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Aligning Technology, Policy, and Culture to Enhance Nuclear Security: A Comparative Analysis of Nigeria and the U.S.

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Abstract

Around the world, current energy and climate change concerns have led to more nations adopting nuclear technology as an option for electricity generation. However, one of the challenges to the peaceful application of this technology is the possibility that it will be misused, or that terrorists with global reach may acquire nuclear materials. Nigeria is one country that has embraced the technology to solve its energy challenges, but the country is now faced with an upsurge in terrorism and uprisings staged by various ethnic groups. In addition, corruption is continually becoming a hindrance to national development. These challenges are critical factors to be considered when vetting and recruiting reliable personnel for peaceful nuclear-related applications. It is important to understand how these human elements and other factors can impact global threats or undermine both Nigeria's national security as well as international security. Knowledge of these matters will help Nigerian bureaucrats anticipate and correct deficiencies that might evolve from current procedures being degraded by these emerging threats and will prevent any catastrophe that any of the highlighted challenges could bring about. Being aware of these challenges and introducing appropriate policy will provide critical guidance to Nigeria and other emerging nuclear countries in a way that could lead to

significant long-term improvements in management, procedures, and overall security of the facilities and materials. The challenge is to establish a Human Reliability Program (HRP) in order to detect and prevent aberrant behavior, thus effecting the safe, secure, and unhindered application of nuclear technology in Nigeria. In addition, this research suggests a strategy for conducting a national threat assessment and evaluation as a first step that precedes the development of an HRP; such a strategy must consider the range of threats present across the country.

Keywords: nuclear security culture, social and cultural factors, ethnicity, heritage, best practice

I. Introduction

Nigeria is among several countries seeking to develop nuclear power technology as a means for handling development-related matters, including improved access to electricity, food and agricultural production, food preservation, water resources, medicine, insect control, improved industrial bases, etc. As such, the federal government of Nigeria has adopted nuclear technology as a comprehensive, long-term electricity generation/distribution strategy in attempts to make up for the shortfall in national capacity and to help meet future demands, while also benefiting from other spin-off effects of the technology's implementation. However, one crucial challenge to the adopted long-term strategy exists at the intersection between extremism and a peaceful application of nuclear technology. Access to electricity is one global goal that has been universally adopted in striving toward poverty reduction and human development [1], but an upshot of globalization is terrorism and related violence in developing countries [2]. Nigeria is presently faced with a rising trend of tribal and religious extremism, and for the country to effectively implement a nuclear power program, it must consider issues of safety, security, culture, and intersecting policies as handled in successful, continuous utilizations of the technology, as in the United States and other nations with longstanding records of effective and peaceful nuclear power programs.

In 2014, Boko Haram, a regional terrorist group, pledged allegiance to the Islamic State (ISIS) [3], internationally known to be seeking nuclear materials for increased terrorist activities across the globe. A former Nigerian president alleged that Boko Haram may have infiltrated the Nigerian government, leading to the expulsion of a sitting judge [4] and the investigation of various security personnel suspected to be leaking information and government tactics to the insurgents [5]. Relationship-building is a central component of Nigerian culture, and there is a real possibility of such a cooperative nature being taken advantage of with the intention of penetrating, infiltrating, or eliciting information from personnel or facilities in Nigeria. The establishment of a well-developed human reliability program (HRP) can mitigate any unwarranted risks involved with the implementation, generally peaceful application, and eventual operations of the Nigerian nuclear power program. An HRP ensures that personnel who—either via their professional positions, privileges, or other appointments—have access to materials, devices, data, instruments, or facilities meet the highest standards of reliability, including mental wellness, in carrying out assigned duties.

The implementation of a U.S.-modeled program such as an HRP may not work well for Nigeria. This research compares the successful U.S.-centric HRP with the Nigerian-espoused attitudes, beliefs, and values related to safeguarding a high-risk nuclear power facility from threats. It is anticipated that the enhanced understanding of culture as well as national and regional beliefs and values that this research strives to attain will help build an environment encouraging stronger nuclear security and nuclear security culture in Nigeria by integrating a successful reliability program into the existing systems.

The basis of this research relies on the analysis of recent survey results obtained from industry practitioners in Nigeria and the United States. The survey addressed both human reliability and social, technical, and organizational culture and practices. The survey was used as a guide for the development a new HRP model for Nigeria and as an index for suggesting the continuous review of the U.S.'s HRP to aid in the identification

of personnel or prospective employees that may potentially be of threat either to facilities or to the security of both countries.

A. Nigerian People and Culture

Figure 1. Map of Nigeria
Source: CIA World Factbook

The history of Nigeria dates back approximately 2,000 years, and today the country is comprised of more than 250 ethnic groups with an estimated 521 local languages [6]. Nigeria is a culturally rich country with longstanding traditions, even though Western values have gained momentum within the wider Nigerian society. Nigerians strive to enhance the quality of life from one generation to the next and generally believe that cultural identity, political affiliation, and personal relationships help to improve their livelihood [7]. However, the country is deeply divided in terms of ethnicity, religion, and regional identities due to inhabitants' feelings of being dominated, oppressed, cheated, or targeted for elimination by other tribes [8]. These divisions have led to fiercely held tribal and political sentiments regarding policy, engagement, and administrative processes, which, if left unchecked, will compromise smooth and unhindered operations, and fragment organizational allegiances in any nuclear facility [9].

Nigeria must strive to develop a new, fundamental approach for change by reorienting the populace and applying new policies that support technological developments devoid of ethnic, religious, and regional prejudices. Some of the perceived factors that led to the present security challenges in Nigeria include:

- Poverty and poor remuneration
- Weak institutions that reduce the administration of justice
- Supplanting of government laws by informal rules ("settling")
- Magnified criminal acts and corrupt behavior
- Nature of the economy (rent-seeking, i.e., overdependence on crude oil for national revenue)
- Past security incidents that show vulnerability in planning and sustenance of critical facilities

Poverty is a root cause of terrorism and other social vices in Nigeria [2]. Moreover, with Nigeria having roughly 250 ethnic groups and 521 local languages spread across six different geopolitical regions, and all while battling the aforementioned challenges, tribal and political affiliations will likely play a significant role in the development of employment opportunities and access to social amenities. Hence, the systematic implementation of a dependable HRP as a vital tool for preventing aberrant, malicious actions by facilities' personnel is much needed.

Nigeria operates seven Centers of Excellence/research institutes under the aegis of the Nigeria Atomic Energy Commission (NAEC). Namely:

- The Centre for Energy Research and Training (CERT), Ahmadu Bello University (ABU), Zaria – the center operates a 30KW Miniature Neutron Source Reactor (MNSR) with Highly Enriched Uranium (HEU) as its fuel type. In 2006, Nigeria joined the International Atomic Energy Agency's (IAEA) Coordinated Research Project (CRP) in conversion studies to a Low Enriched Uranium (LEU).
- Center for Energy Research and Development (CERD), Obafemi Awolowo University, Ile-Ife – 1.7 MeV Tandem Accelerators.
- Gamma Irradiation Facility (GIF), the Sheda Science and Technology Complex, Abuja, Nigeria.
- Center for Nuclear Energy Studies (CNES), University of Port Harcourt, Rivers State.
- Center for Nuclear Energy Research and Development (CNERD), University of Maiduguri, Borno State, Nigeria.
- Center for Nuclear Energy Studies and Training (CNEST), Federal University of Technology, Owerri.
- Federal Government of Nigeria – International Atomic Energy Agency Field Monitoring Station & Laboratory Facility, Koluama, Bayelsa State, Nigeria.

B. Research Objectives and Justification

This research was initiated with the intention of developing and recommending a model HRP structure for Nigeria by examining a similar, existing program in the U.S., which is guided by the U.S.'s Code of Federal Regulations 10 CFR 712 document.

The global need for sustainable HRP evolved from the use of guns, gates, and guards to secure facilities in attempts to mitigate hazards, ensure safety, and address security challenges that arise, whether due to human error or because of intentional harm. In any case, the urgency has resulted in the necessity for emerging nuclear states to develop explicit human reliability methodologies that clearly maintain the states' cultural harmonization while employing globally accepted best practices. Furthermore, the implementation of a culturally driven HRP in Nigeria would address several important concerns, including the need to fortify human resources for the projected increase in the number of reactors worldwide, mostly in developing countries; the need to replace retiring professionals who maintain a nuclear security-related organizational memory acumen as trusted employees; and the need to mitigate widespread global terrorism, which affects the global energy production process.

II. Literature Review

Nuclear energy is cost-effective and has no controlled air pollutant over a large energy density [10]. But the concepts of nuclear technology and nuclear energy can be intimidating to people unfamiliar with the vast benefits of using it. In a survey conducted by the Nuclear Energy Institute in 2015, 83 percent of residents of the U.S. who live near nuclear power plants support the use of nuclear energy, compared to 68 percent of the general American public. The result further revealed that 50 percent of the supporters *strongly* favor the use of nuclear technology, while 27 percent of the general public's supporters strongly prefer it [11].

The need of an HRP in the nuclear power industry grew out of a concern for sabotage by an insider, with or without outside assistance or collaboration, who could adversely affect the facility and, by extension, a country, either directly or indirectly. In turn, the safety and security of plant personnel, the public, and the environment could be put in jeopardy as well [12].

Several factors—faulty planning, tribal sensitivity, nepotism, magnified corruption, poor implementation, etc—could adversely affect or lead to the collapse of a system's HRP and can increase the likelihood of insider threats against the facility and its country. Such weaknesses could result from the advantage that such insiders

may have in positions they occupy or by having access to certain materials, devices, and programs within the facility [13]. However, if efficient policies and processes are put in place alongside a strong, resourceful human resource base, the potentially harmful impacts of insiders can be mitigated. In turn, these precautions will also help generate a necessary critical infrastructure and create an environment yielding the best achievable standards, both inside and outside of the facility.

To this end, securing nuclear materials has become a worldwide priority, but unfortunately, there exist no international or comprehensive rules that articulate the level or extent of security needed to secure nuclear or radiological materials [14].

Recent incidents relating to theft of nuclear materials, elicitation, espionage, and sabotage of nuclear facilities indicate that credible threats do exist [15]. The Doel 4 nuclear plant sabotage of August 2014 in Belgium, costing millions of dollars, is one example among many that an insider could inflict damage on plant operations [16]. Such evidence reinforces the need for plants to have a strong HRP in place. It is therefore apparent that the development of an HRP must incorporate engineered design for access control, psychology, and realistic assessment, based on each country's contemporary threshold and perceived needs [17].

Consequently, a sustainable HRP must be based on a structured model that puts less emphasis on tribal and political affiliation in recruiting for employment and, instead, prioritizes the selection of individuals who can be trusted with access to, and responsibilities for, nuclear and/or radiological materials or facilities. Such a viable HRP's development and implementation in Nigeria will likely contribute to global security and earn Nigeria international confidence in its peaceful application of nuclear technology.

III. Methods and Data Collection

This research employed a data-driven strategy that aggregated experiences of subject matter experts from Nigeria and the United States with the aim of proposing a structured HRP for Nigeria, an emerging country. The result provided straightforward baseline data of unidentified respondents. Comparative deductions were drawn to identify the social actions and gaps that could directly or indirectly impact the implementation of an HRP. Input from the University of Tennessee, Knoxville's (UT) faculties and subject matter experts were taken into consideration for the survey's design and implementation. Additionally, the survey was used to gather information on the working knowledge of HRPs as well as the strategies that could be employed to better mitigate insider threats and protect national assets and high-risk nuclear facilities in Nigeria.

As well, an attempt was made to gather information about the understanding and application of HRPs in the U.S., since the U.S. has significant experience operating and using nuclear and radiological materials. From this information, it was discovered that the waiving of rights and privacy of personnel is considered a vital aspect of employee agreements for personnel in HRP positions or for those working in facilities with high security risks [18] in the U.S. Such legal and legislative frameworks are, as example, used in administering credit checks, drug verifications, and general background checks. In any case, considering the particularities of Nigerian culture, trustworthiness, integrity, and strong family/personal values are essential traits expected of anyone taking on such responsibilities.

The research questions were organized into two sections; the first section was built on open-source experience and a summary of interactions with subject matter experts, and the second section (survey questions) was developed to elicit supplementary data from researchers and personnel in HRP positions. The survey assembled a synopsis of elements that reinforce the program in the U.S. via the assemblage of the factors and any proportional risk(s) associated with increased interest in the technology from a globally consistent and standardized perspective [19]. The survey was also used to infer that the level of application and implementation of HRP programs in developed countries may be adequate for the present status of their programs, but can be improved upon with continuous and recommended supervisory reviews. Furthermore,

interviews with subject matter experts indicated that accidents do not merely occur by chance; they are either caused by deliberate human error, failure of organizational culture, or a combination thereof [20].

A. Research Needs

Global terrorism, the projected global increase in the number of reactors worldwide, and consultation with subject matter experts in the industry raised the following questions requiring additional research:

- Explicit HRP needs for emerging nuclear states that clearly maintain cultural harmonization with global best practices
- Which characteristics of HRPs have enabled the peaceful, unhindered operation of power plants and other critical infrastructure facilities in countries with advanced nuclear programs?
- What policies and procedures enable or hinder the implementation of HRPs in power plants and other critical infrastructure facilities in countries with advanced nuclear program?
- What factors inhibit best practices in HRPs in nuclear power plant operations?
- What role will cultural anthropology—e.g., espoused values, beliefs, and attitudes; political, sociological, economic, and technological adaptations; etc.—play in the planning, application, and accomplishments of HRPs for emerging countries?
- How do management systems affect the smooth implementation and operation of HRPs in emerging countries?
- What knowledge is needed to build out the integration and coordination of facility/stakeholder HRPs into a national plan that can sustain a new nuclear infrastructure?

Based on the abovementioned research needs, a wide-ranging set of twenty-six (26) survey questions was developed and administered online to anonymous nuclear and radiological professionals in research and nuclear plant-operating fields to gain more knowledge of, and better understand, their levels of awareness of human reliability processes and policies in both Nigeria and the U.S. The survey was conducted on the Qualtrics® research suite, as recommended by UT, due to the need for data protection. The data collected on the Qualtrics® platform was loaded into a statistical analysis software, a statistical package for social science (SPSS), to collate and analyze the output from the questionnaire. The SPSS was utilized due to its ability to execute cross-tabulation and descriptive ratios in the identification of group data, as collected. Four out of the twenty-six questions that directly relate to this research were selected, and the output histogram and corresponding error analysis were discussed in the SPSS analysis.

The research (survey) initiative was directed toward identifying knowledge gaps inferred by the outcome of the survey as a preparatory guide for developing a workable HRP that facilitates best practices in the recruitment and retention of trusted personnel in Nigeria. Furthermore, the data analysis explored the intersection of technical and policy-related concerns in ways that helped generate a protective assessment of acceptable HRP norms that are expected to strengthen operations in relevant facilities in Nigeria and, by extension, globally [19]. In addition, the survey's results helped develop an understanding of intricate methods used in applying qualitative results and the analysis of past experiences to shape the future need for trustworthy employee engagement.

The gathered information also indicated that culture is an exceptional component in running a successful organization [21] and program. Elements of nuclear security culture are both positively and negatively influenced by individuals (whether in groups or in isolation), policy makers, regulators, managers, and technical systems. However, domestic models can be developed, with international guidance and best practices in consideration, to create the needed awareness for personnel and stakeholders at all levels [22]. Based on the ideas gathered from the subject matter experts and the survey's results, a new model—a Nuclear Security Culture (NSC) and HRP analysis model—was developed, as depicted in Figure 2. The model proposes the synergy that could further strengthen both the implementation of the program as well as wide-ranging

interconnected elements between nuclear security culture and human reliability in Nigeria. The analysis model in Figure 2 was divided into two levels; the first diagrams the relationship between the HRP, the management system, and the existing national and facility-related culture, and the second compares the impact of either success or failure of an HRP with HRPs in developed countries such as the U.S.

Figure 2. NSC and HRP analysis model

IV. Results and Analysis

A. Response Demography (Nigeria and the United States)

The data collected in this research and the subsequent analysis were evaluated over a larger sample size (data set) of professionals working in HRP-certification and HRP-supervising roles, as well as official and subject matter experts. The data was statistically significant enough to present a valid argument and thus be satisfactorily used as a model for this research's initiative. Of the survey's respondents, 40 percent were from the U.S., and 60 percent were from Nigeria (Figure 3).

A statistical significance test known as the "Significance T-Test" was administered to establish the significance of the data set, since personnel in HRP positions comprise a smaller group than overall personnel groups, and the test was used to simulate the difference between the two group averages. The responses from the U.S. made up the control group, and those from Nigeria comprised the treatment group. For each of the responses, results were evaluated based on the difference in averages and skewness of the output between the control and treatment groups.

Pie charts showing the breakdown of responder affiliation by country are plotted in Figures 3 to 5, and the histogram chart of frequency vs. range of value corresponding to the level of agreements for both groups is plotted in Figures 6 to 10. In addition, a corresponding error bar representing the confidence interval of the mean of both groups is also plotted; the bar reinforces the gaps between Nigeria and the U.S.

Pertinent variances were drawn that culminated in the design of and need for a structured HRP in Nigeria. Based on the result obtained in Figures 6 to 11, an organizational flow diagram was proposed in Figure 12 to guide the implementation of a structured HRP for Nigeria. This structure may be adopted, domesticated, and tailored to meet the respective needs of other emerging nuclear countries.

Figure 3. Survey response by country

Figure 4. Survey response by U.S. affiliation

Figure 5. Survey response by Nigerian affiliation

B. Analysis

The x-axis on the histogram represents the frequency, and the y-axis represents the range of values for the number of occurrences. 1 = strongly disagree, 2 = somewhat disagree, 3 = neither disagree nor agree, 4 = somewhat agree, 5 = strongly agree, and 6 = not applicable. The following results were obtained:

Figure 6. Existence of credible nuclear and radiological threats

Figure 7. Likelihood of a credible threat

Figure 8. Aberrant behavior detection via an HRP

Figure 9. HRP policies and procedures are in place (Nigeria and the United States)

Figure 10. Perceived or implied weaknesses in your facility's HRP

Figure 11. Satisfaction of the overall assessment of country's HRP (Nigeria and the United States)

From the results obtained, as shown in Figure 6, responders agreed that credible nuclear threats exist, and, as shown in Figure 7, that those threats have a reasonable likelihood of becoming a reality. As shown in Figure 8, most responders agreed that aberrant behaviors can be detected and mitigated with an HRP. The results obtained, as shown in Figure 9, suggest that existing HRP policies and procedures in Nigeria are inadequate, while most responses from the U.S. somewhat agreed that the HRP policies might be adequate. Based on the average and skewness of the responses, per Figure 10, it appears that there was consensus that there are facility-level weaknesses between both groups, while Figure 11 shows a consensus that the overall assessment of an HRP in Nigeria is not satisfactory.

Additionally, Figures 9 to 11 were designed to ascertain the gaps between, and applications of, an HRP in both groups. The summation as shown in Figure 9 indicates that the U.S. maintains a greater degree of HRP policies and procedures than Nigeria's lower acceptance frequency. So as to not blanket the result from Figure 9, Figure 10 was developed to ascertain facility-level attributes of the "perceived or suggestive facility weakness." Following the results shown in Figure 10, the aggregate of the results for this question showed that most professionals agreed regarding the existence of an HRP weakness in their facilities, while Figure 11 summed up the unsatisfactory level in their assessment of an HRP in Nigeria, hence the need for continuous periodic review of the American program by the U.S. and the need for a clearly delineated HRP implementation in Nigeria.

Based on the above results, it can also be inferred that there exists a dire need for the development of a comprehensive national policy that will increase international confidence in the Nigerian nuclear program via the establishment of policies and procedures. Such policies and procedures will ensure that the judgment and reliability of current and future personnel and other individuals with access to the facilities and materials are not, or will not be, impaired by mental, physical, and other conditions that may raise security or safety concerns.

Generally, responders had the choice to not answer questions in sections not applicable to their area of operations; this option was included so that responses would be objective and devoid of guessing within subject matter expertise areas. Based on the overall results and analysis as explained above, Nigeria and other countries new to exploring nuclear energy options will likely rely on the planning and implementation experience of developed nations such as the U.S. However, it is significant that the direct application of a full framework of valuable training, experience, and assistance offered by the developed, nuclear-operating countries may or may not fit adequately with that of newcomer countries for the

enhancement of their own programs [23]. Nevertheless, the extent of the cultural differences between developed and developing countries must not negate international best practices in HRP implementations and applications. In light of the above results, Figure 12 was developed and proposed as a guide to help in the design of new programs, based on existing knowledge and levels of threat.

Figure 12. Recommended organizational structure for the implementation of an HRP in Nigeria

V. Conclusion

This project highlighted the precarious need to build a critical mass of trustworthy personnel in an environment enabling the development of a safe and secure nuclear power program in Nigeria. It is generally believed that an HRP encompasses an accurate, timely, and detailed process for analyzing human behavior, and the process can be run via the policies and practices of an organization in order to ensure operational and security-related reliability.

The identified gaps, which are subject to the survey's result and subsequent analysis, include:

- i. More survey responders from Nigeria than from the U.S. agreed that a credible nuclear and radiological threat exists, even though both groups recorded high rates of those who strongly acknowledged that aberrant behavior can be both detected and mitigated via a viable HRP.

Based on the survey's result, an organizational HRP plan was recommended for the implementation of an HRP in Nigeria.

- ii. The likelihood of this credible threat was acknowledged by both groups, but more Nigerians acknowledged the likelihood than responders from the U.S. Hence, our conclusion is that a clearly defined legal and legislative framework should be developed in Nigeria in a manner similar to the 10 CFR 712 document in the U.S. Additionally, it was noted that the ideology of security contributes to confidence-building in support of safe and secure implementation of nuclear technology in the U.S. It is important that Nigeria clearly develop the same ideology to improve the confidence building.
- iii. It is worthy to note the Nigerian group's response on policies and procedures. This section had the lowest degree of consensus among the group, which suggested that little emphasis is presently placed nationally on policies and procedures for an HRP.
- iv. Lastly, more Nigerians believed that weaknesses exist in their facilities' HRP. For an emerging country such as Nigeria, an HRP should likely play an important role in the foundation, development, and implementation of its national nuclear power program.

The dire need for an effective synchronization of culture, technology, and policy in attempts to sustain a nuclear energy program in Nigeria cannot be overemphasized. It is recommended that threats to and vulnerabilities surrounding both the country and facility-level operations must be analyzed seriously and that a viable HRP be developed in accordance with the level of program implementation. Nigeria should endeavor to identify other cultural areas possibly requiring modifications that could accommodate global best practices from lessons learned out of different case studies. Furthermore, a plan must be in place for reviewing and updating procedures on a regular basis or along a schedule to be determined per the national need, depending on the outcome of the evaluation of extant threats.

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