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Suggestions for the Effective Application of IAEA Code of Conduct on Research Reactor Safety to Nigeria

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1. Introduction

The International Atomic Energy Agency (IAEA) accompanied Integrated Nuclear Infrastructure Review Mission for a new Research Reactor (INIR-RR) to the Federal Republic of Nigeria in February 2018. The purpose of this review mission was to assess the status of development of Nigeria's infrastructure to support a new research reactor project. However, the review results revealed that several safety aspects exist and that those safety issues are relevant to the currently operating research reactor, a 31kW miniature Neutron Source Reactor (MNSR). Thus, the review highlighted the present status of the application of the IAEA code of conduct on Research Reactor safety, which requires Nigerian Regulatory Body to use in order to improve regulatory infrastructure in compliance with global standard.

This paper reviews the safety issues and regulatory challenges of the Nigerian research reactor and recommends suggestions to improve the regulatory activities in Nigeria. In order to address the professional's opinion, this paper focusses on developing a questionnaire, which finally identifies the safety issues and possible suggestions made based on the notion provided by the guiding document (IAEA code of conduct on research reactor Safety).[1][2]

2. Safety issues and Regulatory Challenges of Research Reactor operation In Nigeria

Nigeria presently operates a 31kW miniature Neutron source Reactor (MNSR). Its operation began in February 2004 by Centre for Energy research and training (CERT), currently in its first cycle and undertaking conversion from HEU to LEU. The status of the reactor is summarized in Table 1. [3]

The basic problem of MNSR is that it is underutilized as presently and it is used for research and some analytical services only. The reactor has not been used for the production of short and medium life radioisotopes due to lack of radiochemical laboratory (Under-Utilization). [5] Another issue is that of fuel cycle which involves waste management and public perception of their safety (Fuel-Cycle).

On the other hand, from the perspective of safety regulation, many challenges have arisen in recent years, which become the main reason and purpose for this paper, these are listed below. [4][5]

- Inadequate regulatory supervision and inspection
- Lack of quality assurance (QA)
- Absence of financial support for safety measures (e.g. safety reassessment, Safety upgrading) and utilization
- Nonexistence of clear utilization programmes
- Insufficient emergency preparedness
- Scanty safety documentation (e.g., safety analysis report, operating rules, in addition, procedures, emergency plan)
- Scarce training and qualifications of regulators and operators

Table 1. Status of Research Reactor in Nigeria

Item	Status
Reactor Type	Miniature Neutron Source Reactor (NIRR-1) Tank-in-pool
Operating Organization	Centre for Energy Research and Training (CERT)
Fuel	U-Al alloy >90% enrichment
Thermal Power	31 kW
Operation	Feb 2004
Coolant and Moderator	Light water
Reflector	Metallic beryllium
Control Rod material	Cd
Remark	First critical in February 2005, in its first fuel cycle, Undergoing conversion from HEU to LEU

3. Development of Survey Questionnaire

A survey was developed to evaluate the safety issues and regulatory challenges. The main idea of the survey was to obtain the professionals opinion about the importance and status of safety issues. The list of these safety issues was derived from the IAEA Code of Conduct on Research Reactor safety. The respondents were selected from the department of nuclear safety, which is in charge of research reactor safety. They are professionals with excellent knowledge in nuclear safety and represents Nigerian Nuclear Regulatory Authority (NNRA). Ten (10) professionals participated in the survey

Table 2 describes the scoring criteria for the survey, with regards to Importance of safety issues, the highest score is five (5) "Highly important" and the least score is one (1) "not important". In addition to Status, the highest score is five (5) "excellent "and the least score as one (1) "worst".

Table 3 provides the survey questions conducted, which expresses the safety issues based on the performance of the

regulatory body (Section A) and criteria, requirements necessary for regulating the operating organization against these safety issues (Section B).

Table 2. The Scoring criteria used in the Survey for Estimating Safety Issues

	Importance	Current Status
1	Not Important □	Worst □
2	Slightly Important □	Bad □
3	Moderately Important □	Neutral □
4	Very Important □	Good □
5	Highly Important □	Excellent □

Table 3. Survey Questions of safety issues based on the IAEA Code of Conduct on Research Reactor Safety [2][5]

Section A

Role of Regulatory Body

1. Open and Transparent Regulatory Process for public and international confidence and for regulator performance improvement.
2. Application process of issuing authorizations with respect to all stages in the life of a research reactor.
3. Undertaking regulatory inspections of research reactors to determine implementation of regulations and authorizations.
4. Enforcement action on the application of regulations and the authorization, comprising suspension, modification or revocation of the authorization.
5. Review and assessment of compliances on safety from the operating organization both prior to authorization and periodically during the life of the research reactor as appropriate, including in relation to **Modifications** activities important to safety.
6. Review and assessment of compliances on safety from the operating organization both prior to authorization and periodically during the life of the research reactor on the change in **Utilization** activities.
7. Review and assessment of compliances on safety from the operating organization both prior to authorization and periodically during the life of the research reactor on **Experimental activities** important to safety.
8. Safety analysis report to acquire an authorization for siting, construction, commissioning, operation, modifications important to safety, extended shutdown and decommissioning by the operating organization.
9. Intermittent safety reviews at intervals determined by the regulatory body and proposals for improvement and renewal wherever necessary.
10. Internal and external communication between NNRA and the operating Organisation.
11. Operational perimeters and conditions.

Section B

Requirements and Criteria for safety Needed by NNRA from the Operating Organisation.

1. Validation of abundant financial and human resources to support the safe operation of the research reactor.
2. Effective quality assurance programmes at the different phases of the life of the research reactor.
3. Human influences throughout the life of the research reactor.
4. Radiation doses to workers and the public, within prescribed national dose limits.
5. Protection of the environment from the injurious effects of ionizing radiation.
6. Adequate emergency plan.
7. Reactor design to provide defence in depth, diversity, and redundancy.
8. Compliance with the valid codes, standards, specifications, and criteria to determine the quality of construction.
9. Reporting incidence of events significant to safety in accordance with criteria established by NNRA.
10. Classification of temporary modifications according to their safety significance, i.e. Modification in the procedure, which arises from an experiment.
11. Inspection by NNRA to verify compliance with regulatory requirements,
12. Management of radioactive waste from the research reactor.
13. Criteria for research reactors safety in an extended shutdown.
14. Criteria for the release from regulatory control after decommissioning.

4. Results and Discussion

At the end of the survey, the arithmetic mean enable us to determine these safety issues and with the aid of graphs, we were able to know which safety issue necessitates attention of the regulatory body. The results of the survey gave the two graphs in Figure 1 and 2. The mean values were obtained from an average of responses of survey items. Meanwhile, the differences in importance and status were also obtained in Table 4 for Figure 1 and Table 5 for Figure 2. These differences enable us to distinguish the safety issues that necessitates attention to their average. Once, the value of the difference exceeds the average, the safety issue requires attention and need to be examined.

In figure 1, the mean value has two major peaks at (5.0), items 5 and item 8 of section A. Items 6, 8 and 9 of

the same section A requires attention of the regulatory body, and they serve as the main safety issues relating to role of regulatory body due to the largest difference between importance and status.

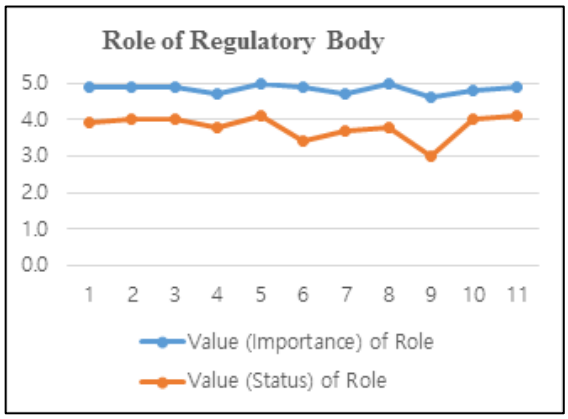

Figure 1. The mean values of importance and status of safety issues in terms of the Role of the Regulatory Body

Table 4. Items for the role of regulatory body which the difference between Importance and Status (Δ) exceeds the average (1.0)

Items	Difference Δ	Safety Issues
6	1.5	Review and assessment of compliances on safety from the operating organization both prior to authorization and periodically during the life of the research reactor on the change in **Utilization** activities.
8	1.2	Safety analysis report to acquire an authorization for siting, construction, commissioning, operation, modifications important to safety, extended shutdown and decommissioning by the operating organization.
9	1.6	Intermittent safety reviews at intervals determined by the regulatory body.

The graph in figure 2 and the table 5 explain the average of each safety issue and the differences of the most important safety issues that must be addressed.

The graph has a major mean value at (4.9) for item 11 of section B and slightly decline at (4.5) on item 10 (section B).

The second red line in the graph represents the status, which has the highest mean value at (4.2) item 4 and lowest mean value at item 13 of this section B.

The most safety issues were found in this section, there are about six and NNRA needs to look into them as they serve as requirements and criteria for research reactor operation.

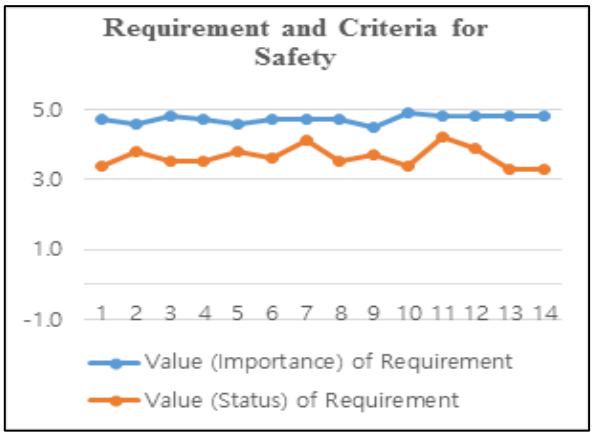

Figure 2. The mean values of importance and status in terms Requirement and Criteria considered by NNRA

Table 5. Items for the requirement and criteria which the difference between Importance and Status (Δ) exceeds the average (1.1) .turnitin.com

Items	Difference Δ	Safety Issues
1	1.3	Validation of abundant financial and human resources to support the safe operation of the research reactor.
3	1.3	Human influences throughout the life of the research reactor.
4	1.2	Radiation doses to workers and the public, within prescribed national dose limits.
8	1.2	Compliance with the valid codes, standards, specifications, and criteria to determine the quality of construction.
10	1.5	Classification of temporary modifications according to their safety significance, i.e. Modification in the procedure, which arises from an experiment.
13	1.5	Criteria for research reactors safety in an extended shutdown.
14	1.5	Criteria for the release from regulatory control after decommissioning.

5. Suggestions for Effective Application of the Code.

Based on the survey results and the gap analysis between the importance and the present status, the following suggestions would improve the regulatory infrastructure of Nigeria with a priority to

- Intermittent safety reviews at intervals determined by the regulatory body. (1.6)

- Review and assessment of compliances on safety from the operating organization both prior to authorization and periodically during the life of the research reactor on the change in **Utilization** activities. (1.5)
- Classification of temporary modifications according to their safety significance, i.e. Modification in the procedure, which arises from an experiment. (1.5)
- Human influences throughout the life of the research reactor.(1.3)
- Validation of abundant financial and human resources to support the safe operation of the research reactor. (1.3)
- Safety analysis report to acquire an authorization for siting, construction, commissioning, operation, modifications important to safety, extended shutdown and decommissioning by the operating organization. (1.2)
- Radiation doses to workers and the public, within prescribed national dose limits. (1.2)
- Compliance with the valid codes, standards, specifications, and criteria to determine the quality of construction. (1.2)

6. Conclusions

It can be eminent that IAEA code of conduct serves as a guide to states on the safety of research reactor; however, it was found by our survey that most of the necessary requirements were not properly employed. In addition, it was found that safety analysis report to obtain an authorization, intermittent safety review, and review and assessment prior to authorization (Utilization) were not given priority. Therefore, much attention is required for the regulatory body to address these safety aspects.

In section (B) of this survey, many grey areas were equally identified. Validation of sufficient financial, human resources, consideration of human influences, and radiation doses to workers and the public, including doses from releases to the environment, which should be given utmost priority but others can easily be addressed because they are most necessary during an extended shutdown and decommissioning.

Nigerian Nuclear Regulatory Authority (NNRA) has the responsibility of regulating all nuclear activities and facilities in Nigeria; NNRA should improve its review and assessment of compliance prior to authorization and periodically during the life of the research, review the final safety analysis report (FSAR) and make comments to the operating organization based on our findings. NNRA should ensure strict application of the code of conduct with respect to the existing research Reactor and the one about to be built.

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