Sustainable Operations in Nuclear Research Reactors – A Bibliographical Study

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1 Introduction

This article presents a bibliographical study on sustainable operations in nuclear research reactors[1]. Sustainability is gaining prominence in the area of operations and we want to understand how it is being addressed in the area of nuclear research reactors.

In this context, a corporate sustainability model known as "Triple Bottom Line" takes place, in which a sustainable company is one that contributes to sustainable development by generating, at the same time, economic, social and environmental benefits to stakeholders.

The purpose of this article is to identify, in available literature, sustainable operations carried out by operating organizations of research reactors and make a theoretical review on the subject. We also plan to identify gaps in literature and propose new studies on the subject.

In a country like Brazil where nuclear activity is geared towards peaceful purposes, any operating organization of research reactors should emphasize its commitment to the sustainability of research reactors' operations, taking into account social, environmental and economic aspects.

In section 2 we present a bibliographical review on sustainable operations management and on research reactors' operations. In section 3 we present the research methodology used. In section 4 we present and analyse the results obtained. A theoretical review on references accepted for this study is presented in section 5. In section 6, conclusions and final considerations of the study are presented. Bibliographical references appear after the conclusions in section 7.

2 Bibliographical review

2.1 Sustainable operations management

APICS *[1]* describes that in operations and supply chain management, sustainability is the idea that business can help ensure markets, commerce, technology, and finance advance in ways that benefit economies, societies, ecosystems, and stakeholders in general or, at a minimum, do no harm and contribute to a more maintainable and inclusive global economy.

Kleindorfer et al. *[2]* define sustainable operations management as the set of skills and concepts that allow a company to structure and manage its business processes to obtain competitive returns on its capital assets without sacrificing the legitimate needs of internal and external stakeholders and with due regard for the impact of its operations on people and the environment.

So et al. *[3]* and APICS *[1]* remark that implementation of sustainability in a manufacturing supply chain shall consider major elements, such as, process innovation, clean production, closed-loop manufacturing, reverse logistics, sustainable procurement or green purchasing; and life cycle management (LCM).

APICS *[1]* relates that sustainable supply chains seek clean methods of production, minimization of the environmental footprint of products and services, and combining environmentally friendly decisions with effective supply chain practices. Clean production has focus on waste minimization and avoidance, reusing waste products when possible, reclaiming products at the end of useful life, preventing or reducing pollution at the source, substituting for toxic and hazardous materials; and reducing waste and potential pollutants in product or service as well as transportation to market.

2.2 Nuclear research reactors

Nuclear reactors can be grouped into two main types: research reactors and power reactors.

Power reactors are designed with the purpose of generating electricity.

Research reactors are characterized for not being used in energy generation are used as neutron sources for various purposes. These reactors offer a wide range of applications, such as neutron research for studies in materials and non-destructive tests, neutron activation analysis to measure quantities of an element, radioisotopes production for medical and industrial use, neutron irradiation for fission and fusion reactors materials testing, doping by silicon neutron transmutation, gems colouring, etc. Another great contribution of research reactors is its use in education and training for operators, operating and maintenance personnel of nuclear facilities, radiation protection personnel, regulatory staff, students and

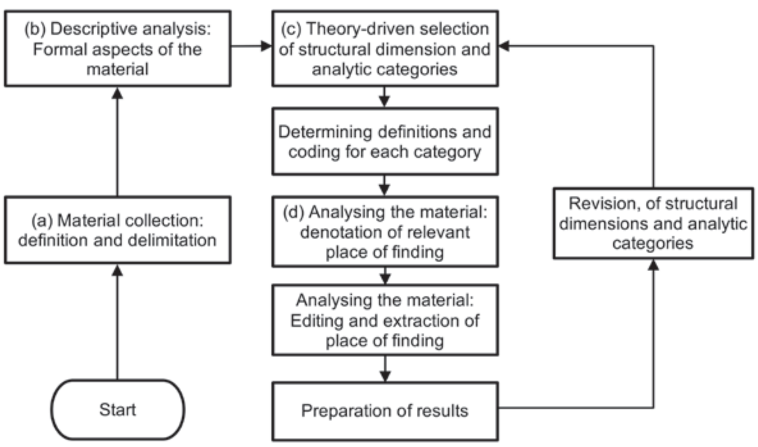

Fig. 1.
Research process of a structuring content analysis *[6]*.

1) From this paragraph on, nuclear research reactors will be referred simply as research reactors.

researchers, in all areas of nuclear technology.

The main types of research reactors developed in the world are *[4]* pool type, graphite, Triga, Argonaut, zero power and high-flux reactors.

According to IAEA Research Reactor Database *[5]*, there are 244 research reactors operating around the world.

The lifespan of a research reactor is estimated to be 40 to 60 years, but there is a possibility to extend this lifespan by modernization of these reactors. Increasing research reactor lifespan by modernization characterizes an increase in its operation sustainability.

a) Analytical categories obtained from Sustainable Sector of Journal of Operations Management *[7]*	b) Analytical categories obtained from the second search step, as described in section 3.1
▪ Sustainable supply chain management; ▪ Closed-loop supply chains; ▪ Sustainable product design; ▪ Sustainable procurement; ▪ Environmental legislation related to operations; ▪ Life cycle analysis; ▪ Industrial symbiosis; ▪ Corporate social responsibility; ▪ Market valuation of environmental and social initiatives; and ▪ Interdisciplinary approaches to sustainability research (OM/Marketing, OM/Finance, OM/Strategy).	▪ Sustainability analysis; ▪ Certification ISO 14000; ▪ Waste management; ▪ Ageing management; ▪ Sustainability indicators; ▪ Strategic planning for sustainability; ▪ Recycling.

Tab. 1.
Analytical categories established for the bibliographic study of research reactor sustainable operations.

3 Methodology

Figure 1 presents a flow chart of methodology used for literature search, adapted from Seuring and Müller *[6]*. The methodology consists of four main steps: (a) material collection, (b) descriptive analysis, (c) category selection and (d) material evaluation. A feedback loop was included between step (c) and (d) for the revision of structural dimensions and analytical categories only for material collected *[6]*.

3.1 Material collection

A structured search for references was performed in academic and nuclear databases, namely, Google Scholar (GS), Web of Science (WS), Scopus (SC), Elsevier (EL); and International Nuclear Information System (INIS). The aim of this structured search was to identify articles published in newspapers and international congresses.

As a first step, we adopted as keywords the topics of interest used by Sustainable Sector of Journal of Operations Management *[7]* added with the term "research reactor". Search engines interpret this combination of key words, as if these were joined by using the Boolean operator "AND". All records obtained in the search have been read and analysed, but only articles with full text were accepted for this study. The search was performed in July 2016 and there was no restriction regarding the period of publication. In this first step, we achieved significant results only in Google Scholar (GS) and INIS databases.

To expand our number of results, in a second step, we made a more generic search in database Google Scholar (GS) with the terms *research reactor operation sustainable* (no quotes) and obtained approximately 341,000 references. Then, using advanced search options, we restricted this search with the term "research reactor operation" combined with the keywords sustainable, sustainability and green.

The results of material collected are presented in section 4.1. Repeated bibliographical references were excluded from the results.

3.2 Descriptive analysis

References accepted for the study were quantified and classified according to the type of publication, year of publication and analytical category.

Regarding the type of publication, references were classified into "article published in congress", "article published in journal", "article or chapter of book" and "book".

Analytical categories selection criteria are described in section 3.3.

3.3 Analytical categories selection criteria

Considering "sustainable operations" our structural dimension, we defined the analytical categories according to the topics of interest adopted by Sustainability Sector of Journal of Operations Management *[7]*, added to the analytical categories obtained in the second step of search as described in section 3.1 above. **Table 1** presents analytical categories established for this study.

3.4 Material evaluation

Articles deemed accepted for the study were read, analysed, evaluated and classified in an analytical category previously established as described in section 3.3.

Material collection results are presented in section 4.1 and analysed in section 4.2.

A theoretical review for each analytical category was conducted, as shown in section 5, in order to observe specific features of sustainable operations in research reactors.

4 Presentation and analysis of results

4.1 Presentation of results

Taking into account the delimitations already mentioned in section 3, the material collection obtained from the literature search resulted in 1074 references of which only 63 (5.9% of the total) were accepted to be used in our study.

Regarding type of publication we obtained 20 articles published in congress, seven articles published in journals, 22 articles or chapters of a book and 14 books.

Regarding year of publication we obtained three publications in the 1980's, four in the 1990's, 19 in the 2000's and 37 in the 2010's.

4.2 Analysis of results

Although sustainable operations management is a reality in academic world, given the existence of a specific academic journal related to this topic – The Journal of Operations Management *[7]*, edited by Elsevier, this approach is still not well defined in nuclear area.

Results presented in section 4.1 returned only 63 published papers accepted for the analysis conducted in this study. Of these, only seven were obtained from academic journals. The majority of accepted references came from nuclear database INIS, Google Scholar database comes in second place and Elsevier in third. Web of Science and Scopus databases did not present significant results.

Regarding the number of references accepted by analytic category, we noticed the predominance of articles published related to the following analytical categories (quantity in brackets): "ageing management" (19), "environmental legislation related to operations" (9), "strategic planning for sustainability" (8) and "sustainable product design" (7).

The analytical categories "sustainable supply chain management", "closed-loop supply chains", "sustainable procurement" and "industrial symbiosis" did not have any accepted reference for our study.

With respect to year of publication, we noticed a significant value of accepted references in 2014, when IAEA published a TECDOC with a collection of articles about research reactor aging management, modernization and refurbishment *[22]*.

References accepted for our study and other references cited in this article are described in section 7.

5 Theoretical review on references accepted for this study

As we grouped the accepted references in the analytical categories previously established, it was possible to elaborate a theoretical review on our study of research reactors sustainable operations. Next, we present the main points discussed in these references, by analytical category.

5.1 Interdisciplinary approaches to sustainability research (OM/Marketing, OM/Finance, OM/Strategy)

Levine *[8, 9]* discusses how a small research reactor supports a national nuclear power program. According to him, a research reactor provides resources for training nuclear engineers, nuclear operators and other nuclear specialists required to construct, operate and maintain a nuclear power plant.

Jackson *[10]* reports the management of uranium materials carried out by the Department of Energy (DOE) of the United States, performed by Uranium Management Group (UMG). This Group is responsible for managing DOE's uranium assets. He performs a life-cycle approach to the management of uranium and addresses the current needs in the context of a long-term strategy.

IAEA *[11]* gives us an idea of how IAEA delivers its budget. About 97 % of the budget is applied in programs of that entity and the remainder is used for payment of services provided by third parties and in the acquisition of safeguards equipment.

IAEA *[12]* reports that decommissioning projects for various types of nuclear facilities have shown that decommissioning costs can be managed.

5.2 Sustainability analysis

Obadia and Perrotta *[13]* present a sustainability analysis for Brazilian Multipurpose Reactor Project. In this analysis, they discuss nineteen items established by IAEA *[14]* for phase 1 of a research reactor project: (1) national position, (2) nuclear safety, (3) management, (4) funding and financing, (5) legislative framework, (6) regulatory structure, (7) safeguards, (8) radiation protection, (9) research reactor utilization, (10) human resources development, (11) stakeholder involvement, (12) site survey, site selection and evaluation, (13) environmental protection, (14) emergency planning, (15) nuclear security, (16) nuclear fuel management, (17) radioactive waste, (18) industrial involvement and (19) procurement.

5.3 Life Cycle analysis

Franke and Vogt *[15]* make an assessment of the environmental impacts resulting from decontamination and decommissioning activities for research reactors at Brookhaven National Laboratory, according to methodology established by ISO *[16]*. LCA studies comprise four phases: definition of objective and scope, inventory analysis, impact assessment and interpretation.

5.4 Certification ISO 14000

Gho *[17]* describes the interest in deploying an ISO 14001 environmental certification system in Experimental Nuclear Reactor RA6, located in Bariloche Atomic Centre (CAB), in Argentina. He claims that an environmental management system ISO 14001 will strengthen society's relationship with environment and the relationship of nuclear energy with society.

5.5 Waste management

Debreuille et al. *[18]* make a study on the treatment of spent nuclear fuel from nuclear reactors of generation IV

According to them, the vast majority of generation IV reactors depend on closed fuel cycle, with great benefits in the areas of resource conservation, waste conditioning performance and management of waste toxicity.

Devgun *[19]* reports that the proper management of spent fuel, resulting from the production of nuclear energy is a key issue for the sustainable development of nuclear energy. Two options are usually considered: the closed fuel cycle and the once through fuel cycle.

IAEA *[20]* describes the procedures for the return of spent fuel from the research reactor to the country of origin. Managing the end of the nuclear fuel cycle process of a research reactor is very important to the non-proliferation of nuclear materials, physical protection of nuclear installation and environment protection.

Sikorin et al. *[21]* reports the experience of nuclear spent fuel storage with highly enriched uranium in Research reactors IRT-M and Pamir-630, located in Minsk, Belarus and its transportation for reprocessing in Russian Federation. This eliminated spent nuclear fuel storage problem in Belarus.

5.6 Ageing management

IAEA *[22]* contains a collection of articles published about experiences obtained from aging management projects, modernization and refurbishment of research reactors.

As most research reactors are over 40 years old, maintenance, modernization and renewal are very important for a viable and safe operation of these reactors.

From IAEA *[22]* we highlight works from Carvalho *[23]*, Chilian and Kennedy *[24]*, D'Arcy et al. *[25]*, Daie *[26]*, Kamoon and Ali *[27]*, Kombele et al. *[28]*, Kutlu *[29]*, Luch et al. *[30]*, Nitiswati et al. *[31]*, Ramanathan et al. *[32]*, Sharma and Raina *[33]*, Shepitchak *[34]*, Tippayakul *[35]*, Xiao *[36]* and Younoussi *[37]*.

In addition to the works mentioned above, we highlight works of ANSTO *[38]*, Ciocanescu *[39]*, and Perrotta, *[40]*, who also regard research reactors aging management.

5.7 Sustainability indicators

Csullog et al. *[41]* address the implementation of sustainable development indicators for radioactive waste management. According to them, sustainability is the point at which the amount of radioactive waste awaiting disposal is not increasing, the waste is in the final form required for disposal and it is being safely stored.

5.8 Environmental legislation related to operations

Boyd *[42]* describes that the Atomic Energy Control Act of Canada does not require public hearings; these are required by municipal legislation for projects under its environmental legislation. For federal projects, there is a proposal for revising federal government policy, so that a public hearing assessed by federal environmental service is established.

Konopaskova and Nachmilner *[43]* describe that environmental legislation, which is substantial in the process of public involvement, postulates to assess all the types of risk.

Andersson et al. *[44]* describe that according to most environmental legislation, every large construction project must be assessed in relation to its environmental impact, the societal need of the project, and the alternatives (including a "zero-alternative", i.e. doing nothing).

CNEN *[45]* reports that nuclear installations are subject to both a nuclear license by CNEN and an environmental license by Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA), with the participation of state and local environmental agencies, as stated in the National Environmental Policy Act.

Santos *[46]* describes a methodology for implementing an environment, health and safety policy at Nuclear Fuel Centre (CCN) in IPEN, This allows the use of detailed data reports and fulfilment of applicable legislation.

Kralj and Zelezniki *[47]* report Slovenian environmental and nuclear legislation, which integrate strategic planning of radioactive waste management with environmental protection planning.

Sjöblom and Lindskog *[48]* describe and analyse characteristics of various prerequisites for and obstacles against fulfilment of the polluter pays principle in the case of decommissioning of old Swedish nuclear research and development facilities, as established in Swedish nuclear and environmental legislation.

Mattos et al. *[49]* developed environmental management systems tools for Nuclear Fuel Centre at IPEN. They report that nuclear and radioactive installations of IPEN passed through an environmental compliance process, legally named Conduct Adjustment Agreement.

Serra *[50]* proposes an integrated regulatory structure based on quality and environment issues to be implemented in the licensing process of Brazilian nuclear research reactors.

5.9 Strategic planning for sustainability

According to Belgian Nuclear Research Centre *[51]*, sustainability means persistent safety of present nuclear infrastructures, a continued long-term strategy towards nuclear waste issues, and initiatives to support research for future nuclear systems – like fusion or GEN IV that sustain the security and efficiency of supply and demonstrate lifetime reduction of nuclear waste. Last but not least sustainability means the adequate protection of mankind, the public acceptance of nuclear energy, and the appreciation of its societal spin-offs, especially in the field of medical applications.

Ciocanescu et al. *[52]* presents a strategic planning for improving sustainability of TRIGA 14 MW Research Reactor located in Pitesti, Romania. For them, sustainability, in the context of research reactors, is defined as the ability to keep equilibrium between utilization and depreciation of a complex system of resources, and the capacity of research reactors in making products and services for other processes, which should also be sustained.

Goldman et al. *[53]* present an initiative to form one or more coalitions of research reactor operators and stakeholders to improve the sustainability of research reactors through improved market analysis and strategic/business planning, joint marketing of services, increased contacts with prospective customers and enhanced public information.

Ridikas et al. *[54]* discuss activities related to research reactor coalitions and networks made by IAEA in the two previous years.

Ridikas et al. *[55]* describe activities to enhance the use and application of research reactors. They report that about 50% of research reactors in operation are underutilized. They estimate that out of 244 reactors in operation in the world today, only 100 to 150 will be fully operational in 2020.

Wheeler and Gawthrop *[56]* describe the transformation project of the nuclear research complex V (TA-V) of Sandia National Laboratories (SNL), consisting of two research reactors, a gamma irradiation facility and other facilities for the assessment of the effects of radiation on nuclear materials.

Perrotta and Obadia *[57]* present the stage of development of Brazilian Multipurpose Reactor (RMB). This reactor will replace IEA-R1 Reactor, which is in operation for 50 years and may operate only for another ten years.

Ridikas *[58]* describes how to develop a strategic plan for the effective utilization of research reactors, according to guidelines established by IAEA *[14]*. He is convinced that the long-term sustainability of many research reactors around the world depends upon the development and implementation of an effective and achievable strategic plan for their utilization. He suggests a modular approach for the strategic plan of a research rector.

5.10 Sustainable product design

Guyon *[59]* describes the refurbishment and perspective for the Institut Laue-Langevin reactor (ILL) in France. Due to this refurbishment, it was possible to increase safety, technological quality and experimental performance of this reactor.

Saxena *[60]* describes refurbishments carried out in IPEN IEA-R1 Research Reactor, in São Paulo. He reports that modernization and refurbishment programmes for small research reactors must be a continuous activity where small steps must be taken to improve the performance of the reactor with moderate budgets and shorter shutdown periods rather than very extensive refurbishment programmes that require large sums and long shutdown times.

Lyric et al. *[61]* make a study about the optimum burnup of TRIGA Mark II research reactor of Bangladesh Atomic Energy Commission (BAEC). Optimum fuel burnup strategy has been investigated for BAEC TRIGA core, where three out-to-in loading schemes have been inspected in terms of core life extension, burnup economy and safety.

Lobach *[62]* describes the concept used for WWR-M Reactor renovation, in Kiev, Ukraine. The renovation concept is based on the technical solutions, which guarantee the maintaining of the reactor operational parameters at the proper level and the safety level in accordance with the national legislation and the international recommendations.

Ramli et al. *[63]* describe Research Reactor Triga Mark II PUSPATI refurbishment, in Malaysia. They provide the details of design, installation, testing and commissioning of the refurbishment.

Sanda *[64]* describes the low-enrichment uranium conversion and modernisation of systems related to Triga 14 MW research reactor safety at Institute for Nuclear Research, in Pitesti, Romania.

Stander et al. *[65]* describe the beryllium reflector replacement in SAFARI-1 research reactor, located in Pelindaba, South Africa. This was necessary to reduce the risks involved with core elements breakage or deformation at SAFARI-1.

5.11 Recycling

Nieves et al. *[66]* make an assessment of radioactive metal scrap recycling in relation to human health risks, environmental and socio-political impacts, its final disposal and replacement.

Skea and Cartwright *[67]* report their experience with uranium recovery from scraps and mixtures of recycled uranium from material testing reactors, on uranium conversion facility Dounreay, in United Kingdom.

Bouchardy and Pauty *[68]* describe the processes of recycling and conversion of uranium inventories in various forms and levels of enrichment at COGEMA Pierrelatte installation, in France.

IAEA *[69]* provides a linear decision approach for acceptance of materials and components recycling or reuse from nuclear fuel cycle facilities tailings.

5.12 Corporate social responsibility

Abramenkovs *[70]* describes the role of stakeholders in the preparation, update and implementation of decommissioning plan of Salaspils Research Reactor, located near Riga, Latvia.

Heldt *[71]* discusses some foundations of the corporate social responsibility movement and position it into the context of governance of the nuclear sector.

5.13 Market valuation of environmental and social initiatives

Gawande et al. *[72]* developed a study on the depreciation of property values along a path of rail transport of radioactive nuclear spent fuel in Charleston County, South Carolina, United States.

6 Conclusions and final considerations

The main purpose of this article was to identify sustainable operations carried out by operating organizations of research reactors and form a theoretical review on the subject.

At first, we performed a theoretical approach on sustainable operations and research reactors, in order to establish our concept on these matters.

Then, we conducted a literature search, using methodology developed by Seuring and Müller *[6]*, allowing the analytical categorization of references accepted for our study.

The literature search was conducted by using structured keywords in academic databases, such as Google Scholar, Web of Science, Elsevier and Scopus and a nuclear database INIS.

Within the structural dimension "sustainable operations", we took as a basis the analytical categories established by the Journal of Operations Management *[7]* that receives articles for publication in its sustainable operations management department. From the results obtained, it was necessary to assign new analytical categories to those originally established.

The results were satisfactory, the references were classified according to the type of publication, year of publication and related analytical category.

We noted that some established analytical categories were not covered with any reference, namely, "sustainable supply chain management", "closed-loop supply chains", "sustainable procurement" and "industrial symbiosis". This characterizes a gap in literature on sustainable operations and can turn into opportunities for the development of new studies and papers on the subject.

On the other hand, we realized that analytical category "aging management" contemplated greater number of references. By analysing this analytical category, we realized that sustainable operations in research reactors are directly related to maintaining the operation safety of these reactors by means of modernization and renovation of systems, structures and components.

The analytical categorization of references accepted for this study enabled structuring a theoretical review on research reactor sustainable operations. This theoretical approach may be used by scientists and researchers in the area of research reactors to improve their processes with respect to sustainable operations management.

Future work may and must be prepared to contribute for a better understanding on research reactor sustainable operations.

Although sustainable operations management is a reality in several economy sectors, in the area of research reactors this approach is very recent and little publicized.

The results and conclusions reached with this work may serve as a reference in establishing sustainable operations management goals for research reactors in operation and also for research reactors under development. The approach presented in this article is unprecedented, no studies or similar approaches were found in literature.

References

[1] APICS. *APICS Operations Management Body of Knowledge Framework.* 3. ed. Chicago, IL, USA: APICS, 2011. 107 p.

[2] KLEINDORFER, P. R.; SINGHAL, Kalyan; WASSENHOVE, Luk N. Sustainable operations management. *Production and operations management,* v. 14, n. 4, p. 482-492, 2005.

[3] SO, S.; PARKER, D.; XU, H. A conceptual framework for adopting sustainability in the supply chain. In: *ANZAM operations, supply chain and services management symposium.* ANZAM, 2012. p. 397-413.

[4] TERREMOTO, L. A. A. *Disciplina TNR5764 Fundamentos de Tecnologia Nuclear Reatores.* 2. ed. São Paulo: IPEN, 2004. 120 p.

[5] INTERNATIONAL ATOMIC ENERGY AGENCY – IAEA. *Research Reactor Database.*

[6] SEURING, S.; MÜLLER, M. From a literature review to a conceptual framework for sustainable supply chain management. *Journal of cleaner production,* v. 16, n. 15, p. 1699-1710, 2008.

[7] *JOURNAL OF OPERATIONS MANAGEMENT: Sustainable Operations.* Amsterdam, jul. 2016.

[8] LEVINE, S. H. Incorporating the operation of a small research reactor facility to support a national nuclear power. In: ANNUAL MEETING OF THE ISRAEL NUCLEAR SOCIETIES, 11., 1983, Haifa, Israel. *Safety and Siting Problems of Nuclear Power Reactors in a Small Country.* Haifa, Israel: Technion Israel Institute of Technology, 1983. v. 11, p. 10 - 15.

[9] LEVINE, S. H.; KENNEY, E. S. Incorporating the operation of a small research reactor facility to support a national nuclear power program. In: INTERNATIONAL ATOMIC ENERGY AGENCY - IAEA. *Technical committee meeting on research reactor activities in support of national nuclear programmes:* IAEA-TECDOC-409. Vienna: IAEA, 1987. p. 215-225.

[10] JACKSON, D.; MARSHALL, E.; SIDERIS, T.; VASA-SIDERIS, S. Uranium management activities. In: INTERNATIONAL CONFERENCE ON NUCLEAR ENGINEERING (ICONE), 9., 2001, Nice, France. *Proceedings.* Nice, France: IAEA, 2001. p. 1 - 8.

[11] INTERNATIONAL ATOMIC ENERGY AGENCY – IAEA. *Annual Report 2002:* GC(47)/2. Vienna: IAEA, 2003. 151 p.

[12] INTERNATIONAL ATOMIC ENERGY AGENCY – IAEA. *Planning, managing and organizing the decommissioning of nuclear facilities: lessons learned:* IAEA-TECDOC-1394. Vienna: IAEA, 2004. 111 p.

[13] OBADIA, I. J.; PERROTTA, J. A. A sustainability analysis of the Brazilian Multipurpose Reactor project. In: RRFM 2010: INTERNATIONAL TOPICAL MEETING ON RESEARCH REACTOR FUEL MANAGEMENT (RRFM), 14., 2010, Marrakech. *Transactions.* Brussels: European Nuclear Society, 2010. p. 311 - 315.

[14] INTERNATIONAL ATOMIC ENERGY AGENCY – IAEA. *Specific Considerations and Milestones for a Research Reactor Project:* IAEA Nuclear Energy Series No. NP-T-5.1. Vienna: IAEA, 2012. 107 p.

[15] FRANKE, B.; VOGT, R. *Assessment of the Environmental Impacts of Decontamination and Decommissioning Activities for Research Reactors at the Brookhaven National Laboratory.* Heidelberg, Germany: Ifeu, 2004. 26 p.

[16] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION – ISO. *ISO 14040:* Environmental management - Life cycle assessment - Principles and framework. Geneva, Switzerland: ISO, 2006. 20 p.

[17] GHO, C. J. Factibilidad de certificación ISO 14000 del Reactor nuclear RA-6 del Centro Atomico Bariloche. In: REUNION ANUAL DE LA ASOCIACION ARGENTINA DE TECNOLOGIA NUCLEAR (AATN), 30., 2003, Buenos Aires. *Actas.* Buenos Aires: AATN, 2003. p. 1 - 14.

[18] DEBREUILLE, M. F.; DEVEZEAUX DE LAVERGNE, J. G.; KAPLAN, P.; NG, S.; VINOCHE, R. Used nuclear fuel treatment in the 21st century. In: INTERNATIONAL CONFERENCE ON TOPICAL ISSUES IN NUCLEAR INSTALLATION SAFETY: CONTINUOUS IMPROVEMENT OF NUCLEAR SAFETY IN A CHANGING WORLD, 2004, Beijing, China. *Book of Contributed Papers.* Beijing, China: IAEA, 2004. p. 26 - 29.

[19] DEVGUN, J. *Managing Nuclear Projects.* Cambridge, UK: Woodhead Publishing, 2013. 384 p.

[20] INTERNATIONAL ATOMIC ENERGY AGENCY - IAEA. *Return of Research Reactor Spent Fuel to the Country of Origin: Requirements for Technical and Administrative Preparations and National Experiences:* IAEA-TECDOC-1593. Vienna: IAEA, 2008. 349 p.

[21] SIKORIN, S. N.; POLAZAU, S. A.; LUNEU, A. N.; HRIGAROVICH, T. K. The Experience of Storage and Shipment for Reprocessing of HEU Nuclear Fuel Irradiated in the IRT-M Research Reactor and Pamir-630 Mobile Reactor. In: INTERNATIONAL ATOMIC ENERGY AGENCY – IAEA. *Project Experiences in Research Reactor Ageing Management, Modernization and Refurbishment:* IAEA-TECDOC-1748. Vienna. 2014. p. 23-28.

[22] INTERNATIONAL ATOMIC ENERGY AGENCY - IAEA. *Project Experiences in Research Reactor Ageing Management, Modernization and Refurbishment:* IAEA-TECDOC-1748. Vienna: IAEA, 2014.

[23] CARVALHO, P. V. R. Modernization of Safety and Control Instrumentation of the IEA-R1 Research Reactor. In: INTERNATIONAL ATOMIC ENERGY AGENCY – IAEA. *Project experiences in research reactor ageing management, modernization and refurbishment:* IAEA-TECDOC-1748. Vienna: IAEA, 2014. p. 29-42.

[24] CHILIAN, C.; KENNEDY, G.. Self-sustainability of a research reactor facility with neutron activation analysis. In: RRFM 2010: INTERNATIONAL TOPICAL MEETING ON RESEARCH REACTOR FUEL MANAGEMENT (RRFM), 14., 2010, Marrakech. *Transactions.* Brussels: European Nuclear Society, 2010. p. 184 - 188.

[25] D'ARCY, A. J.; STANDER, H. J.; VLOK, J. W. H. An Ageing Management Programme for the SAFARI-1 Research Reactor. In: INTERNATIONAL ATOMIC ENERGY AGENCY – IAEA. *Project experiences in research reactor ageing management, modernization and refurbishment:* IAEA-TECDOC-1748. Vienna: IAEA, 2014. p. 130-141.

[26] DAIE, J. Modernization and Refurbishment of the RECH-1 Reactor. In: INTERNATIONAL ATOMIC ENERGY AGENCY – IAEA. *Project experiences in research reactor ageing management, modernization and refurbishment:* IAEA-TECDOC-1748. Vienna: IAEA, 2014. p. 44-47.

[27] KAMOON, A.; ALI, A. Ageing Management Based Maintenance at ETRR-II. In: INTERNATIONAL ATOMIC ENERGY AGENCY – IAEA. *Project experiences in research reactor ageing management, modernization and refurbishment:* IAEA-TECDOC-1748. Vienna: IAEA, 2014. p. 60-66.

[28] KUTLU, O. Y. Ageing Management and Modernization of TR-2 Research Reactor. In: INTERNATIONAL ATOMIC ENERGY AGENCY - IAEA. *Project experiences in research reactor ageing management, modernization and refurbishment:* IAEA-TECDOC-1748. Vienna: IAEA, 2014. p. 156-160.

[29] KOMBELE, D. G.; KANKUNKU-K, P.; MWAMBA, V. L.; KOBAKOZETE, J. I.; KIAMANA, M. M.; LUKIBANZA, J. W.; KALALA, A. T.; MFINDA, D. M.; BILULU, T. L.; ILUNGA, S. T. Ageing Management of the Kinshasa Trico II Research Reactor Components and Structures: A Case Study of the 5 Tonne Overhead Travelling Crane and the Ventilation System Inlet and Outlet. In: INTERNATIONAL ATOMIC ENERGY AGENCY – IAEA. *Project experiences in research reactor ageing management, modernization and refurbishment:* IAEA-TECDOC-1748. Vienna: IAEA, 2014. p. 53-59.

[30] DI LUCH, A.; FABBRI, S.; VEGA, G.; VERSACI, R. Life management programme for long term operation of reactors and nuclear facilities: Ageing management of research reactors in Argentina. In: INTERNATIONAL ATOMIC ENERGY AGENCY – IAEA. Project experiences in research reactor ageing management, modernization and refurbishment: IAEA-TECDOC-1748. Vienna: IAEA, 2014. p. 5-13.

[31] NITISWATI, S.; SYARIP; TJIPTONO, T.; WANTANA. Ageing Management Programme: An Experience of In-Service Inspection of the Kartini Heat Exchanger. In: INTERNATIONAL ATOMIC ENERGY AGENCY – IAEA. *Project experiences in research reactor ageing management, modernization and refurbishment:* IAEA-TECDOC-1748. Vienna. 2014. p. 85-88.

[32] RAMANATHAN, L. V. Ageing Management Programme for the IEA-R1 Reactor in São Paulo, Brazil. In: INTERNATIONAL ATOMIC ENERGY AGENCY – IAEA. *Project experiences in research reactor ageing management, modernization and refurbishment:* IAEA-TECDOC-1748. Vienna: IAEA, 2014. p. 43.

[33] SHARMA, R. C.; RAINA, V. K. An Overview of Ageing Management and Refurbishment of Research Reactors at Trombay. In: INTERNATIONAL ATOMIC ENERGY AGENCY – IAEA. *Project experiences in research reactor ageing management, modernization and refurbishment:* IAEA-TECDOC-1748. Vienna: IAEA, 2014. p. 67-84.

[34] SHEPITCHAK, A. Research Reactors of Ukraine. In: INTERNATIONAL ATOMIC ENERGY AGENCY – IAEA. *Project experiences in research reactor ageing management, modernization and refurbishment:* IAEA-TECDOC-1748. Vienna: IAEA, 2014. p. 161-170.

[35] TIPPAYAKUL, C. Approach for Establishment of an Ageing Management Programme for Thai Research Reactor-1/Modification 1 (TRR-1/M1). In: INTERNATIONAL ATOMIC ENERGY AGENCY – IAEA. *Project experiences in research reactor ageing management, modernization and refurbishment:* IAEA-TECDOC-1748. Vienna: IAEA, 2014. p. 150-155.

[36] XIAO, H. Ageing management of CARR. In: INTERNATIONAL ATOMIC ENERGY AGENCY – IAEA. *Project experiences in research reactor ageing management, modernization and refurbishment:* IAEA-TECDOC-1748. Vienna: IAEA, 2014. p. 48-52.

[37] YOUNOUSSI, C. E.; NACIR, B.; BAKKARI, B. E.; BOULAICH, Y. Ageing Management in the CENM Triga Mark II Research Reactor. In: INTERNATIONAL ATOMIC ENERGY AGENCY – IAEA. *Project experiences in research reactor ageing management, modernization and refurbishment:* IAEA-TECDOC-1748. Vienna: IAEA, 2014. p. 100-103.

[38] AUSTRALIAN NUCLEAR SCIENCE AND TECHNOLOGY ORGANISATION – ANSTO. *Proposed replacement nuclear research reactor at Lucas Heights Science and Technology Centre, NSW:* Statement of evidence to the Parliamentary Standing Committee on Public Works. Lucas Heights, NSW, Australia: ANSTO, 1999. 101 p.

[39] CIOCANESCU, M. Ageing of research reactors. In: INTERNATIONAL CONFERENCE ON TOPICAL ISSUES IN NUCLEAR SAFETY, 2001, Vienna. *Contributed papers.* Vienna: IAEA, 2001. p. 225 - 229.

[40] PERROTTA, J. A. Status of Research Reactor Utilization in Brazil. In: INTERNATIONAL ATOMIC ENERGY AGENCY – IAEA. *Research Reactor Application for Materials under High Neutron Fluence:* IAEA-TECDOC-1659. Vienna: IAEA, 2011. Cap. 4. p. 21-29.

[41] CSULLOG, G. W.; SELLING, H.; HOLMES, R.; BENITEZ, J.C. The Net Enabled Waste Management Database in the context of an indicator of sustainable development for radioactive waste management: IAEA-CN-90/76. In: INTERNATIONAL ATOMIC ENERGY AGENCY – IAEA. *International conference on issues and trends in radioactive waste management.* Vienna: IAEA, 2002. p. 401-408.

[42] BOYD, F. C. *Licensing and safety of nuclear power plants in Canada. Ottawa, Canada:* Atomic Energy Control Board, 1981. 19 p.

[43] KONOPASKOVA, S.; NACHMILNER, L. Risk assessment of institutional waste disposal systems in the Czech Republic. In: INTERNATIONAL CONFERENCE ON THE SAFETY OF RADIOACTIVE WASTE MANAGEMENT, 2000, Cordoba, Spain. *Contributed papers.* Vienna: IAEA, 2000. p. 70 - 74.

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[44] ANDERSSON, Kjell et al. *Nuclear Safety in Perspective.* Roskilde, Denmark: Nordic Nuclear Safety Research (NKS), 2002. 74 p.

[45] Comissão Nacional de Energia Nuclear – CNEN (Org.). *National report of Brazil 2008 for the 3rd review meeting of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.* Rio de Janeiro, Brasil: CNEN, 2008. 135 p.

[46] SANTOS, G. R. T.; DURAZZO, M.; RIELLAB, H. G.; CARVALHO, E. F. U. Environmental concerns regarding a materials test reactor fuel fabrication facility at the Nuclear and Energy Research Institute – IPEN. In: CONGRESS OF THE INTERNATIONAL RADIATION PROTECTION ASSOCIATION, 12., 2008, Buenos Aires. *Proceedings.* Buenos Aires: IRPA, 2008. p. 1 - 10.

[47] KRALJ, M.; ZELEZNIK, N. Operational Programs for National Program on Radioactive Waste and Spent Fuel Management in 2012-2015. In: INTERNATIONAL NUCLEAR ENERGY FOR NEW EUROPE CONFERENCE, 21., 2012, Ljubljana, Slovenia. *Nuclear Energy for New Europe.* Ljubljana: Nuclear Society of Slovenia (NSS), 2012. p. 1201.1 - 1201.8.

[48] SJÖBLOM, R.; LINDSKOG, S. Management of Intergenerational Environmental Liabilities: Example of Decommissioning of Nuclear Res. *International Journal of Sustainable Development and Planning.* Southampton, UK, p. 135-158. 29 jun. 2012.

[49] MATTOS, L. A. T.; MELDONIAN, N. L.; MADI FILHO, T. Environmental management systems tools applied to the nuclear fuel center of IPEN. In: 2013 INTERNATIONAL NUCLEAR ATLANTIC CONFERENCE - INAC 2013, 6., 2013, Recife, Pe, Brasil. *Anais.* Rio de Janeiro: ABEN, 2013. p. 1 - 8.

[50] SERRA, R. C. *Licenciamento de Reatores: Proposta de uma Estrutura Regulatória Integrada com Abordagem em Qualidade e Meio Ambiente para Reatores de Pesquisa no Brasil.* 2014. 125 f. Tese (Doutorado) – Curso de Tecnologia Nuclear – Aplicações, Instituto de Pesquisas Energéticas e Nucleares – IPEN, São Paulo, 2014.

[51] BELGIAN NUCLEAR RESEARCH CENTER SCK-CEN. *Scientific Report 2006.* Mol, Belgium: Belgian Nuclear Research Center, 2007. 146 p.

[52] CIOCANESCU, M.; PAUNOIU, C.; TOMA, C.; PREDA, M.; IONILA, M. Improvement of research reactor sustainability. In: RRFM 2010: INTERNATIONAL TOPICAL MEETING ON RESEARCH REACTOR FUEL MANAGEMENT (RRFM), 14., 2010, Marrakech. *Transactions.* Brussels: European Nuclear Society, 2010. p. 194-198.

[53] GOLDMAN, I.; ADELFANG, P.; ATGER, A.; ALLDRED, J.; MOTE, N. Developing research reactor coalitions and centres of excellence. In: INTERNATIONAL TOPICAL MEETING, 11., 2007, Lyon, France. *Research Reactor Fuel Management (RRFM) and Meeting of the International Group on Reactor Research (IGORR).* Brussels, Belgium: European Nuclear Society, 2007. p. 53 - 58.

[54] RIDIKAS, D.; ADELFANG, P.; ALLDRED, K.; FERRARI, M. New Opportunities for Enhanced Research Reactor Utilization through Coalitions and Networks. In: RRFM (EUROPEAN RESEARCH REACTOR CONFERENCE) 2011, 15., 2011, Rome, Italy. *International Topical Meeting on Research Reactor Fuel Management (RRFM).* Brussels, Belgium: European Nuclear Society, 2011. p. 114 - 119.

[55] RIDIKAS, D.; MANK, G.; ADELFANG, P.; ALLDRED, K.; BRADLEY, E. E.; GOLDMAN, I. N.; KHVAN, A.; PELD, N. The IAEA activities towards enhanced utilization, sustainability and applications of research reactors. In: RRFM 2010: INTERNATIONAL TOPICAL MEETING ON RESEARCH REACTOR FUEL MANAGEMENT (RRFM), 14., 2010, Marrakech. *Transactions.* Brussels: European Nuclear Society, 2010. p. 21-25.

[56] WHEELER, D. M.; GAWTHROP, M. *SANDIA REPORT:* Technical Area V (TA-V) Transformation Project Close-Out Report. Albuquerque, NM, USA: Sandia National Laboratories, 2010. 54 p.

[57] PERROTTA, J. A.; OBADIA, I. J. The RMB project development status. In: INTERNATIONAL CONFERENCE ON RESEARCH REACTORS, 2011, Rabat, Morocco. *Safe Management and Effective Utilization.* Viena: IAEA, 2012. p. 1 - 11.

[58] RIDIKAS, D. Developing strategic plans for effective utilization of research reactors. *Ens News.* Brussels, Belgium, p. 1-8. maio 2015.

[59] GUYON, H. Refurbishment and perspective for ILL. In: INTERNATIONAL TOPICAL MEETING, 11., 2007, Lyon, France. *Research Reactor Fuel Management (RRFM) and Meeting of the International Group on Reactor Research (IGORR).* Brussels, Belgium: European Nuclear Society, 2007. p. 24-32.

[60] SAXENA, R. N. Modernization of the IEA-R1 research reactor to secure safe and sustainable operations for radioisotope production. In: INTERNATIONAL ATOMIC ENERGY AGENCY – IAEA (Ed.). *Research Reactor Modernization and Refurbishment:* IAEA-TECDOC-1625. Vienna: IAEA, 2009. p. 33-40.

[61] LYRIC, Z. I.; MAHMOOD, M. S.; MOTALAB, M. A.; KHAN, J. H. Optimum burnup of BAEC TRIGA research reactor. *Annals of Nuclear Energy.* Amsterdam, p. 225-229. maio 2013.

[62] LOBACH, Y. N. Concept for the WWR-M Reactor Renovation. *International Journal of Nuclear Energy Science and Engineering.* Terre Haute, IN, USA, p. 26-33. mar. 2014.

[63] RAMLI, S.; ZAKARIA, M. F.; MASOOD, Z. Refurbishment of the Primary Cooling System of the Puspati Triga Reactor. In: INTERNATIONAL ATOMIC ENERGY AGENCY - IAEA. *Project experiences in research reactor ageing management, modernization and refurbishment:* IAEA-TECDOC-1748. Vienna: IAEA, 2014. p. 89-99.

[64] SANDA, R. M. Research Reactor Conversion to LEU and Modernization of Safety Related Systems. In: INTERNATIONAL ATOMIC ENERGY AGENCY – IAEA. *Project experiences in research reactor ageing management, modernization and refurbishment.* Vienna: IAEA, 2014. p. 117-121.

[65] STANDER, H. J.; DE KOCK, M.; VLOK, J. W. H.; STRYDOM, W. J.; D'ARCY, A. J.; BELAL, M. G. A. H. Replacement of the Core Beryllium Reflector in the SAFARI-1 Research Reactor. In: INTERNATIONAL ATOMIC ENERGY AGENCY – IAEA. *Project experiences in research reactor ageing management, modernization and refurbishment:* IAEA-TECDOC-1748. Vienna: IAEA, 2014. p. 142-149.

[66] NIEVES, L. A.; CHEN, S. Y.; KOHOUT, E. J.; NABELSSI, B.; TILBROOK, R. W.; WILSON, S. E. *Evaluation of radioactive scrap metal recycling.* Argonne, IL, USA: Argonne National Laboratory, 1995. 474 p.

[67] SKEA, D.; CARTWRIGHT, P. Recovery of uranium from manufacturing scraps and blending of recycled MTR uranium. In: EUROPEAN NUCLEAR SOCIETY (Org.). *RRFM '97: 1st. International topical meeting on research reactor fuel management.* Bruges, Belgium: European Nuclear Society, 1997. p. 15-20.

[68] BOUCHARDY, S.; PAUTY, J. F. Highly enriched uranium recycle and conversion facility at COGEMA Pierrelatte. *Nuclear Engineering and Design.* Amsterdam, p. 107-109. 26 mar. 1998.

[69] INTERNATIONAL ATOMIC ENERGY AGENCY – IAEA. *Recycle and reuse of materials and components from waste streams of nuclear fuel cycle facilities:* IAEA-TECDOC-1130. Vienna: IAEA, 2000. 56 p.

[70] ABRAMENKOVS, A. The Role of Stakeholders in the Decommissioning of Salaspils Research Reactor. In: 2009 WASTE MANAGEMENT SYMPOSIUM – WM2009/WM'09, 2009, Phoenix, AZ, USA. *HLW, TRU, LLW/ILW, Mixed, Hazardous Wastes and Environmental Management - Waste Management for the Nuclear Renaissance.* Phoenix, AZ, USA: WM Symposia, 2009. p. 1 - 9.

[71] HELDT, T. Corporate Social Responsibility (CSR) and its relevance for the nuclear sector. In: (ED.), Rafael Mariano Manóvil. *XXI AIDN / INLA Congress:* Nuclear Law in Progress, Derecho Nuclear en Evolución. Buenos Aires: Legis Argentina S.A., 2014. p. 135-155.

[72] GAWANDE, K.; JENKINS-SMITH, H.; YUAN, M. The long-run impact of nuclear waste shipments on the property market: Evidence from a quasi-experiment. *Journal of Environmental Economics and Management.* Amsterdam, p. 56-73. 20 jul. 2012.

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