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A Semi-Qualitative Safety Assessment of the Central Radioactive Waste Management Facility in Tanzania Using Analytical Hierarchical Process

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

This study identified normal and abnormal conditions, features, events and processes (FEPs) those potentially influence the integrity and safety of the facility that might originate outside or inside the facility. Four hazards, namely terrorist activity, fire outbreak, floods and human intrusion were selected basing on the following criteria; physical reasonableness, probability of occurrence and potential consequences associated with the occurrence of these FEPs. With the use of Analytical Hierarchy Process (AHP), the FEPs were ranked for prevention and mitigation plan based on the following criteria: occurrence probability, potential impact and prevention/mitigation cost. The results show the terrorist activity as the most dangerous hazard to the facility. Terrorist activity has to be given first priority in risk reduction strategy followed by flood. The next are fire outbreak and human intrusion. The study recommended that the resources should be allocated at first to protect the damage of the central radioactive waste management facility from terrorist activity and flood.

Keywords: Feture, Events and Process (FEPs); Central Radioactive Waste Management Facility (CRWMF); Analytical Hierarchy Process (AHP).

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1. INTRODUCTION

The legislation for the control of ionizing radiation in the United Republic of Tanzania was first enacted in 1983 through the "Protection from Radiation Act, No. 5, 1983, which established the regulatory body namely the National Radiation Commission (NRC) [1]. In 2003, the Parliament of the United Republic of Tanzania (URT) enacted the Atomic Energy Act No. 7 of 2003; this Act replaces the Protection from Radiation Act, No. 5 of 1983 [2]. Section 5 (1) of the atomic energy act establishes the body corporate known as Tanzania Atomic Energy Commission (TAEC). Also section 37 of the atomic energy act establishes the Central Radioactive Waste Management Facility known by its acronomy as CRWMF which shall serve as a National Centre for the collection, characterization, conditioning, segregation and generally the safe management of radioactive wastes.

Tanzania promulgated the radioactive waste management regulations for the protection of human health and environment in 1999. In the same year, NRC procured a "Temporary Radioactive Waste Storage Facility" which was basically a 30 feet ISO container (Fig. 1a). In 2001, the government of URT allocated fund for the construction of CRWMF, which commissioned in July 2005 (Fig. 1b). The International Atomic Energy Agency (IAEA) in the technical manual for management of low and intermediate level wastes generated at small nuclear research centres and by radioisotopes users in medicine, research and industry, provides recommendations on the planning, siting, design and operation of a CRWMF [3]. All recommendations were adhered except for geological and meteorological data which were expensive to collect [4]. Instead, historical data were used for selecting the site. The completion and commissioning of this Facility paved the way to a better radioactive waste management regime in the country [5].

After radioactive waste is under control, there must be radioactive waste management plan. The plan includes a safety assessment. The safety assessment include identification of normal and abnormal conditions, features, events and processes that potentially influence the integrity and safety of the facility, that might be originate outside or inside the facility. Annexes from the IAEA safety guide on predisposal of radioactive waste (IAEA safety guide no.WS-G-2.5) provides list of possible condition, processes and events for consideration in safety assessment of the facility [6].

There are number of factors to consider in the prioritization process. Some of factors to be considered in deciding the priority within the strategy action plan are; probability of occurrence, potential impact and prevention or mitigation cost. Also, in making the strategy action plan, the following steps needs to be taken into account, risk identification, risk assessment, risk mitigation and risk tracking and reporting [7]. Risk assessment involves not only the assessment of hazards from a scientific point of view, but also the socio-economic impacts of a hazardous event. It involves the hazard

Fig. 1 (a) **Fig. 1 (b)**

Fig. 1. (a) The Temporary Radioactive Waste Management Facility used from 1999-2005, (b) The Central Radioactive Waste Management Facility used from 2005 to Date

assessment, location of the building subject to hazards, potential exposure to the physical effects of a hazardous situation and the vulnerability of the community when subjected to the physical effects of the event.

Risk assessment aids decision makers and scientists to compare and evaluate potential hazards, set priorities on what kinds of mitigation are possible, and set priorities on where to allocate available resources. This study is therefore, aimed at ensuring that the facility will not cause unacceptable adverse impacts on human health and the environment. However, one of the main challenges facing the regulatory bodies including TAEC is the ability to make priority due to multi-criteria consideration. Therefore, the current study applies Analytical Hierarchy Process (AHP) for assessing and allocating weights and priorities for solving the problem of multi criteria consideration for management plan of CRWMF in Tanzania.

2. MATERIALS AND PROCEDURES

2.1 Feature, Events and Processes (FEPS)

The framework for quantitative risk assessment needs to answer the following questions. *1. What events and processes can take place at the facility? 2. How likely are these events and processes? 3. What are the consequences of the events and processes? and 4. What features have potential impact to facility?.* To answer these questions we need to know the FEPs and to have complete data of the area where facility is located.

The “Features, Events, and Processes” (FEPs), forms the basis for scenarios that are evaluated to assess safety of the facility. *Feature* –A large-scale property of the system under consideration, example, a fault. Features includes elements of engineered or natural system that are important part or characteristic (of the facility or its environment; include the components of the site, such as soil and water bodies or condition that has a potential to affect storage facility). *Event* – Occurrence that affects the storage facility; a qualitative or quantitative change or complex of changes located in a restricted portion of time and space. Event can be natural or human-caused phenomenon that has a potential to affect storage system performance and that occurs during an interval that is short compared to the period of performance [8]. *Process* – a phenomena marked by gradual changes that lead towards a particular result. It can be natural or human-caused phenomenon that has a potential to affect the storage system performance and that occurs during all or a significant part of the period of performance [8].

The assessment need to consider all FEPs that have potential impacts to the facility. This study takes into considerations the FEPs described into IAEA safety standards [6]. Both external and internal factors were considered. External factors are those with causes or originate outside the storage facility. These factors include natural events and human decision or actions, many of which could define scenarios or cases to be considered in the safety assessment. Internal operational factors are those with causes or originate inside the storage facility. These factors include natural events and human decision or actions, many of which could define scenarios or cases to be considered in the safety assessment.

2.2 Initial Screening of FEPs

The purpose of FEPs screening is to identify those FEPs that should be accounted for assessment, and those FEPs that need not be considered further. Initial screening of FEPs is done by considering the following criteria [9]

1. Physical reasonableness of the features, events and processes being considered.

FEPs whose occurrence is practically impossible due to the physical characteristic of the waste and characteristics of the engineered facility will be eliminated by this screening criterion, example, for tsunamis, a facility far away from coastal regions.

2. Probability of occurrence of the event

FEPs with very "small" probability will be generally rejected. The specification of "small" will be limit of 10^{-6} per year

3. Potential consequences associated with the occurrence of these FEPs

As used in this report, "consequences” have different interpretations, depending upon the stage of the screening process. For example, in the earlier stages of the screening process, "consequences" generally refers to the effects that a certain event, feature or process might have on the facility.

4. FEPs that their consequences have been incorporated to another FEP already accounted for the analysis can be eliminated.

2.3 FEPs that have been Considered for Analysis

Hazards which are likely to occur to the facility have been described below by considering the criteria described in section 2.2.

a) Terrorist activity

In August 7, 1998, two nearly simultaneous massive bomb attacks happened to the U.S. embassies in Nairobi, Kenya and Dar es salaam-Tanzania killing a hundreds of people and wounding thousands people. [10]. Also in the year 2013, a church in Arusha, Tanzania where the CRWMF is located was bombed by a massive bomb. These facts are evidences that terrorist activity is likely event that can occur to the storage facility. Terrorist activity; includes use of weapons like bombs, explosion and crashes from sources of high energy from machines and flying objects and other unpredicted mobile sources.

b) Floods

The facility is located in area where there is higher variation of rainfall. The average annual rainfall of the area is 600 mm. From 1985-2013, floods occurred 4 times in this region. Presence of Mount Meru, 40 km away from the facility elevates flood risk to the facility. The risk of floods is likely to increase as a result of predicted heavy rainfall in future. Also recently there was a heavy rainfall fallen on 21-22 January 2014 in the Manyara, Morogoro and Dodoma region of Tanzania, causing severe floods. All these facts provide evidence of flood to be likely event to occur to the facility.

c) Fire

A fire hazard on the facility is a likely event to occurs as like to other workplace. The situation that increases the likelihood a fire at the facility includes electrical system installed and terrorist attack. Fire outbreak includes faults of electric systems and bush fires.

d) Human intrusion

The facility is located in area with low population, but the number of residence is increasing each year. Continue increasing the population near the facility increases the risk of human intrusion to the facility. The following events were incorporated in human intrusion; sabotage, civil disorder, strikes and blockades, war, military exercises, theft, explosion and crashes rash.

Basing on the initial screening of criteria of FEPs, some of the hazards described in the IAEA safety standards were eliminated.

2.4 FEPs Ranking Methodology

The study applied the Analytic Hierarchy Process (AHP) in the prioritization and selection of FEPs. AHP is one of the mathematical models currently available to support the decision theory. The ranking of FEPs is based on the following criteria: occurrence probability, potential impact and prevention/ mitigation cost. The relative importance of each hazard is selected based on expert argument and authors experience resulted from scientific point of view.

The fundamental scales has been shown to be scales that captures individual preferences with respect to quantitative and qualitative attributes well or better than other scales [11, 12, 13]. They converts individual preferences into ratio scale weights that can be combined into a linear additive weight for each alternative. In this study, all the criteria have been rated from 1 to 9 (Table 1), while the alternatives were ranked using scales from Table 2, 3 and 4 respectively. The method allows decision maker to provide judgments of about relative importance of each criteria. The weights of importance of criteria are also determined by using pair wise comparisons. The priority vector is driven from comparison matrices by using eigenvector method [12].

Some key and basic steps involved in this methodology are: One, define the problem and state the goal or objective and its outcome. Two, define the criteria or factors that influence the goal. Structure these factors into levels and sublevels. Three, use paired comparisons of each factor with respect to each other that forms a comparison matrix with calculated weights, ranked eigenvalues, and consistency measures. Four, synthesize the ranks of alternatives until the final choice is made.

Step 1: Define the problem, State goal or objective and its outcome

Problem: Tanzania has been facing difficulties regarding the prioritization for risk reduction strategy. These difficulties are due to the multi-criteria consideration before a decision making. *Objective:* Prioritization risk reduction strategy and *Outcome:* Making risk management plan.

Step 2: Developing the AHP hierarchy

The control measures need to be independent. Although decisions are based on values and preferences of the decision makers, a set of criteria or specific objectives can be used while prioritizing risk reduction. From this fact, three criteria have been chosen; Occurrence probability, Potential impact and prevention /mitigation cost.

Structure the problem in a hierarchy of different levels constituting goal, criteria and sub-criteria (Fig. 2).

a) Occurrence probability

The occurrence probability is an estimate of how often a hazard event. One of the most important deciders of priority within the national strategy action plan is that which concerns the occurrence probability of the hazard. If the identified hazard is most likely to occur and cause potential impacts to human health and environment, then it should be taken care of quickly and it becomes the top priority. Occurrence probability is most considered criteria compared to others because is always considered first before effect as a safety culture. Also prevention/mitigation cost depend on degree to which FEPs occurs and its potential impact.

b) Potential impacts

The next consideration would be the degree of potential hazard. Primary, secondary and tertiary effects must be taken account in making management plan.

c) Prevention or mitigation cost

After considering probability of occurrence of the hazards and potential impacts then we can develop an action to take to minimize the risk. Mitigation involves identifying the various activities, or steps, to reduce the probability and/or impact of an adverse risk. Taking early steps to reduce the probability of an adverse risk occurring may be more effective and less costly than repairing the damage after a risk has occurred. However, some risk mitigation options may simply be too costly in time or money to consider.

Step 3: Pairwise comparison

Data were collected from experts and/or decision markers corresponding to the hierarch structures, in the pair wise comparison of alternatives on a qualitative scale as shown below. The opinions were collected in a special designed format as shown in Fig. 3. The relative importance of one

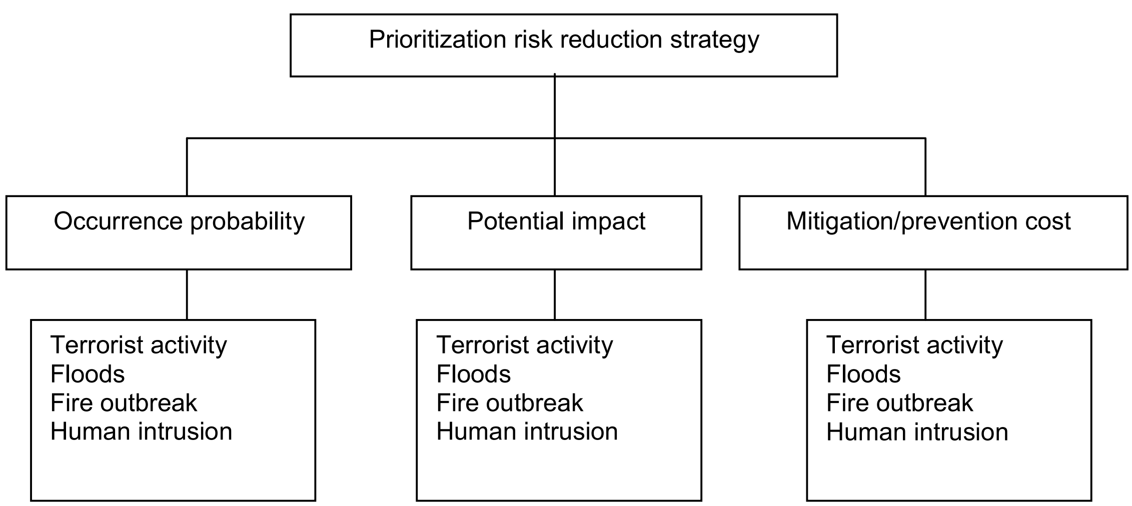

Fig. 2. Hierarch of criteria and FEPs

criterion over another has been determined by comparing all the criteria in pairs: the more important the criterion, the greater its influence on the selection of the alternative. If the judgment value is on the left side of 1, we put the actual judgment value on the matrix. However, if the judgment value is on the right side of 1, we put the reciprocal value in the matrix.

The rank of the alternatives has been defined individually by each criteria meeting expert, on the basis of his/her personal experience. For any pairing of alternatives, within each criterion, every alternative is awarded a score (see Table 2, 3 and 4) according to how well one alternative meets the criterion under study compared to the other alternative. Then, the ratings of all the alternative ranking by expert have been normalized and averaged, once again.

a) Occurrence probability

A review of historic events assists with this determination. Each hazard of concern is rated in accordance with the numerical ratings and definitions in Table 2. The Table 2 was used to scale the responses which generated the matrix or Table 6.

b) Potential impact

For any hazard, the most severe consequence class assessed for the different targets has been used in order to define the associated risk level. The decision matrix for the potential impact criteria is given in Table 3.

Table 1. Gradation scale for quantitative comparison of alternatives

Option	Explanation	Numerical Values
Equal	Two activities contribute equally to the objective	1
Marginally strong	Experience and judgments slightly favor one activity over another	3
Strong	Experience and judgment strongly favor one activity over another	5
Very strong	An activity is favored very strongly over another and dominance is demonstrated in practice	7
Extremely strong	The evidence favoring one activity over another is of the highest possible order of affirmation	9
Intermediate value between the two adjacent judgments	When compromise is needed	2, 4, 6 and 8

Table 2. Risk of occurrence probability

Weight	Occurrence probability(occurred)	Risk Likelihood
1	< 1000000 years	Unlikely
2	< 100000 years, but >1000 years	Moderate likely
3	< 1000 years ,but >100 years	Likely
4	< 100 years, but >10 years	Strong likely
5	< 10 years	Extremely likely

Table 3. The consequence categories used in the risk matrix

Weight	Qualitative severity level	Description
1	Negligible	No failure of engineered features (fences, building etc.)
3	Minor	Failure of physical barriers
5	Moderate	Building collapse
7	Major	Radioactive release
9	Severe	Deaths, environment contamination
2, 4, 6 and 8	Intermediate values	When compromise is needed

c) Prevention or mitigation cost

Prevention refers to avoiding the impact of hazards, while mitigation includes recognizing that disasters will occur and attempt to reduce the harmful effects of hazards, and to limit their impact on human suffering and environment. For prevention plan, need quantitative and qualitative assessment of the cost benefit of preventing hazards. According to Mark G Steward on cost effectiveness of risk mitigation strategies for protection of building against terrorism attack, economic risk due to terrorism when compared to those natural hazards are more effective [14]. The possible scale of "P" value (from 1 to 9) is showed in Table. 4.

To make sure every respondent's judgement is taken into consideration. The following formula was used.

$$Q_n = \sqrt[n]{a_1 x a_2 ......a_n} \quad (1)$$

For instance, with the use of figure 3, n=5 (number of respondents), a_1=1, a_2=3, a_3=5, a_4=5 and a_n=3 are responses when comparing two criterions (P_1 and P_2). With the use of equation 1, Q_n = 2.95 (*approx 3.0*). Therefore, 3 will be inserted into the matrix. This process was done throughout this paper whenever the judgments of respondents are not the same. However, if the scores are on the right hand side, 1/3 (reciprocal) will be inserted in the matrix.

Normalization: For each matrix, the normalized principal eigenvector that identified the most important factor was calculated. Eigenvectors were derived from eigenvalues of normalized measures (The proportion of the row/column factor divided by the row/column sum).

Table 4. Scale of values for p index

Opportunity	Criterion	"P" Value
Very Low	No prevention action is possible	1
Low	Few preventions actions are possible	3
Medium	Some prevention action are possible	5
High	Many prevention actions are possible	7
Very high	A lot of prevention actions are possible	9
Intermediate Values	When compromise is needed	2, 4, 6 and 8

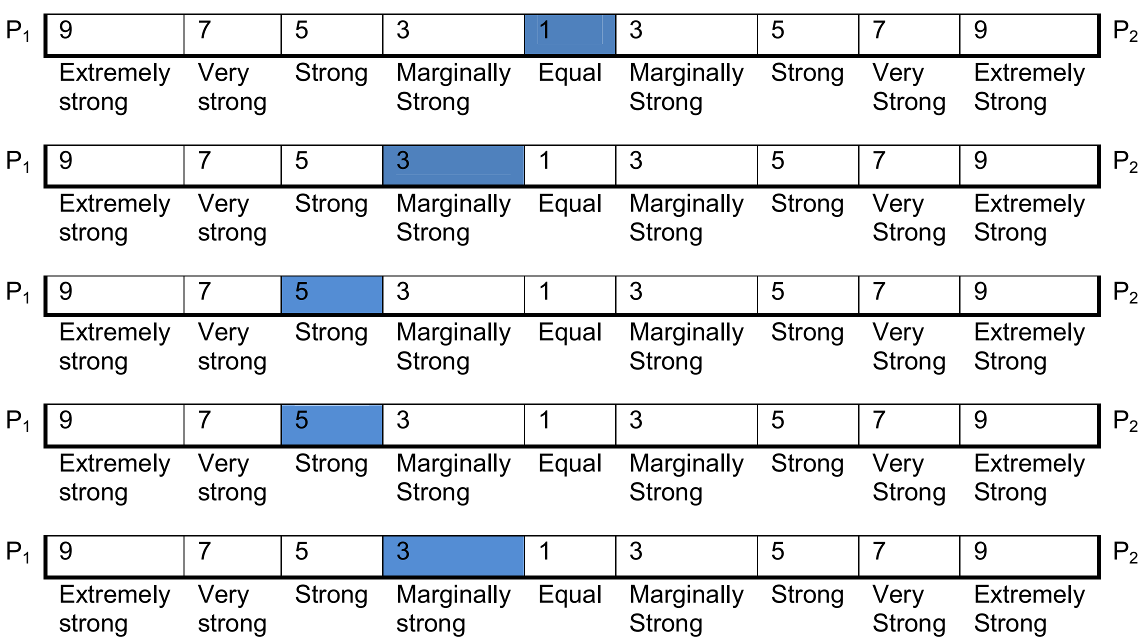

Fig. 3. Pair wise comparison on two criterions (P_1 and P_2) with five respondents.

Table 5. Random consistency indices

Description	**Orders and Indices**									
Order (n)	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Normalization put the factors on a common scale ranging from 0 to 1. The scores given to each criterion have been then normalized and averaged in order to obtain the weight for each criterion.

Estimate the Eigenvalues: Given a matrix A of real or complex numbers and size n*n, an eigenvalue λ_{max} and its associated generalized eigenvector (w) are a pair obeying the relation below.

$$(A - I\ \lambda_{max})\ w = 0 \quad (2)$$

Where

A is the comparison matrix of size n*n, for n criteria, also called priority matrix, *w* is the Eigenvector of size n*1, also called priority vector, λ_{max} is the biggest Eigenvalue of matrix A and I is a unit matrix.

Check the consistency Index: The consistency of the matrix of order *n* is evaluated. Comparison made by this method is redundancy in the approach. If this consistency index fails to reach a required level then answers to comparison may be re-examined. The consistency index, CI, is calculated as

$$CI = (\lambda_{max} - n) / (n - 1) \quad (3)$$

Where; λ_{max} is the maximum eigenvalue of the judgment matrix. This CI can be compared with that of a randomly matrix, RI. The consistency index of a randomly generated reciprocal matrix shall be called to the random index (RI). An average RI for the matrices of order 1–10 was generated by using a sample size of 100 [15] and given in table 5. The ratio derived, CI/RI, is termed the consistence ratio, CR. Saaty suggest the value of the CR should be less than 0.1 for the judgments to be consistent.

$$\text{Consistency Ratio (CR)} = CI / RI \quad (4)$$

If the value of Consistency Ratio (CR) is smaller or equal to 10%, the inconsistency is acceptable. If the Consistency Ratio is greater than 10%, need to revise the subjective judgment.

Step 4: Synthesize the ranks of alternatives

The rating of each alternative is multiplied by the weights of the sub-criteria and aggregated to get local ratings with respect to each criterion. The local ratings are then multiplied by the weights of the criteria and aggregated to get global ratings. And finally an alternative with large weight is selected.

3. RESULTS AND DISCUSSION

3.1 Weighting the Assessment Criteria

Prevention or mitigation costs depend on severity of harm, and also depend on the occurrence probability. The Occurrence probability has equal weight with potential impact when we consider in terms of prevention plan. But when we consider mitigation plan, potential impact is important factor to be considered. For risk reduction strategy, occurrence probability is somewhat more importance when compared with prevention cost. Also potential impact is somewhat more importance when compared with mitigation cost.

Table 6. Comparison matrix for criteria raking

Weighting criteria	**A_1**	**A_2**	**A_3**
Occurrence probability (A_1)	1	1	3
Potential impact (A_2)	1	1	3
Prevention or Mitigation cost (A_3)	1/3	1/3	1

Squaring the matrix above (Table 6) and normalize the values, the weighted priority vector for assessment criterion were found to be: 0.4286 for Occurrence probability, 0.4286 for Potential impact, 0.1428 for Prevention or Mitigation cost. **Note:** λ_{max} = 3.000, CI = 0, CR = 0 were calculated using equations 2-5; Then evaluation is consistent as CR (0) is less than 0.1.

3.2 Ranking the Alternatives

For all the criteria defined above, the possible alternatives have been compared each other considering the occurrence probability, potential impact and prevention or mitigation cost of the identified hazards.

Squaring the matrix above (Table 7) and normalize the values, the priority vector for hazards for occurrence probability criteria were found to be: 0.5000 for terrorist activity, 0.1667 for fire outbreak, 0.1667 for floods and 0.1667 for human intrusion. **Note:** λ_{max} = 4.0000, CI = 0, CR = 0 were calculated using equations 2-5; Then evaluation is consistent as CR (0) is less than 0.1

With the responses from Table 8. The priority vector for hazards for potential impact criteria were found to be: 0.6400 for terrorist activity, 0.1504 for fire outbreak, 0.1489 for floods and 0.0607 for human intrusion. **Note:** λ_{max} = 4.0733, CI = 0.0244, CR = -0 .0275 were calculated using equations 2-5; Then evaluation is consistent as CR (-0.0275) is less than 0.1.

Also squaring the matrix below (Table 9) and normalize the values, the priority vector for hazards for prevention or mitigation cost criteria were found to be: 0.5950 for terrorist activity, 0.1655 for fire outbreak, 0.0818 for floods and 0.1577 for human intrusion. **Note:** λ_{max} = 4.1767, CI = 0.0589, CR = -0 .0662; Then evaluation is consistent as CR (-0.0662) is less than 0.1

The last step is to find the priority vector of each hazard. The priority vector of each hazard is multiply by each column of the corresponding criteria weight or ranking as showing in Table 10.

Table 7. Pair wise comparison matrix for occurrence probability

Occurrence probability	Terrorist activity	Fire outbreak	Floods	Human Intrusion
Terrorist activity	1	3	3	3
Fire outbreak	1/3	1	1	1
Floods	1/3	1	1	1
Human intrusion	1/3	1	1	1

Table 8. Pair wise comparison matrix for potential impact

Potential impact	Terrorist activity	Fire outbreak	Floods	Human Intrusion
Terrorist activity	1	5	5	7
Fire outbreak	1/5	1	1	3
Floods	1/5	1	1	3
Human intrusion	1/7	1/3	1/3	1

Table 9. Pairwise comparison matrix prevention or mitigation cost

Prevention or mitigation cost	Terrorist activity	Fire outbreak	Floods	Human Intrusion
Terrorist activity	1	5	4	5
Fire outbreak	1/5	1	2	1
Floods	1/4	1/2	1	1/3
Human intrusion	1/5	1	3	1

Table 10. Final priority ranking

Hazards	Priority vectors of alternatives and criteria				Priority vector
	Occurrence probability	Potential impact	Prevention or mitigation cost	Criteria weight/ Ranking	
Terrorist activity	0.5000	0.6400	0.5950	0.4286	0.5736
Fire outbreak	0.1667	0.1504	0.1655	0.4286	0.1595
Floods	0.1667	0.1489	0.0818	0.1428	0.1469
Human intrusion	0.1667	0.0607	0.1577		0.1200

The multi-criteria analysis ends with a more or less stable ranking of the given alternatives and hence a recommendation as to which hazard mitigation measures should be preferred. Regarding our problem hazards assessment for CRWMF, the result is a ranking of hazard with regard to their risk level. Table 10 show the relative and weight of each hazard, its rank and its assigned weight according to each criterion. It should be noted that the value of terrorist activity is higher in all criteria, implies that terrorist activity have higher chance of occurrence, higher potential impact and higher prevention or mitigation cost when compared with other hazards.

Table 11. Final ranking of hazards

Hazard	Priority vector	Rank
Terrorist activity	0.5736	1
Floods	0.1595	2
Fire outbreak	0.1469	3
Human intrusion	0.1200	4

The results from Table 11 show the terrorist activity as the most dangerous hazard. Terrorist activity has to be given first priority in risk reduction strategy followed by flood. The next are fire outbreak and human intrusion. Although there have been few acts of terrorism committed by terrorist groups in Tanzania, but still the is higher chance of occurrence of this accidents. Terrorist activities are difficult to prevent, however, mitigation may limit the effect of the terrorist activity. Mitigate precautions should involve; the training of response personnel and elected officials and the development of policies and procedures relating to the response to suspected terrorist acts.

Therefore, for long term storage, radioactive sources must be secured against malicious attack and its consequences at all times. As these values show, the risk associated of human intrusion is very low. But we cannot ignore this risk. Reasonable resources must be allocated to combat human intrusion to the storage facility. TAEC should implement the following action as a preventive measure against human intrusion; proper design of security fences and vehicle gates, intrusion detection systems, surveillance systems, site access control systems, security procedures, cyber security procedures, and proper training and qualification of security personnel.

The estimated extent of flooding, give the flood second priority in risk reduction followed by fire. TAEC should maintain effective flood drainage systems and regulating construction to reduce floods risk. Fire has higher risk compared to human intrusion scenario. Fire management is important for the safety of the facility. Suitable fire detection, alarm and suppression systems must be installed to the facility. Once the facility is installed with appropriate fire detection, alarm and suppression system, these system must be checked, tested and maintained to ensure they remain effective. Some checks can be performed by site staff, such as routine weekly alarm tests. However, other tests and checks should be performed by a competent fire engineer. Also fire and rescue services vehicles should be unobstructed at all times. TAEC also need to restrict the continued increasing the population near the facility as this increases the risk of human intrusion to the facility. Also some human activities might cause fire outbreak into their premises and the fire may spread into surrounding areas including the CRWMF.

4. CONCLUSION

Risks on CRWMF are consequent on man-made as well as natural hazards. The research focused on the study of hazards assessment with results to reduce their impacts. After getting priority risk scores for the hazards, the mitigation plan for the hazard is prepared accordingly so that precautionary actions can be taken for most risk hazard on priority basis and safety of the facility can be improved. Terrorist activity has to be given first priority in risk reduction strategy followed by flood. The next are fire outbreak and human intrusion. Usable resources should be allocated at first to protect the damage of CRWMF from terrorist activity and flood. The study also recommends that TAEC needs to develop a waste management strategy which sets the priority of hazards prevention in order to allocate the limited fund effectively and to establish safety measures that should be introduced to eliminate or minimize the risks, as identified in the assessment. Lastly, the Government needs to establish an integrated national emergency plan, preparedness and response term in the case of radiological emergency or accident.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. United Republic of Tanzania. The Protection from Radiation Act, 1983, Government Publications Dar es salaam, Tanzania; 1983.
2. United Republic of Tanzania. Atomic Energy Act No.7 of 2003, Government Publications Dar es salaam, Tanzania; 2003.
3. IAEA – International Atomic Energy Agency-TECDOC. Reference design for a centralized spent sealed sources facility IAEA-TECDOC-806, VIENNA; 1995.
4. Shao D, Sungita Y, Banzi F. Central radioactive waste management facility, the existing storage facility in the United Republic of Tanzania, IAEA-CN-135/79; 2005.
5. Kifanga LD, Mompome WK, Shao D. Experience of consolidation of disused sources in developing countries. WM2008 Conference, February 24-28; 2008.
6. IAEA- International Atomic Energy Agency. Safety standards series, Predisposal Management of Low and Intermediate Level Radioactive Waste, IAEA safety guide no.WS-G-2.5, ANNEX IV; 2003
7. Risk management plan. Available:http://www.phe.gov/about/amcg/toolkit/Documents/risk-management.pdf
8. Geoff Freeze. Features, Events, and Processes (FEPs) for Nuclear Waste Repository Systems, Sandia National Laboratories Albuquerque, NM, USA; 2010.
9. Posiva Report. Safety Case for the Disposal of Spent Nuclear Fuel at Olkiluoto, FEP Screening and Processing, POSIVA 2014-03; 2014.
10. Andre Lesage. The rising terrorist threat in Tanzania; 2014.
11. Saaty TI. A scaling method for priorities in hierarch structure. 1977;15:234-281.
12. Thomas LS, Joseph MK. How to make a decision, the analytical hierarchy process, European Journal of Operational Research. 1990;48:9-26. North –Holland.
13. Rajnish, Kumar, The mathematical way to decide, analytical hierarchy process.
    Available:http://www.nair.indianrailways.gov.in/uploads/files/1392267597384-The%20Mathematical%20way%20to%20Decide%20-%20Rajnish%20Kumar.pdf
14. Mark GS. Cost effectiveness of risk mitigation strategies for protection of buildings against terrorist attack, 2008: Technical Notes:
    DOI: 10.1061/(ASCE)0887-3828(2008)22:2(115)
15. Nobre FF, Trotta LTF, Gomes LFAM. Multi -criteria decision making–an approach to setting priorities in health care. Statistics in Medicine. 1999;18(23):3345-3354.

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