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# Strengthening National Regulatory Capabilities InCountries Embarking On New Commercial Nuclear Power Programs PostFukushima Accident.

A. Hamed, A.A. Gadalla & Eltohamy. R. Elsharkawy
*Nuclear and Radiological Emergency Centre,Nuclear and Radiological Regulatory Authority, Cairo Egypt*

## ABSTRACT

**ABSTRACT:-** The mainobjective of this paper is to highlight the lessons learned to date from the Fukushima Daiichi accident that are relevant to strengthening the effectiveness of national regulatory bodies. The paper is focusing and spot lights on the processes and activities undertaken in Egypt for strengthening the nuclear and radiological regulatory effectiveness in the light of the lessonslearned from the accident at the Fukushima Daiichi NPP.Among other Arab countries, Egypt is considered as a newcomer country planning to introduce NPPs for electricity generation. One of the apparent actions taken in Egypt, to improve its nuclear safety management and regulatory system, is the activation and re-organizing its newly developed and independent nuclear regulatory body, the Egyptian Nuclear and Radiological Regulation Authority (ENRRA), which is assigned directly to the prime minister. Bythe end of the year 2011, the executive regulatory requirements for nuclear and radiological activities got into force to direct the processes of learning and acting upon lessons to strengthen nuclear safety, emergency preparedness and radiation protection of people and the environment in Egypt. A complete reorganizing process for ENNRA has been initiated by the separation between the research and the regulatory sectors. Additional activation processes have been achieved to strengthen the practical capabilities of the regulatory sector with emphasis to human resources capacity building, accident management, and on-site and off-site emergency management. Review and assessment as well as regulatory inspection committees in the ENRRA have been activated for the enforcement processes regarding research reactors, fuel manufacturing pilot plant and other radiological activities in the country to update and improve their safety requirements, guides and emergency plans according to the lessons learned after Fukushima accident.

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## I. INTRODUCTION

No doubt that the severe accident at Fukushima Daiichi Nuclear Power Station, triggered by the natural disaster on March 11, 2011, taught Japan and the world many important lessons on nuclear safety and regulatory issues among other things, the issue of the national regulatory frameworks and the national regulatory authorities[1]. These lessons have opened many more issues to be learned, especially in newcomer countries embarking on new nuclear power programmers for electricity generation. Following this accident, many regulatory bodies all over the world carried out a complete and intensive review of safety guidelines and regulatory requirements with the aim of formulating a set of new regulations to protect people and the environment. The accident at the Fukushima-Daichii nuclear plant has generated worldwide news and precipitated public concern about the safety of nuclear power in general. The accident has already caused some governments to re-think their nuclear energy policies, notably including the Japanese and German governments. There have been calls for cancellation of nuclear construction projects and reassessments of plant license extensions. This may lead to a global slow-down of the nuclear enterprise, based on the perception that nuclear energy is not safe enough [2].

## II. GLOBAL NUCLEAR POWER BEFORE AND POST FUKUSHIMA ACCIDENT

As of 2004, construction starts per year began to rise and reached 16 new builds by 2010 - a level of construction starts not witnessed since 1985 (see
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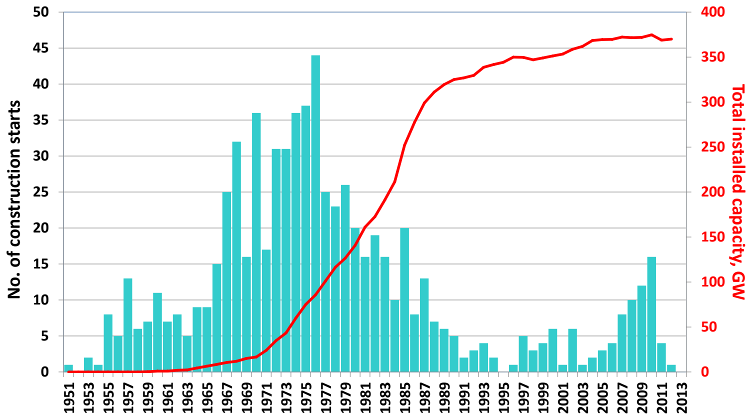

**Figure 1: Number of construction starts globally and total installed generating capacity, 1951 - 2012 (30 June 2012). Source: IAEA, 2012a.[3]**

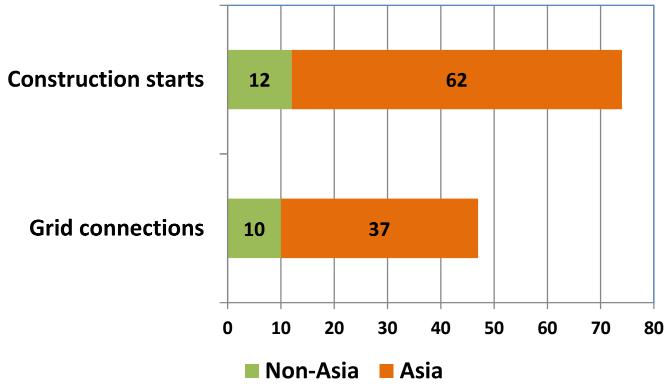

**Figure 2: Construction starts and grid connections since 01 January 2000. Source: IAEA, 2012a.[3]**

All starts since 2000 have occurred in countries with already existing nuclear power plants, with Asian countries taking the global lead (see

**Figure 2**).As of 25 of July 2012, the global fleet of nuclear power plants consisted of 435 reactors with a combined installed nuclear generating capacity of 370 GWe (375.5 GWe on 10 March 2011). Note: the total includes plants that currently are off-grid such as the remaining 48 reactors in Japan but not declared as permanently shut down. In 2011 nuclear power accounted for 12.3% of global electricity supply down from 13.5% the year before. Figure 3 (left) depicts the regional distribution of nuclear generating capacities.

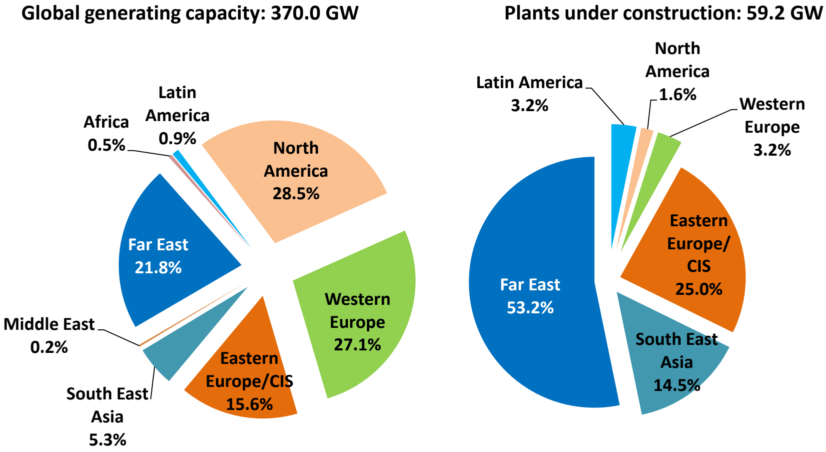

**Figure 3: Global generating capacity (left) and plants under construction (right) - as of 25 July 2012. Source: IAEA, 2012a [3]**

Despite the Fukushima Daiichi accident, the trend of uprates and renewed or extended licences for many operating reactors continued in many countries. Uprates of some 400 MWe and the grid connection of 8 new build reactors (totaling 5.7 GWe since the accident helped mitigate the lost capacities of the 15 reactors (11.4 GWe) declared shut-down for good. The right panel of 3 shows the regional distribution of the 62 reactors currently under construction with a combined generating capacity of 59.2 GW. It highlights the shift in expansion from the traditional nuclear countries in North America and Europe which dominate the current regional capacity distribution to Asia where the long term growth prospects remain centered.[3]

## III. LEARNING LESSONS FROM THE FUKUSHIMA ACCIDENT

However, the lessons to be drawn from the Fukushima accident are different. First, the accident was a result of the worst earthquake and tsunami in Japan's modern history( see figure 4),an event which has caused the loss of over 20,000 lives and up to $300 billion in damages.

Fig.4The damaged reactor buildings at Fukushima Daiichi (Photo: Reuters/DigitalGlobe/Handout

Second, given the extraordinary magnitude of the initiating events (i.e. earthquake was 9.0 vsdesign 8.2, tsunami wave was 14 m vs design 5.7 m), the Fukushima-Daichii plant has performed relatively well in some respects and so far there is no evidence of major human errors in handling the crisis. It is noted that the containments at Units 1 and 3 have not failed, in spite of the exceptional loads they have been subject to, i.e. earthquake, tsunami, hydrogen explosions in the reactor buildings, steam discharges from the reactor pressure vessel, exposure to hot seawater, pressure above design limits for days. It is likely that there is a leaking the containment at Unit 2[4].The release of radioactivity from the plant has been large (with contributions also from containment venting and spent fuel pool overheating) and some workers have received significant radiation doses (>100 mSv whole-body equivalent), but health risks for them and the general population are expected to be negligible. In fact, no loss of life has occurred as a result of the accident. Direct damage and casualties inflicted onJapan by the earthquake and tsunami far exceed any damage caused by the accident at the nuclear plant. The Fukushima accident has been rated at the maximum level (Level 7) on theIAEA nuclear event scale, indicating an accident with large release of radioactivity accompanied by "widespread health and environmental effects", like Chernobyl. However, there are very significant differences between Fukushima and Chernobyl. Briefly, the amount of the release (~10% of Chernobyl), the presence of the containment structures, the radio nuclidesreleased (mostly iodine and cesium isotopes vs. the entire core inventory), the physical form of the releases (mostly aqueous vs. volatile), the favorable currents and winds at the site, and the timing of the release with respect to population evacuation resulted in vastly smaller overallconsequences. Having said this, it is important to analyze the technical lessons that can be learned from Fukushima, so that the safety of nuclear plants in the U.S. and worldwide can be further enhanced and attractiveness of nuclear energy sustained over the long term.

## IV. EMERGENCY RESPONSE FOR BEYOND DESIGN BASIS EXTERNAL EVENTS, OBSERVATIONS FROM FUKUSHIMA:

There were concerns that TEPCO could not ensure proper staffing of the plant throughout the accident, if a significant fraction of the local staff had been killed or injured by the earthquake and tsunami. The U.S. NRC called for a much larger evacuation zone for U.S. citizens around theFukushima plant ("This is the same advice that the NRC would give if this incident were taking place in the United States, to evacuate beyond a 50-mile radius," NRC Chairman Jaczko, March17, 2011). While precautionary, this call did not seem consistent with the magnitude of the radioactivity releases; it undermined the Japanese regulator's credibility, and created anxiety and confusion in the media, local population and general public. Communication of radiation levels to the public was made difficult by three factors: the use of three different scientific quantities (dose, dose equivalence and activity), the use of two systems of units (SI units used worldwide and the older units still in use in the U.S.), and a lack of context for understanding the meaning of these radiation levels [6].

### 4. 1 Key questions:

How can proper staffing be assured if a significant fraction of local staff are killed by the initiatingexternal event? How can the extension of the required evacuation zone be determined when great direct damage is inflicted on the area surrounding the plant by the initiating external event? What is the best method to communicate radiation risk to the public in a simple and effective manner?[7].

### 4. 2 Possible corrective actions at current and future plants:

• A rapid-response team of essential workers could be transported to a stricken plant for scenarios in which the plant owner/operator cannot staff the plant properly. In the U.S., training and operating costs for this rapid-response team could be borne by INPO and/or consortia of utilities with similar plants, and also assisted by the Air Force for rapid deployment to the site. The U.S. Federal Aviation Agency (FAA) has a system that may serve as one model. In countries with a smaller nuclear fleet, the rapid-response team may even be international.• Over-conservative evacuation zones (e.g. >20 miles) should not be implemented in case of accidents initiated by natural catastrophes (e.g. earthquake, tsunami, hurricane) that have already affected the local population significantly. Large evacuations divert resources away from the much greater disaster and may create undue stress on the population trying to cope with the direct consequences of the initiating event. Assessment of the tradeoffbenefits between sheltering and evacuation needs re-emphasis. Evacuation strategies should be based on minimizing risk to the public from all causes. Extension of evacuation zones should become a function of both radioactive releases as well as direct damage inflicted on local area by the initiating event.• Regulators could demand more on-site personnel to have independent and timely sources of information, and the ability to influence, or if necessary direct, the owner/operator behavior during the accident. Note that in such cases where the regulator takes an active role, the overall responsibility for consequences will then be diffused.• Radiation risk during nuclear accidents should be communicated to the public using a qualitative, intuitive scale vs. the traditional quantities of dose rate and activity. For example, the units of 'natural background dose equivalence rate' could be adopted. To avoid the necessity of adjusting for local background variations, the world average dose-rate from natural sources should be used: 2.4 mSv/year or 0.27 µSv/hr. Thus the elevated levels due to contamination would be presented in terms of the factor by which natural background radiation is exceeded. This approach has several advantages. First, no effort is needed to understand the unit used. For instance, 10 times natural background is easier to grasp than2.7 µSv/hr since no prior learning in a specialized field is required. Second, there is never need to convert between unit systems or to be mindful of numerical prefixes (milli-rem,micro-Sv, etc.). Third, this method of conveying information about radiation levels reinforces the concept that some level of radiation exposure is both natural and normal. Finally, use of this unit implies no estimation of the magnitude of the health hazard from the radiation levels. This is important since we do not know how hazardous chronic, elevated background dose rates are, though it is noted that there are regions of the world with background radiation dose rates one order of magnitude higher than the world-average and yet with no measureable health consequences[8].

## V. PUBLIC HEALTH IMPACTS OF FUKUSHIMA AND RADIONUCLIDES OF CONCERN

On March 22, MEXT announced an action plan for monitoring coastal waters near the Fukushima Daiichi NPP site. Air and seawater samples were collected on March 23 in coastal waters along transects that are separated by 10 kilometer intervals – sampling was performed along each transect to a distance of about 30 kms offshore. The results published on March 24 03:00 UTC are presented below in table.1[9]. While there are many radionuclides that can be released at the time of a reactor accident, not all have the potential to impact public health because of issues related to: abundance,

***Table(1): The results published on March 24 03:00 UTC .***

| **Sampling Point** | **Sampling Date and Time (UTC)** | **Seawater concentration (Bq/L)** | | **Dose Rate (microSv/h)** | **Dust in Air Radionuclide Concentration (Bq/m3)** | |
|---|---|---|---|---|---|---|
| | | **I-131** | **Cs-137** | | **I-131** | **Cs-137** |
| 1-1 | 22-Mar 23:10 | 24.9 | 16.4 | 0.034 | 0.133 | 0.00676 |
| 1-2 | 23-Mar 00:00 | 30.0 | 11.2 | 0.038 | 0.0623 | 0.0694 |
| 1-3 | 23-Mar 00:30 | 76.8 | 24.1 | 0.049 | 0.0936 | -- |
| 1-4 | 23-Mar 01:15 | 37.3 | 18.2 | 0.054 | 0.0866 | 0.016 |
| 2-1 | 23-Mar 02:20 | 54.7 | 12.7 | 0.035 | -- | -- |
| 2-2 | 23-Mar 03:00 | 42.0 | 12.8 | 0.030 | -- | -- |
| 2-3 | 23-Mar 03:37 | 29.0 | 15.3 | 0.040 | -- | -- |
| 2-4 | 23-Mar 04:32 | 39.4 | 15.2 | 0.040 | -- | -- |

decay scheme, half-life, and chemistry (which ultimately affects route into the body, anatomical area of concentration, and residence time).Noble gases such as krypton and xenon rapidly disperse in the atmosphere; heavy elements are non-volatile so, if released outside the containment, tend to stay at the plant or in the near vicinity. The isotopes of particular concern are 131I and 137Cs. Both decay by a combination of beta and gamma emission, which means they can represent both an internal and an external hazard. They are released in relatively high abundance and their half-lives (8 days and 30 years, respectively) are sufficiently long that they do not decay before being widely distributed in the local environment, yet are sufficiently short that enough nuclei will decay to result in significant and measureable doses in the time scales important to human life. Measured external gamma dose-rates following the tsunami and subsequent damage to the cooling systems at the Daiichi nuclear power plants spiked on March 15 and 16 and thereafter gradually declined. The rate of decline is a result of the combined effects of environmental dispersion and physical decay with a mix of the short half-life 131I and the much longer half-life 137Cs. Nine weeks after the emission spike the effective half-life of the measured gamma dose rate is approximately 70 days. The effective half-life continues to increase but will always be smaller than the physical half-life of 137Cs due to effects of weathering and further distribution in the environment. Peak gamma dose rates at different geographical locations depended on both distance from the damaged plant and on wind and rain patterns. Iodine and Cs reach the ground via dry deposition but deposition is hastened by rainfall which can lead to local areas of high activity. Wet and dry deposition onto crops and subsequent human ingestion, or ingestion by cattle followed by consumption of contaminated milk, is the most common route into the body. Radioiodine was of most concern in the immediate aftermath of the accident both from an external dose perspective and because of the potential for induction of thyroid cancer, particularly in children (internal dose). Drinking water restrictions based on 131I levels were in place for a number of days, particularly for infants for whom a maximum level of 100 Bq/L was recommended1.It is 137Cs that represents the most significant long-term hazard of a contaminated environment. Chemically it behaves like potassium which is found in all of our cells, so it is readily taken up and used if available. Like iodine it will settle out of the radioactive cloud onto fields and crops. Since it binds tightly to moist soil it is not readily taken up via the root structures of plants however it can enter plants upon falling onto the surface of leaves. Elevated levels of 137Cs in several foodstuffs required restrictions on consumption and prompted a number of countries to limit imports from Japan for some time. All drinking water interdictions were lifted in early May however several foodstuffs still show radiation levels that exceed regulation values set by Japanese authorities[10].

### 5.1 Radiation Doses

Deposition of I-131 and Cs-137 has been reported in about 10 prefectures. As the Table.2 illustrates, deposition rates vary appreciably from one day to the next. If rainfall occurs, there can be substantial changes in deposition (i.e. wet deposition). This may explain the increased deposition in Tokyo between the March 20-21 and March 21-22 measurements. New and updated data is underlined[9]. Attempts are ongoing to keep the cumulative radiation doses to the Japanese public below 20 mSv in the first year following the reactor accident.

[Doses will be substantially lower in subsequent years due to environmental dispersion and physical decay of residual 137Cs.]

***Table (2): Deposition (Bq/m2) measured during a 24 hour period, from 9:00 to 9:00[9]***

| **Location** | **Mar 18-19** | | **Mar 19-20** | | **Mar 20-21** | | **Mar 21-22** | | **Mar 22-23** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **I-131** | **Cs-137** | **I-131** | **Cs-137** | **I-131** | **Cs-137** | **I-131** | **Cs-137** | **I-131** | **Cs-137** |
| Iwate(Morioka) | ND | ND | ND | 0.24 | 4800 | 690 | ND | ND | 23 | 13 |
| Yamagata(Yamagata) | ND | ND | 22 | 20 | 58000 | 4300 | 590 | 140 | 2100 | 1900 |
| Ibaraki | - | - | 490 | 48 | 93000 | 13000 | 85000 | 12000 | 27000 | 420 |
| Tochigi(Utsunomiya) | 1300 | 62 | 540 | 45 | 5300 | 250 | 25000 | 440 | 23000 | 99 |
| Gunma(Maebashi) | 230 | 84 | 190 | 63 | 990 | 87 | 1500 | 72 | 310 | ND |
| Saitama(Saitama) | 64 | ND | 66 | ND | 7200 | 790 | 22000 | 1600 | 22000 | 320 |
| Chiba(Ichihara) | 21 | ND | 44 | 3.8 | 1100 | 110 | 14000 | 2800 | 22000 | 360 |
| Tokyo(Shinjyuku) | 51 | ND | 40 | ND | 2900 | 560 | 32000 | 5300 | 36000 | 340 |
| Yamanashi(Kouhu) | 175 | ND | ND | ND | ND | ND | 4400 | 400 | 110 | 26 |

This effort involves (i) monitoring radioactivity levels in foodstuffs and water and prohibiting sale and consumption where necessary , (ii) recommending sheltering indoors in areas where cumulative dose-rates over one year are expected to be > 10 mSv, and (iii) relocation of residents from within a 20 km radius zone around the plant. 70,000-80,000 residents were relocated in the first month after the accident but relocations are continuing in areas where residents are predicted to receive doses in excess of 20 mSv in the first 12 month period. Doses to people living further from the Daiichi plant are much lower. In Tokyo, 240 miles away, residents can expect an additional cumulative radiation dose of 1 mSv from the first year, a 40 % addition to the 2.4 mSv they already receive from natural sources. As of the first week of May, external gamma-dose rates in Tokyo are 0.09 µSv/hr, a factor of almost two above natural levels (0.05 µSv/hr). Since external gamma dose contributes ~ 20% to the total background dose (the remaining dose components are cosmic rays, internal radio nuclides, and radon daughters), this increase in gamma ray exposure currently adds 16% to the daily radiation dose to Tokyo residents [11].

### 5.2 Health Implications

The impact of low doses of radiation on our health is assumed to be an increase in the probability of being diagnosed with cancer. No other natural disease shows a significant elevation following exposure to low dose radiation and no unusual or unique diseases are created. Radiation-induced cancers have a latent-period of 20-30 years (shorter for leukemia)and tend to appear at the same time in irradiated as in unirradiated populations. Since the cancers induced by radiation are the same types of cancers observed ‘naturally’, determining the number of *additional* cancers caused by a small dose of radiation when baseline cancer rates are already high has not been possible for doses in the 20 mSv range (or even higher).Although no data have ever demonstrated that 20 mSv over 1 year results in measureableharm, this dose range has long been relevant to the occupational radiation protection field and thus there has been a need to generate radiation risk estimates, even in the absence of actual data. These estimates come primarily from the long-term evaluation of the A-bomb survivor population and are a result of adopting a hypothetical model of extrapolating the risk per unit dose at high dose levels down to the low dose range. Use of this extrapolation model in the generating of risk estimates incorporates a number of assumptions appropriate to radiation protection in the workplace but not appropriate to determining the hazards of an environment contaminated with a long-lived radionuclide. Accordingly, scientific bodies evaluating risk often specifically caution *against* extending these strategies to predicting the long term effects of small doses to a large population. Unfortunately, more applicable risk estimates do not exist and so this caution is routinely ignored when the potential impact of low doses is of interest [12].

## VI. RESPONSE OF THE ENRRA EMERGENCY CENTRE TO FUKUSHIM ACCIDENT,TECHNICAL SAFETY MEASURES

An intensive capacity building training programs in cooperation with the IAEA, the EC and R.ofS. Korea have been initiated to improve the regulatory capabilities of ENRRA man power especially in the fields of review and assessment and regulatory inspection for NPPs. Agreements with other TSOs in the universities and nuclear centers have been activated to enhance safety culture and strengthen the technical capabilities of workforce in the nuclear field. Regarding accident management and emergency management tasks, a complete reorganizing process of the emergency management center of the ENRRA(See figs 5, 6) has been achieved with emphasis to training capabilities of the human resource in this center. Participation in several IAEA workshops and Exercises or drills on the international levels have been successfully implemented. Essential importance was placed on the third and fourth layers of the concept of “Defense-in-Depth”for prevention and mitigation of the consequences of simultaneous loss of all safety functions due to common cause failures. In this regard, the previous assumptions on the impact of earthquakes, tsunamis and other external events such as volcanic eruptions, tornadoes and forest fires were re-evaluated, and countermeasures for nuclear safety against these external events were decided to be enhanced. Furthermore, additional countermeasures against internal fires and internal flooding have been undertaken to enhance the reliability of on-site and off-site power sources to deal with the possibility of station blackout (SBO). In addition to the above-described enhancement of countermeasures established at design basis, countermeasures for severe accident response against core damage, containment vessel damage and a diffusion of radioactive materials, enhanced measures for water injection into spent fuel pools, countermeasures against airplane crash, and an installation of emergency response building are also required[13].The new regulatory requirements were developed taking into account the lessons-learnt from the accident at Fukushima Daiichi NPP that were identified in the reports of the National Diet’s Nuclear Accident Investigation Commission, the Government’s Nuclear Accident Investigation Committee and the Independent Investigation Commission on the Fukushima Daiichi nuclear accident, considering the harsh natural conditions unique to Japan, and in line with the consistency with the safety standards and guidelines of the IAEA. So-called “safety myth” had critically impeded efforts for nuclear safety in Japan before the accident at Fukushima Daiichi nuclear accident, however, more stringent regulations have been developed with an underlying assumption that severe accidents could occur at any moment. In the sense of “Back-fit”, the new regulations are applied to the existing nuclear power stations, however, a five-year deferment period from the time of enforcement of the new regulations is given to a realization of some safety measures including filter vents for pressurized water reactors (PWR) and control rooms for the time of emergency. Nuclear power reactors, that are generally limited to 40 years of operation life-time, will be given one-time legal permission to extend it to another 20 years. Under the revised Reactor Regulation Act, operators applying for such an extension are required to implement special inspections to assess whether their facilities meet or not the latest technical standards and properly maintain or not their operation from the viewpoints of any expected and deterioration of facilities and equipment in the 20-year time period. In the situation that the NRA has been tackling on the on-going serious conditions at Fukushima Daiichi Nuclear Power Station, the new regulatory requirements and regulations were developed with strict time constraints. Therefore, it will be necessary to be constantly reviewed with new findings and scientific technologies that are acknowledged in Japan and overseas with continuous efforts to enhance nuclear safety. Although restoring trust in Japan’s nuclear safety regulations after the accident at Fukushima Daiichi Nuclear Power Station will be extremely difficult, “Safety Culture “in which safety is paramount should be fostered among operators, other industry sectors and the ENRRA. The ENRRA hopes that the new regulatory requirements and regulations will become both the guidepost and the foundation to improve “Safety Culture “not only in Japan but also in countries all over the world[14].

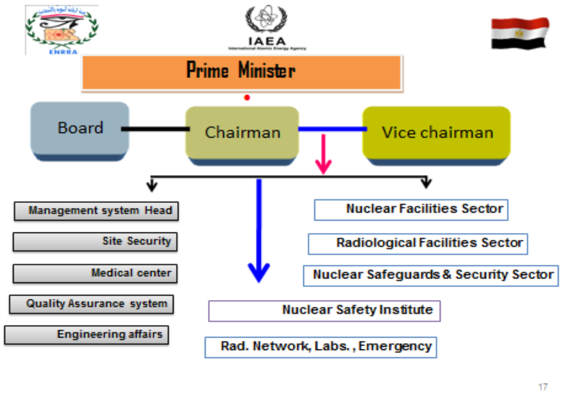

**Fig. 5 Organization Structure of ENRRA**

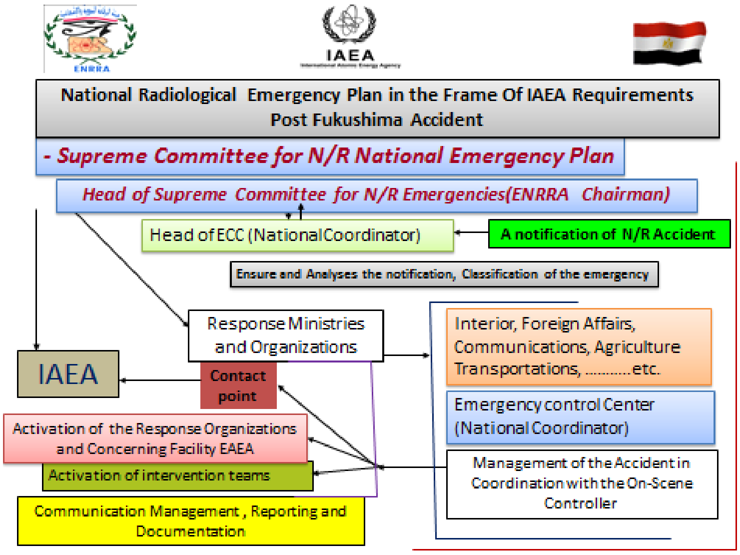

**Fig. 6Response organizations with ENRRA in case of N/R Emergency**

## VII. CONCLUSION

An obvious approach for possible future improvements in existing nuclear power plants would be to choose sites away from highly seismic areas and coasts, to greatly reduce (and perhaps eliminate) the possibility of damage due to massive earthquakes, tsunamis and floods. It is noted that people tend to congregate near coasts and faults (river valleys); therefore, there are strong synergies between minimizing the probability of an adverse external event and maximizing the distance from densely populated areas. The vast majority of nuclear plants worldwide are already located away from highly seismic areas. Notable exceptions are the plants in Japan, Taiwan and California; however, the larger seismic challenge (i.e. higher expected ground motions) in these regions is currently overcome by a more stringent seismic design of the plants located in these regions. The strategic question here is: should there be a requirement to avoid identified vulnerabilities or should plants be allowed to design against them? • The number of allowable units at a single plant site could be determined based on an analysis which accounts for the following, often conflicting, factors: (i) reduction of common cause vulnerabilities, (ii) availability of staff and resources to address a severe accident impacting all units simultaneously, (iii) reduction of potential source terms, (iv) high standardization (shared learning), (v) shared equipment (with implications on both economics and safety), and (vi) low environmental impact of multi-unit cooling.

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