
- The data generated by the seismic and hydro-acoustic stations helped to raise rapid alerts by tsunami warning centres in the Pacific region, in accordance with cooperation arrangements with tsunami warning centres recognized by the United Nations Educational, Scientific and Cultural Organization
- Infrasound detections provided evidence of explosions at the Fukushima nuclear power plant
- As the only global radioactivity network, radionuclide and noble gas monitoring stations provided independent, reliable, real-time, accurate and verified data on the global impact of releases from the power plant
- Atmospheric transport modelling predicted with a high degree of accuracy which stations and countries were going to be affected by the releases. Atmospheric transport modelling, developed in cooperation with the WMO, is central to the Comprehensive Nuclear-Test-Ban Treaty verification and provides validated information on the possible points of origin of the releases, as well as information on material dispersion, allowing accurate predictions on when and where detections may be expected. Atmospheric transport modelling prediction of the plume and real detections of enhanced activity concentrations reported from International Monitoring System stations that detected Fukushima releases were more than 95 per cent accurate, highlighting the predictive capabilities of that modelling technique

3. The release of radionuclides was first detected on 15 March at the Takasaki station, 200 kilometres south-west of the power plant. Observations at International Monitoring System stations in Petropavlovsk-Kamchatskiy, Russian Federation, and Sacramento, United States of America, confirmed the release. Detections indicated the release of large portions of gaseous radioactive materials and a small portion of solid materials.

4. The Comprehensive Nuclear-Test-Ban Treaty Organization radionuclide system is able to detect low-level radioactivity; it can detect one radioactive decay per second in up to one million cubic metres of air. The organization's noble gas detection system provides unique information on gaseous releases, and, under certain conditions, those detections can already be used as an early warning sign of developing conditions. As a result of the system's ultra high sensitivity, the detected concentration levels were generally not considered harmful for human beings despite the clear detection of radioactivity.

5. By end of May 2011, activity concentrations at most stations had returned to background level. During the course of the release, 41 radionuclide stations detected released radionuclides; also 19 noble gas (xenon) systems provided clear indication of detection. Those detections covered all of the Comprehensive Nuclear-Test-Ban Treaty Organization's radionuclide measurement systems in the northern hemisphere and a few in the southern hemisphere.

6. Data related to the radioactivity release was immediately made available to States Signatories to the Comprehensive Nuclear-Test-Ban Treaty. Member States were also kept informed of the development of the situation by way of six technical briefings since 15 March 2011. Inter-agency cooperation started with IAEA on 21 March 2011. Subsequently, special briefings using data from the Preparatory Commission were held for WMO, WHO, IAEA and the Office for Disarmament Affairs of the United Nations Secretariat.

Lessons learned from the experience of the Comprehensive Nuclear-Test-Ban Treaty Organization

7. The transboundary nature of nuclear accidents requires urgent measures to strengthen global emergency preparedness and to devise efficient disaster response systems. While short-term responses are able to address immediate safety and security related issues, "over the horizon" action over the next 10 to 20 years could include the following:

(a) A multiple stakeholder strategic planning review of the global emergency response framework should be undertaken, including national Governments, international and regional organizations, national and international commercial entities, and academic and scientific research centres;

(b) As part of the strategic review, a thorough capacity mapping (to identify strengths and weaknesses) of existing global monitoring systems utilized by several organizations should be conducted. Given current financial hardships, this is not the time for duplication of systems. Significant human resources and capital (approximately $1 billion) have already been invested in the verification regime of the Comprehensive Nuclear-Test-Ban Treaty Organization. Already more than 80 per cent complete, the International Monitoring System will consist of 321 seismic, hydro-acoustic, infra-sound and radionuclide monitoring stations and

16 laboratories built worldwide and linked to an extensive and sophisticated global communication network. Radioactivity is monitored by the International Monitoring System radionuclide network, comprising 80 particulate stations, 40 of which will be equipped with noble gas monitoring systems;

(c) Existing systems and expertise should be utilized and shared, as appropriate, through cooperative agreements among organizations. Improvement of and synergies between existing monitoring systems should be emphasized with due focus on the need for cost effectiveness and existing expertise. Institutional cooperation and specialized knowledge-sharing between regional and international organizations in accordance with their respective thematic mandates needs to be fostered and maximized;

(d) State-of-the-art technology should be mastered, including through scientific interaction and technology foresight. An effective transboundary disaster response system should employ and account for future technological developments through ongoing dialogue with the scientific community. Issues such as synergistic use of monitoring systems, information management and knowledge-sharing should be investigated. It would also be vital to stay attuned to the "over the horizon" long-term developments in the sciences and technologies underpinning those efforts, so that relevant and credible solutions can be made available to meet global public interest and expectations;

(e) Capacity development, education and training should be implemented in order to push the rapidly expanding scientific frontier even further. In addition to its regular training activities, the recently launched Capacity Development Initiative of the Preparatory Commission includes several online and classroom-based course modules on global responses to nuclear and other natural disasters. Similar initiatives by other international organizations would serve to strengthen and broaden participation in their respective areas of competency and significantly strengthen the international emergency response framework in the event of nuclear accidents, particularly in regions lacking national technical and scientific capacity in those areas.

World Meteorological Organization

Introduction

World Meteorological Organization missions

8. The mission of the World Meteorological Organization (WMO), as presented in the Convention establishing the organization is:

(a) To facilitate worldwide cooperation in the establishment of networks of stations for the making of meteorological observations as well as hydrological and other geophysical observations related to meteorology, and to promote the establishment and maintenance of centres charged with the provision of meteorological and related services;

(b) To promote the establishment and maintenance of systems for the rapid exchange of meteorological and related information;

(c) To promote standardization of meteorological and related observations and to ensure the uniform publication of observations and statistics;

(d) To further the application of meteorology to aviation, shipping, water problems, agriculture and other human activities;

(e) To promote activities in operational hydrology and to further close cooperation between meteorological and hydrological services;

(f) To encourage research and training in meteorology and, as appropriate, in related fields, and to assist in coordinating international aspects such as research and training.

9. In the light of its mission and the decision of its 189 members to address a set of global societal needs, WMO is committed to achieving its vision of providing world leadership in expertise and international cooperation in weather, climate, hydrology and water resources and related environmental issues, which will contribute to the safety and well-being of people throughout the world and to the economic benefit of all nations.

WMO institutional role and responsibilities

10. WMO delivers to its members through programmes approved by the World Meteorological Congress, a major pillar being the World Weather Watch.

11. The WMO World Weather Watch programme facilitates the development, operation and enhancement of worldwide systems for observing and exchanging meteorological and related observations and for the generation and dissemination of analyses and forecast products, as well as severe weather advisories and warnings and related operational information. The activities carried out under this programme collectively ensure that members have access to the required information to enable them to provide users with data, prediction and information services and products. The World Weather Watch is organized as an international cooperative programme, under which the infrastructure, systems and facilities needed for the provision of the services are owned, implemented and operated by the member countries. This is based on the fundamental understanding that the weather systems and patterns do not recognize national boundaries and are always evolving on varying temporal and spatial scales, and that international cooperation is paramount, as no individual country can be fully self-sufficient in the provision of all weather-, water- and climate-related services.

12. The World Weather Watch is the key programme of WMO in providing basic data, analyses, forecasts and warnings to members and other WMO and co-sponsored programmes, such as the Global Climate Observing System and the Global Ocean Observing System, and relevant international organizations.

13. As a component of the World Weather Watch programme, the Emergency Response Activities are of particular relevance to United Nations system-wide study.

Purpose and scope

14. The WMO Emergency Response Activities assist national meteorological and national hydrological services and other relevant agencies of members, as well as relevant international organizations, to respond effectively to environmental emergencies associated with airborne hazards, such as those caused by nuclear accidents or events, volcanic eruptions, chemical accidents, smoke from large fires and other events that require emergency atmospheric transport and dispersion

modelling support. Those Activities are carried out through the provision of specialized products by designated Regional Specialized Meteorological Centres; the development and implementation of efficient emergency procedures for the provision and exchange of specific data, information and products related to the environmental emergency; regular exercises; and training for users.

15. Activities related to airborne radionuclide hazards fall under two categories. First, nuclear accidents or radiological incidents fall under the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of Nuclear Accident or Radiological Emergency, to which WMO is a party, along with other international organizations, under the overall coordination of IAEA, with which WMO signed an agreement in 1960. Second, WMO collaborates with the Comprehensive Nuclear-Test-Ban Treaty Organization, with which it signed an agreement in 2003. WMO also provides specialized operational modelling in support of the Treaty Organization's verification regime.

Organization, governance, plans

16. WMO, as a party to the Conventions on Early Notification and Assistance, is a participating member, along with many other international organizations, in the 2010 Joint Radiation and Emergency Management Plan of the International Organizations. Within that context, in the event of a nuclear accident or radiological emergency, the roles and responsibilities of relevant international organizations, including WMO, are clearly described. IAEA coordinates the Joint Plan through the Inter-Agency Committee for Radiological Nuclear Emergencies.

17. The operational procedures for WMO are stated in its Manual on the Global Data-Processing and Forecasting System.[a] The regional and global arrangements for environmental emergency response are set out in appendix I-3 of the Manual, while a users interpretation guide is contained in appendix II-7. Those technical requirements are developed and recommended by the body that oversees the implementation and maintenance of the World Weather Watch, the WMO Commission for Basic Systems, and are reviewed regularly by its Coordination Group on nuclear Emergency Response Activities, whose members include all Regional Specialized Meteorological Centres with atmospheric transport modelling specialization (8 Centres for forward modelling, and 7 of those plus 2 others for back-tracking), with the participation of IAEA, ICAO and the Comprehensive Nuclear-Test-Ban Treaty Organization. WHO has been invited to join this group, but has not yet participated.

18. The regional and global arrangements require the three Regional Specialized Meteorological Centres in the WMO Asian Region (Beijing, Tokyo, and Obninsk, Russian Federation) to act as lead Centres during any confirmed nuclear/radiological incident in that region.

19. Routine exercises take place at least four times a year, with the participation of all Regional Specialized Meteorological Centres with atmospheric transport modelling, and a few national meteorological and national hydrological services (voluntary). As part of the International Conventions, Conventions Exercises are carried out with different scopes of testing, with different frequencies. The last two

[a] Available from www.wmo.int/pages/prog/www/DPS/Manual/WMO485.pdf.

full international exercises were level 3 exercises conducted in 2005 and 2008; the next in this series is scheduled for 2012.

WMO operations during the accident at the Fukushima Daiichi nuclear power plant

20. At the request of IAEA, WMO activated its Emergency Response Activities mechanism on 11 March 2011 to provide meteorological information to designated authorities on the likely evolution of the radioactive cloud that was accidentally released from the Fukushima Daiichi power plant. Operating 24 hours per day, WMO Regional Specialized Meteorological Centres in Asia (Beijing, Tokyo and Obninsk, Russian Federation) issued forecast charts of the dispersion of the nuclear material from the Fukushima Daiichi power plant on a routine basis until they were no longer required. The remaining five WMO Regional Specialized Meteorological Centres in other parts of the world also prepared dispersion charts for comparison and validation purposes.

21. WMO also made arrangements with the ZAMG meteorological service of Austria to provide meteorological support to the IAEA Incident and Emergency Centre in Vienna, while similar arrangements were made with MeteoSwiss, the meteorological service of Switzerland, to provide meteorological support to the World Health Organization in Geneva.

22. The WMO liaison office in New York prepared a package of information on the level of radiation and weather conditions in the incident-affected areas, with reference to the official data sources such as the Japan Meteorological Agency website. The package was presented at a meeting of the United Nations Communication Group and distributed by the Group to United Nations agencies and entities as science-based information.

Nuclear safety and security

Disasters caused by natural hazards

23. It should be noted that earthquakes and tsunamis do not fall under WMO responsibility and are not hazards related to hydro-meteorological events. There are therefore no comments about those phenomena or their impacts in this section. However, it should be recalled that the WMO Global Telecommunication network is used to transmit tsunami-related warning and information worldwide to national meteorological and national hydrological services, in operation 24 hours a day, 7 days a week, which can relay those warnings at the national level to the relevant authorities.

Links between natural hazards of hydro-meteorological origin and nuclear safety and security

24. Every year, disasters related to meteorological, hydrological and climate hazards cause significant loss of life and set back economic and social development by years, if not decades.

25. Disaster risk reduction is at the core of the mission of WMO, and the national meteorological and hydrological services of its 189 members. WMO, through its scientific and technical programmes, as well as the above-mentioned network of Regional Specialized Meteorological Centres and national meteorological and national hydrological services, provides scientific and technical services. They

include observing, detecting, monitoring, predicting and early warning of a wide range of weather-, climate- and water-related hazards. Through a coordinated approach, and working with its partners, WMO addresses the information needs and requirements of the disaster risk management community, effectively and in a timely fashion.

26. Preparedness and prevention, combined with effective emergency management and early warning systems, can significantly contribute to reducing the impacts of hazards on human life and economic losses. Moreover, the utilization of climate information for medium- to long-term sectoral planning can reduce the economic impacts of disasters.

27. Because of the need for water to cool their reactors, nuclear power plants[b] are located by coasts and rivers. Their functioning is therefore highly sensitive to any weather or climate conditions that affect the quantity and quality of the required water directly, such as coastal inundations and river flooding, unusually low water levels or high water temperatures, or indirectly, for example, ground movements such as induced subsidence due to soil dryness or extensive use of ground water in prolonged drought conditions.

28. Under extreme circumstances, nuclear power plants and/or their environment can be sensitive to the effects of wind, water and waves, thus making the operations inside or outside the nuclear power plant more difficult. In the case of the accident of the Fukushima Daiichi nuclear power plant, the combination of electricity cuts and disruption of electricity generators prevented the safety systems from functioning as expected.

29. One lesson learned is that safety- and security-related accident prevention and emergency plans and systems must not only allow for natural hazards on a type-by-type basis, but must also include a multi-hazard approach that allows for the possible impacts of combined hazards.

30. In that respect, WMO is working in partnership with the United Nations and other international agencies to support the strengthening of multi-hazard early warning system capacities, especially in developing countries, including: (a) the detection, monitoring and forecasting of meteorological and hydrological hazards; (b) analysis of hazards/risks and incorporating risk information in emergency planning and warnings; (c) dissemination of timely and authoritative warnings to authorities; and, (d) community emergency planning and preparedness and the ability to activate emergency plans. Those four components should be coordinated across several agencies at the national and local levels.

Possible changes of hazards with time

31. Natural hazards can change in intensity, frequency and location depending on factors other than climate change, namely:

- Changes to the physical geography of a drainage basin, including the estuaries; the offshore bathymetry, coastal profile and catchments areas; or the surface

[b] For the purposes of the present text, “nuclear power plants” should be considered in a generic sense and assumed to cover other types of nuclear installations, such as waste reprocessing plants.

roughness of the area around the site, which may influence the effects of wind on the plant

- Changes of land use in the area around the site
- Changes in the availability of water due to upstream dams or modification of use (such as irrigation)

32. For river basins, the design-basis flood is to a great extent dependent on the physical nature of the basin. For estuaries, the design basis flood can evolve over time as a result of changes in the geography or other factors, such as the construction of storm surge barriers.

33. The continuing validity of the design basis flood should be checked through periodic surveys of the conditions in the basin that may be related to floods (such as forest fires, urbanization, changes in land use, deforestation, closure of tidal inlets, construction of dams or storm surge barriers, changes in sedimentation and erosion). Those surveys should be carried out at appropriate intervals, mainly by means of aerial surveys supplemented, as necessary, by ground surveys. Special surveys should be undertaken when particularly important changes have occurred (for example, extensive forest fires). Where the size of the basin precludes carrying out sufficiently frequent air surveys, the use of data obtained by satellite imaging and sensing should be considered.

34. The data obtained from flood forecasting and monitoring systems and from the operation of any warning systems should be periodically analysed for changes in the flood characteristics of drainage basins, including estuaries.

35. Indications of changes in the flood characteristics of drainage basins should be used to revise, as appropriate, the design basis flood values and to improve the protection of systems and structures, the forecasting and monitoring systems, and the emergency measures. The forecasting models should be updated if necessary.

36. In some coastal areas, coastal erosion or land subsidence (natural or induced by humans, relating to the extraction of oil, gas or water) may have to be taken into consideration in the estimation of the apparent water height at the site, to be combined with the phenomena resulting from climatic changes.

37. A permanent uplift of the Earth’s surface due to an earthquake could result in a permanent low water scenario in areas close to large earthquake rupture zones. Similarly, a permanent subsidence of the Earth’s surface due to an earthquake could result in a permanent inundation in areas close to large earthquake rupture zones.

Climate change

38. Changes in the intensity and frequency of hydrological and meteorological extremes are considered to be key manifestations of regional and local climate changes associated with global climate change, particularly in the context of unequivocal evidence that global warming is already taking place and expected to be further enhanced.

39. Due attention should therefore be paid to the implications of climatic variability and change, and particularly the possible consequences in relation to meteorological and hydrological extremes and hazards that should be considered for the planned operating lifetime of power plants. The planned operating lifetime of

nuclear power plants is assumed to be about 60 to 100 years. Over such a period, it is expected that the global climate is likely to undergo significant changes, with widely varying regional or local manifestations, both in terms of the mean conditions and fluctuations on a range of timescales and of their impacts (for instance, evolution of permafrost areas leading to change in soil hydro-thermo-mechanical properties). With the mounting evidence of the sensitivity of such changes to human activities and socio-economic development pathways, future considerations should include the various plausible climate scenarios developed through state-of-the-art climate models. It is important to consider the future scenarios of changes in the variability as well as means of key climatic variables, particularly on the regional and local scales, with due attention to uncertainties in long-term climate projections.

40. While rapid advances have taken place in climate research, reliable climate change scenarios on the regional scale are still not widely available. Regional climate models are being increasingly used to downscale global climate projections to the region of interest. Further, century-scale future projections are subject to large uncertainties resulting from both the assumptions used in developing greenhouse gas emission/concentration scenarios and the inherent limitations of climate models. Those factors are now being included both in the dynamic and statistical approaches to downscaling climate projections to the local and regional levels. Equally important is the verification of past projections using available observational records to build confidence in their results for the future. Therefore, maintenance and stewardship of local and regional observations for the verification and analysis of observed trends are critically important. Major research efforts are under way to improve the reliability of climate predictions/projections on decadal timescales, in order to assess the likelihood of extreme events (such as floods, storms, heat and cold episodes).

41. The major effects with regard to hazards to nuclear power plants are related to the following causes:

(a) Changes in air and water temperatures;

(b) Changes in sea level;

(c) Changes in the frequency and intensity of meteorological and hydrological phenomena such as severe rainstorms, heat waves, intense tropical cyclones, storm surges, river discharges and severe drought conditions.

42. Future nuclear power plant designs should include additional safety margins for climate variability and change, especially with respect to extreme events. Design parameters should be periodically re-evaluated as the uncertainties affecting the estimates of future climate extremes are better quantified, based on climate observations and models. WMO will be working on development of climate information and services to support sectoral risk assessment and planning (for example, infrastructure and urban planning) with consideration for the changing characteristics of extreme events.

International emergency response framework

Adequacy of preparedness measures

Recommendations

43. As previously stated, preparedness for both plant design and emergency response should be multi-hazard oriented, with increased attention paid to the medium- and long-term evolution of both hazards statistics and the conditions of the surrounding environment.

44. This should be reflected in training programmes as well as in the design and return of experience of emergency response exercises.

Cooperation between international organizations

Implications of the Fukushima accident

45. According to agreed procedures, the WMO emergency preparedness and response system was activated on 11 March 2011 at the request of the IAEA Incident and Emergency Centre for emergency support. All eight WMO Regional Specialized Meteorological Centres, including the three primary Centres in the Asia region (Beijing, Tokyo and Obninsk, Russian Federation), were requested to produce and provide charts that estimated the possible spread of airborne radioactivity from the Fukushima accident site, based on the agreed default accident scenario of one unit release of radioactivity (Cs-137, I-131). The requested products of the Centres have been published on the IAEA Emergency Notification and Assistance Convention website.[c]

46. Throughout the nuclear emergency,[d] WMO also collaborated very closely with the Comprehensive Nuclear-Test-Ban Treaty Organization, WHO, ICAO and IMO. During the first few weeks of the emergency, atmospheric scientists from the national meteorological services of Austria and Switzerland, on behalf of WMO, provided assistance at the IAEA Incident and Emergency Centre and at WHO headquarters, respectively, in interpreting the atmospheric transport modelling outputs of the Regional Specialized Meteorological Centres.[e]

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[c] Early in the compounded earthquake, tsunami and nuclear emergencies, the Japan Meteorological Agency created public web pages that provided relevant information, including in English, on current weather conditions and winds along with forecasts for the disaster stricken area. This special service met the very large worldwide demand for weather information on Japan. Several other national meteorological services also posted on their respective public websites weather information on Japan or the region, in other languages.

[d] As decided by the accident country, the official classification used by IAEA for the emergency has been "General Emergency" since the beginning. That could mean that response organizations have to maintain emergency operations until a new classification is dictated.

[e] In addition, some WMO centres collaborated with the IAEA Incident and Emergency Centre in developing a best-estimate emission sequence from the beginning of the nuclear emergency, using high-resolution (5 km) atmospheric transport modelling results, and comparing them with radionuclide monitoring data. That emission sequence was then used by several meteorological centres to re-compute best-estimated dispersion and deposition patterns in high spatial resolution.

Trends and developments

47. As illustrated above, there is an increasing need for stronger integrated cooperation between United Nations agencies, so that all aspects and impacts of a nuclear or radioactive accident can be comprehended in a coordinated way. The same applies for information to be disseminated to media and the general public. This would require more intense and comprehensive training and exercises.

Recommendations

48. The current context provided by the Inter-Agency Committee and Joint Plan has to be evaluated, with any weaknesses corrected and new components added to ensure a more effective and efficient international emergency response.

49. The process of determining the classification of the emergency and which actions may be required in the resulting International Organizations Review needs to be reviewed, with a view to coordinating the operations of international organizations beyond several days in the event of protracted emergencies. That includes, for example, ensuring ongoing contacts among Joint Plan members at all times, and coordinating the flow of information between organizations and to the public.

Development of new monitoring and scientific capabilities

50. WMO provides the authoritative scientific voice on the state and behaviour of the Earth's atmosphere and climate. Its operations include around-the-clock monitoring, data and information exchange, production and provision of forecasts and warnings, and services to the general public, disaster management organizations, international organizations and many socio-economic sectors. Operational arrangements for nuclear emergency response are published as part of WMO technical regulations, regularly updated and included in the organization's Manual on the Global Data-Processing and Forecasting System. The arrangements include the functioning of the Regional Specialized Meteorological Centres with specialization in atmospheric transport and dispersion modelling, and are maintained in cooperation with IAEA, and exercised routinely. Numerical weather prediction models provide input for atmospheric transport models used for assessing (e.g. analyses and hindcasts) and predicting the atmospheric movement, dispersion and deposition of airborne radioactivity. The present arrangements and products of the Centres provide for global and continental-scale numerical simulations at medium-resolutions over large regions. The Centres also have the capability to provide operational atmospheric transport modelling "backtracking" services, as has been established with the Comprehensive Nuclear-Test-Ban Treaty Organization as part of a joint response system for its treaty verification. The backtracking system computes and estimates the possible location of the source of anomalous radioactivity measurement detected at a monitoring network location, anywhere in the world.

Trends and developments

51. Meteorological data, analyses, predictions, related information, and their timely exchange among WMO members are the focus of WMO operational systems. Numerical weather prediction systems represent an integrator of data and relevant environmental information and an essential tool for analysing, assessing and

predicting the state of the atmosphere, including the transport, dispersion and deposition of airborne materials.[f] Data requirements for improved predictions are continuously reviewed and addressed, for example in the ever-increasing use of data from satellite-based monitoring systems.[g]

52. Recognizing that actionable and scale-relevant climate information, in terms of data as well as tailored products representing the past, present and future status of the climate, is essential for decision-making, WMO, along with its partners, is working towards the implementation of a global framework for climate services. The global framework is expected to facilitate the development of climate services operating at the global, regional and national levels in a well-coordinated and user-oriented manner. The new initiative could be a good opportunity to identify and communicate the climate information needs of nuclear installations and operations to the relevant entities of the global framework.

Recommendations

53. Lessons learned from the accident at the Fukushima Daiichi nuclear power plant include the following:

- The Environmental Emergency Response mechanism worked well. The dispersion charts provided decision makers with scientifically sound estimates of the dispersion of the nuclear material in the atmosphere. However, it is time to review the products and procedures for issuing those in the light of experiences during the event and taking account of recent developments in both the science and technologies used in generating the products
- A particular problem for users of the dispersion charts was the use of an arbitrary concentration scale and predefined levels of release. The need for this arose because the details of the source term for the emission of the radioactive material were not known. Adequate monitoring systems should be located around each nuclear power plant so that the source term is known accurately and quickly. There should also be more coordination between the nuclear power industry and responsible international agencies for exchanging and using such information
- Standard procedures urgently need to be updated for assessing the hydrological and meteorological hazards, including climate change, for existing and proposed nuclear power stations

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[f] High resolution numerical weather prediction and atmospheric transport Models, already widely available, could be used to gain in the details of atmospheric transport estimates; however, their use in emergency response should be carefully implemented based on realistic best-available estimates of the amount of radioactivity released. Radionuclide monitoring data should be used to calibrate the simulations and to improve assessments and predictions. In addition, since atmospheric washout is a key to the deposition of airborne radioactive contamination, precipitation data and high-resolution analyses are crucial.

[g] Atmospheric transport modelling systems for nuclear emergency response will be a direct beneficiary of these developments, especially when radioactivity monitoring data become available for model validation and calibration, in a range of model resolutions and coverage. Techniques using an ensemble of forecasts from numerical models, with slightly different initial conditions and representation of physics in the Earth’s boundary layer, are being developed to derive uncertainty information for atmospheric transport modelling outputs.

54. Some general recommendations are also valid to better cover the whole service life of nuclear installations with respect to the influence of weather, climate and water, both on the efficiency and the safety and security of their operations.

55. When any meteorological or hydrological event proves to be a significant hazard for the site of a nuclear installation, it is essential that the site be continuously monitoring from the site selection study phase and throughout the entire service life of the nuclear installation, for the following purposes:

- To validate the design basis parameters, especially in cases for which the series of historical data are very poor
- To support the periodic revision of the site hazards in the light of the periodic safety assessment; this concern is becoming increasingly urgent as a follow-up of the consequences of global climate change
- To provide alarm signals for operators and emergency managers

56. For meteorological and hydrological events, the monitoring and warning measures that should be taken during the operation of the nuclear installation will depend on the degree of protection offered by the selected site and on the consideration of the hazards in the design basis of the installation. Some of the measures should be implemented at an early stage of the project.

57. The data to be used for long-term monitoring and those to be used for a warning system should be chosen on the basis of different criteria, since the purposes of monitoring and those of the warning system are not the same. The purpose of long-term monitoring is to evaluate or re-evaluate the design basis parameters, for example when performing a periodic safety review. The purpose of the warning system is to forecast any extreme event that may affect operational safety. Special care should be taken regarding the ability of the warning system to detect any extreme events in sufficient time to enable the installation to be brought under safe conditions. A warning system should be put in place for sites where the hazards are significant for the design of the installation.

58. The warning system should be used in connection with forecasting models, since the time period that the operator would need to put the installation into a safe status may necessitate acting on the basis of extrapolations of trends in phenomena without waiting for the actual occurrence of the hazardous event.

59. In the case of the occurrence of an event for which the operator relies on forecasting models that are made available by organizations external to the operating organization, validation of the models and of the communication channels with those organizations should be carried out in order to ensure their availability and reliability during the event.

60. Specific quality management or management system activities should be carried out to identify the competences and responsibilities for installing and operating the monitoring systems, the associated data processing and the appropriate prompting of operator action. Those activities should include planning and executing drill exercises at given intervals for all parties involved.

61. In general, the following monitoring networks and warning networks should be considered:

- A meteorological monitoring system for basic atmospheric variables

- A meteorological warning system for rare meteorological phenomena (such as hurricanes, typhoons and tornadoes)
- A water level gauge system
- A tsunami warning system
- A flood forecast system

62. Furthermore, roles and responsibilities of various public and private sector stakeholders should be reflected in the national and local regulatory frameworks and planning.

Concluding remarks

63. The WMO strategic plan has identified five priority areas:

- Implementation of the Global Framework for Climates Services
- More coordinated disaster risk reduction
- Improved observation and information systems
- Capacity development to help developing countries share in scientific advances and their applications
- Improving meteorological services for the aviation sector that enhance both safety and operational efficiency

64. All of those priority efforts should lead to better monitoring of nuclear installations and a more secure, safe and peaceful use of nuclear energy worldwide. WMO is committed to strengthening dialogue with all relevant stakeholders in order to better define the information and services required for optimizing the preparedness, monitoring and emergency response for/by them, and with a view to improving and promoting the safety standards and to maximizing the overall engagement of the international community for peaceful use of nuclear energy to the benefits of humanity.