
Challenges and Opportunities in the Sustainable Radioactive Waste Management

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Abstract

Nuclear power plants are worldwide operated. While some countries consider phasing out nuclear power, others are considering building new power plants. Controversial debates have always arisen over the sustainability of nuclear energy, and radioactive waste has been the main topic.

The possibility of long term management of radioactive waste considering the population behavioural and demographic characteristics is of particular importance in this study.

The aim of the study was to examine if demographic factors and behavioural factors influence the sustainable management of radioactive waste, more precisely their final disposal. In particular, we analysed the relationship between each variable and the acceptance of the final disposal of radioactive waste and the location of the disposal facility.

To find the answer of the present research study, we set the acceptance of the final disposal of radioactive waste and the location of the disposal facility as dependent variable and two demographic variables and two behavioural variables as independent variables. Statistical correlations were performed between the selected variables by using SPSS Statistics to establish the relationship between the factors at the individual level and the acceptance of the final disposal of radioactive waste in the context of sustainable development. Questionnaires were used as research tool.

Based on this investigation, it was found that there is no correlation between perceived risks and the acceptance of the final disposal of radioactive waste and the location of the disposal facility.

Likewise, this study shows that individuals' acceptance of radioactive waste is based on individual behaviour, but it is also influenced by the demographic characteristics.

Keywords: radioactive waste management, sustainable development, final disposal, population behavior, nuclear energy, challenges and opportunities

1. Introduction

Every day radioactive waste is generated throughout the world. Operating nuclear power plants for electricity production generates radioactive waste. Radioactive waste is a by-product from nuclear activities as electricity production and fuel processing, medical activities, industrial or

research activities. Decommissioning and dismantling of different nuclear facilities also generate waste (U.S.NRC, 2019).

Sustainable development of radioactive waste involves permanent disposal, so that will not remain as a burden for future generations. As the case of U.S. when the process of final disposal started early in the 1982s through the Nuclear Waste Policy Act, there are many countries where such processes started but not ending with a concrete solution (U.S.NRC, 2019). Sustainability is one of the most researched concepts in the world in all aspects due to the benefits it brings to the whole society (Mojarad, A. A. S., 2021).

Worldwide international organisations, governments, regulators, operators conduct missions related with safe and sustainable radioactive waste management for establishing frameworks, policies, and clear roles and responsibilities. Also, significant research studies were dedicated to radioactive waste management and safe final disposal. A global effort is being made for finding the most suitable options.

Exploring the factors which influence the final disposal brings significant contributions for the scientific fields, especially the social ones which are extremely sensible to external influences. Radioactive waste is an extraordinarily complex technical and economic issue (Kraft et al., 1993; Kemp and O’Riordan, 1988). Radioactive waste issues generated many conflicts throughout the world (Fischer and Boehnke, 2004; Wärnbäck et al., 2013; Yli-Kauhala and Hänninen, 2014).

Research studies on population perceptions and acceptance determinants for nuclear facilities have taken place all this time (Kim and Kim, 2014; Peters et al., 2004; Seidl et al., 2013). Also, studies on the acceptance of radioactive waste disposal facilities have been conducted (Chung et al., 2008; Chung and Kim, 2009). Mentioned studies used the opinion surveys to examine the processes.

Early studies were performed in 1990s to find the perceptions related with Yucca Mountain Nuclear Waste Repository in Nevada (Slovic et al., 1991; Frey, 1993; Bassett et al., 1996). Year 2000 was also characterized by several studies on the perceptions and location of a radioactive waste disposal facility and results showed a constant concern in this regard (Rechard et al., 2014). Throughout the world, in the United States, Europe or Japan, location of a radioactive waste disposal facility uncounted many difficulties so that many studies on the impact of the population were conducted (Sjöberg, 2004, 2006, 2009; Saling, 2001; Adair, 2015). Most studies which analysed the population perception, attitudes, behaviour, or acceptance included local acceptance questionnaires, information system data, case studies and statistical models. There are few studies which integrate mixed methodologies (Kim et al., 2015).

Present research study analyses the acceptance of the final disposal of radioactive waste and the location of the disposal facility by using the traditional questionnaire method.

The current study on the acceptance of the final disposal of radioactive waste and the location of the disposal facility aims to contribute to the nuclear field by exploring the demographic factors and behavioural factors of the population.

Also, the study aims to emphasize the importance of a proper disposal of radioactive waste, to identify and evaluate the main factors which influence the process of final disposal of radioactive waste and the location of the disposal facility with respect to social indicators and sustainable development.

This analyse is very important because many local communities had rejected projects of radioactive waste disposal in different countries during the last two decades of the XX century (Blowers & Sundqvist, 2010). Also, Nuclear Energy Agency consider that there is a need to improve the involvement of the stakeholders in the process of locating a radioactive waste disposal facility (Kari et al., 2021). Therefore, at present, population is playing a more important role and the technocratic management solution which were counterproductive in the past must be eliminated.

Perceived benefits and risks are key variables to explain the acceptance of nuclear facilities (Fischhoff, B, 1978). Perceived risks and benefits are two main drivers of population acceptance, but to some extent perceived risks seems to be more important and the perceived benefits in terms of the acceptance of nuclear facilities, as the radioactive waste disposal facility is.

In the research, we considered the following objectives and hypotheses:

Objective 1: Determining the link between the degree of acceptance of the final disposal of radioactive waste and the location of the disposal facility and the demographic characteristics of the participating population.

Hypothesis 1: The degree of acceptance of the final disposal of radioactive waste and the location of the disposal facility differs depending on the demographic characteristics of the population.

Objective 2: Determining the acceptance of the final disposal of radioactive waste and the location of the disposal facility by offering benefits with implications at individual and regional level that determine the improvement of the acceptance.

Hypothesis 2: Respondents consider that to increase the acceptance of the final disposal of radioactive waste and the location of the disposal facility it is important to stimulate the population with different individual and local benefits to increase the degree of involvement of the population.

Objective 3: Determining the acceptance of the final disposal of radioactive waste and the location of the disposal facility by how population perceive the associated risks.

Hypothesis 3: The risks perceived by the respondents influence the acceptance of the final disposal of radioactive waste and the location of the disposal facility.

2. Method

Questionnaires are one of the most common methods used for qualitative research analysis. Together with observation and data collection from different documents, questionnaires could be used in a mix or single way depending on the research question and research resources (Tuomi & Sarajärvi, 2018; Ijje et al., 2021).

The current study used a questionnaire as a research tool to collect information regarding the population characteristics and behaviour related with nuclear field, especially the radioactive waste. The two parts of the questionnaire collected the information regarding demographic characteristics of the participants in the first part and in the second part they gathered information about the variables.

Several stages were conducted to perform the proposed analysis. Firstly, all answers obtained after completing the questionnaires were collected. Then, all data was processed and analysed. The last stage was represented by the results interpretation.

Firstly, we performed a characterization of the variables included in the study by systematizing the survey data. Later, the objective was to analyse the variables by performing statistical correlations between the variables. A correlation matrix was developed based on the dependent and independent variables. The dependent variable was the acceptance of the final disposal of radioactive waste and the location of the disposal facility. Independent variables were as follows: age, hierarchy, benefits, and perceived risks. In the benefits category were the following: the social and economic development of the area, financial compensations, attractive jobs for the locals and shares in the companies involves in disposal facility construction. Risks category comprised: the impact over health and mental state, over the environment, on the future generations, on society and economy and on investments in the area and on tourism.

Both the dependent variable and the independent variables were measured on an ordinal scale. Each of the variables was designed at 5 levels.

In total, for this study a number of 360 validated responses were used. Participants had the possibility to answer to the questionnaire in printed format or online format according to their needs. Participants were not chosen by specific criteria, but the aim was to get answers from the key population such as those who live far from nuclear facilities or those who live either around power plant or in the area of radioactive waste repositories. The restrictions encountered in obtaining the answers were of a financial nature, logistic or time. An issue encountered in the first phase of the research was related to the availability of the rural population to answer a nuclear questionnaire. After the first phase of data collection, the next phase consisted of data processing and analysis by using the SPSS Statistics.

3. Results

3.1. Profile of participants

As Table 1 emphasize, 37,2% of participants are aged between 18-25 years. So that, the young people included in the questionnaire represent the largest part of the total number of participants, while the people over the age of 55 are at the opposite pole with a percentage of 4,2 %. Additionally, out of 360 participants, 50,8 % (183) were male, and 49,2 % (177) were female. In terms of residence, 10,8 % of participants answered they live in rural area, while 50,8 % answered they live in urban area. The discrepancy in this case is very high because of the rural population who refused to answer at first because they did not understand the topic. Regarding

work experience, 62,2 % have less than five years of experience and 17,8% have more than 21 years of work experience.

Table 1. Demographic characteristics of participants

Condition	Criteria	Frequency	Percentage
Age	18-25	134	37,2
	26-35	116	22,2
	36-45	46	12,8
	46-55	49	13,6
	>55	15	4,2
Gender	Male	183	50,8
	Female	177	49,2
Residence	Rural	39	10,8
	Urban	321	89,2
Work experience	< 5 years	224	62,2
	6-10 years	24	6,7
	11-20 years	48	13,3
	> 21 years	64	17,8
Hierarchy	Criteria	Frequency	Percentage
	Employee	287	79,7
	Head	31	8,6
	General director	2	0,6
	Others (students, retirees)	40	11,1

Table 1 shows also that most participants 79, 7% (287) were employees, 31 (8, 6%) were heads and only 2 participants (0,6%) were general directors. Also, part of the study were also students and retirees, and they are 11,1% of all participants.

3.2. Correlation Analysis

In order to test the hypotheses was used a Kendall's tau_b correlation between the acceptance of the final disposal of radioactive waste and the location of the disposal facility as dependent variable and age, hierarchy, benefits and perceived risk as independent variables.

The correlation matrix shows that the dependence between age and the acceptance of the final disposal of radioactive waste and the location of the disposal facility is positive (,363, $p < 0,05$), so that young people are much less permissive and accept radioactive waste to a lesser extent. The older the participants, the lower is the acceptance of the final disposal of radioactive waste and the location of the disposal facility.

The correlation established between hierarchy and the acceptance of final disposal of radioactive waste and the location of the disposal facility shows a positive correlation (,300, $p < 0, 05$). In other words, the higher the hierarchy position of the participants, the more they accept radioactive waste and related implications. A higher hierarchy position involves a higher level of education and knowledge suggesting that the better prepared the participants, the more they accept the final disposal of radioactive waste and the location of the disposal facility.

Notwithstanding, older age and knowledge-based occupation is not necessarily a significant factor in accepting radioactive waste. Therefore, the values of the non-parametric correlation coefficients are low due to the complexity of the field and the related notions that are not widely used and have not been freely discussed at the population level. There are multiple justifications, but mainly this area requires a lot of stakeholder involvement and takes a long time to become somewhat familiar with the population.

Regarding the positive correlation relationship between the benefits and the acceptance of the final disposal of radioactive waste and the location of the disposal facility it is observed that higher the benefits, higher the acceptance. This result is very important for the stakeholders which can also benefit in this way and gain the acceptance of the population.

As seen in the illustration, the significance coefficient in case of risks perceived by the participants with regard to the location of a radioactive waste disposal facility is 0.3, which is significantly higher than the $p = 0.05$ used for this test. Besides, the correlation coefficient is $-.040$, as seen in Table 2 below, indicating that there is no correlation between the two variables. Therefore, the risks perceived by the participants is not correlated with the acceptance of the final disposal of radioactive waste and the location of the disposal facility. A valuable explication is that the participants do not have enough information or knowledge regarding the radioactive waste disposal and such a disposal facility and for this reason they cannot assess the risks involved.

Table 2. Correlations matrix

		disp_loc	age	hierarchy	benefits	risks
disp_loc	Correlation Coefficient	1,000	,363**	,300*	,579**	-,041
	Sig. (2-tailed)	.	,000	,032	,000	,342
	N	360	360	360	360	360
age	Correlation Coefficient	,363**	1,000	-,066	,174**	-,043**
	Sig. (2-tailed)	,000	.	,162	,000	,326
	N	360	360	360	360	360
Kendall's tau_b hierarchy	Correlation Coefficient	,300*	-,066	1,000	,202**	-,008*
	Sig. (2-tailed)	,032	,162	.	,000	,865
	N	360	360	360	360	360
benefits	Correlation Coefficient	,579**	,174**	,202**	1,000	,031**
	Sig. (2-tailed)	,000	,000	,000	.	,476
	N	360	360	360	360	360
risks	Correlation Coefficient	-,041	-,043**	-,008*	,031**	1,000
	Sig. (2-tailed)	,342	,326	,865	,476	.
	N	360	360	360	360	360

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed)

4. Discussion

Different behaviours formulated based on many external factors can have serious consequences effects on the development of a radioactive waste disposal facility.

Considering the factors included in this study, many benefits to the nuclear field and to the stakeholders will be brought. Providing attention to the population and including it in all

processes will automatically lead to an increase in knowledge and information, thus facilitating their ability to assess the risks associated with nuclear technologies.

Establishing the benefits offered to the population from the very beginning and notifying them about this aspect will automatically lead to the acceptance of the radioactive waste disposal facility.

Regarding the demographic characteristics, the study shows that a possible target population for clear success is represented by the one which is older or the one that has a higher level in the hierarchy.

In this context, this research study manages to bring importance and quality to the field of radioactive waste and constitutes a valuable reference for all stakeholders involved with radioactive waste management.

At the same time, the improvement of the process of locating a radioactive waste disposal facility and its construction according to the established data, more precisely 2050, will lead to the fulfilment of the sustainable development goals.

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