The Evaluation of the Radiological Impact for a New Nuclear Facility on a Multi-facility Site

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Abstract

It is beneficial to site new nuclear installations on existing nuclear sites. Pelindaba is the location of SAFARI-1 and many other chemical and nuclear facilities. The siting process for a new installation on this Brownfields multi-facility site is tailored from the IAEA guidelines. This paper briefly describes the siting process adopted by Necsa for siting at Pelindaba. The South African regulations on siting new nuclear installations require a cumulative radiological impact assessment. This paper also explores the question of selecting a representative person for radiological consequence assessment for the multi-facility Pelindaba site. Groups were selected based on a community survey and then ranked according to their effective doses. It is shown that although predictions of the representative person for a new installation can be made, a cumulative assessment is necessary. Additionally, the representative person for normal situations is not necessarily the representative person for accident scenarios.

Key words: Siting, Brownfields Site, Representative Person

1 Introduction

There are many exciting developments in the nuclear sector globally and new nuclear facilities are required for various activities in the nuclear fuel cycle, nuclear power plant development and in the nuclear isotopes industry. The question of where these new facilities should be located has many dimensions. Often it is most practical to develop new nuclear facilities on existing nuclear sites. The South Africa Nuclear Energy Corporation (Necsa) is based at one such site: Pelindaba.

Pelindaba is south of the Hartebeespoort Dam in the North West Province of South Africa. It is approximately 27 km west of Pretoria and stretches over 2362 hectares in area. It houses multiple chemical and nuclear facilities including the material test reactor, SAFARI-1, and NTP PTY Ltd: the major international commercial isotope producer which includes Molybdenum-99 utilised for medical imaging. Pelindaba is the hub of South Africa's nuclear technology development.

As South Africa prepares to develop further nuclear capacity, Necsa is investigating the prospect of new facilities at Pelindaba. In order to establish a new nuclear installation in South Africa an applicant must comply with the National Siting Regulations [1]. This paper briefly discusses the siting process that Necsa has adopted and then examines the site related information used in the radiological impact assessment required to site on a multi-facility site, such as Pelindaba.

2 Necsa's Siting Process

The majority of the guidance around siting for nuclear installations addresses Greenfields sites. This is due to the need to identify a suitable location out of a large number of potential sites that may be in significantly different geographical areas. Since Necsa intends to develop new installations on an existing Brownfields site, the siting process requires some tailoring.

The International Atomic Energy Agency (IAEA) guidelines on siting [2] and [3] were used as the basis for Necsa's siting process shown in Figure 1. The first two stages involve identifying potential locations on the existing site, screening and then ranking them in order to identify a preferred site. The site selection for a proposed new reactor at Pelindaba is described in [4]. The site assessment stage is where the bulk of the work for siting lies. At the end of this stage a Site Safety Report is compiled. This is the principal document for submission to the National Nuclear Regulator (NNR) to obtain a site license.

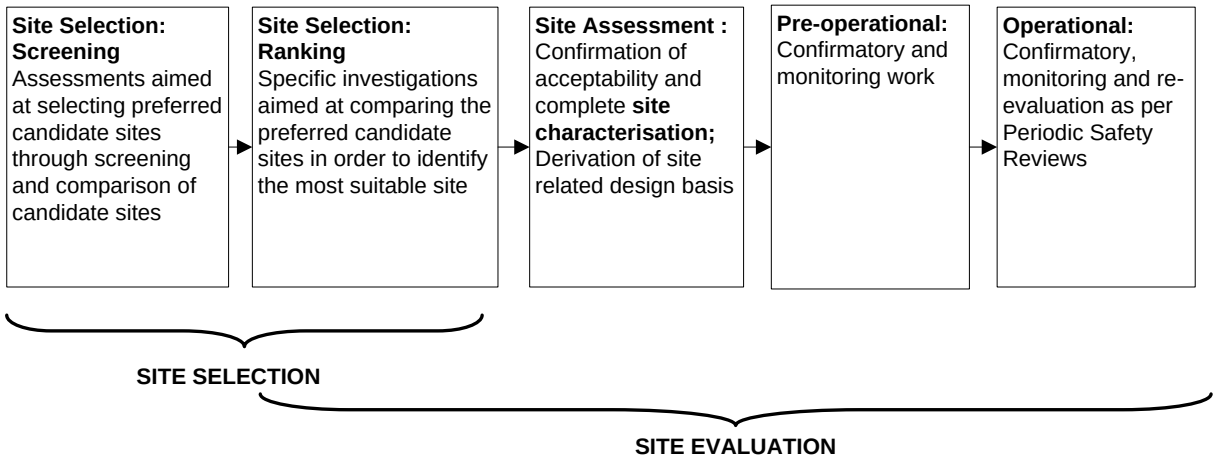

Figure 1: Necsa's Siting Process for New Installations at Pelindaba

The Site Safety Report details all the site characterisation studies. All of these studies have aspects that are common to all facilities at Pelindaba for instance the regional geology is common to all facilities at Pelindaba. In addition, the specific site location within the Pelindaba boundaries may require additional characterisation, for instance soil profiles and other specific geological characteristics that vary over shorter distances. Refer to [4] for further discussion.

Once the site is characterised, conclusions can be drawn regarding, for instance, the external events that are relevant to the site, assessment of the radiological impact of a new facility on the public in the vicinity and the adequacy of the existing emergency plan for an additional facility.

In terms of the radiological impact assessment, the Siting Regulations [1] call for a cumulative radiological impact of all nuclear installations, those already authorised and the proposed new installation. The question then arises: is there a single representative person for the Pelindaba site in order to assess compliance?

3 A Representative Person for a Multi-Facility Site

3.1 Defining groups

Although Necsa has been engaging with the members of the public in the vicinity of Pelindaba regularly for a number of years, the dose assessments associated with the facilities at Pelindaba have used conservative generic habit data. The International Commission on Radiological Protection (ICRP) recommends using site specific data when available. So in preparation for assessments of radiological impact for new facilities, a study of the site data was performed in order to select a representative person.

The region around Pelindaba is zoned for agriculture, conservation and country living. A community survey form is distributed to the people residing around Pelindaba annually. From this database groups of people whose habits are relatively homogeneous and may received doses from the facilities at Pelindaba were identified. The following groups were assessed in this study.

- Resident Group – This group of people reside within the 5 km zone. Some of residents surveyed partake in small scale farming, so a small vegetable garden is included in group scenario. In the Pelindaba survey there are various permutations regarding whether the respondents were present all the time, during the day only, during the night only or only on the weekends. The potential exposure would be higher for people present all the time. Therefore, the resident group is considered to reside and work within the 5 km zone. This group comprises of all age groups.
- Informal Resident Group – This group of people resides and works within the 5 km zone, like the Resident group. However, they are of a lower socioeconomic status. Thereby, the housing type is less formal and the shielding effect related to housing is adjusted appropriately. The primary drinking water source is conservatively considered to be surface water from the river. Thus they are assumed to live along the river bank. A vegetable garden is also included in this group scenario. Additionally, since catching and consuming fish from the river is likely to correspond to a lower socioeconomic status, the potential ingestion dose is considered. This group comprises of all age groups.
- Worker Group – This group considers people who work in the area and are only present during the day. The work is considered to be manual labour outdoors, so the breathing rate is adjusted appropriately. This group only comprises of adults. Their diet does not include locally produced food.
- Farmer Group – The Farmer group is the same as the Resident group, except that their diet is entirely locally produced foodstuffs, excluding drinking water. This is overly conservative, as much of a farmer's diet will be store-brought produce. However, this assumption may be refined in further iterations of this study. This group comprises of all age groups.
- Farm Worker Group – The Farmer Worker group are the labourers living on the farms of the Farmer group. They are considered of a lower socioeconomic status. Thereby, the housing type is less formal and the shielding effect related to housing is adjusted appropriately. Their diet is exclusively local produce, except drinking water, and their consumption rates would correspond to the average South African with a lower socioeconomic status. Since the farm worker is assumed to perform manual labour, the breathing rate is adjusted accordingly. This group comprises of adults.
- Informal Farmer Group – The Informal Farmer group are subsistence farmers who live along the river downstream from Pelindaba. The primary water source for both drinking water and irrigation is from the surface water and that locally produced and grown food is consumed. They are considered of a lower socioeconomic status. Their diet is exclusively local produce, including drinking water and fish from the river, and their consumption rates would correspond to the average South African with a lower socioeconomic status. This group comprises of all age groups.
- Tourist Group – There are a number of visitors to the region for holidays and day trips to participate in the various activities along the river and on the dam. The activities that may lead to doses would be water sports, such as swimming and boating (exposure via the liquid pathway only). This group comprises of adults. There is no ingestion pathway for this group.

The community survey forms provide an indication of the types of local foods consumed but not the consumption rates. The South African Department of Health commissioned a study of food consumption data in South Africa [5]. The average consumption figures for South Africa were used. This data includes two estimates of adult consumption which allows for differences in socio-economic conditions.

The recommended breathing rates from the ICRP [6] were used and shielding parameters were compiled from the IAEA [7], the United Kingdom [8], the United States of America [9] and the South African regulatory guidance [10].

3.2 Important Groups

The concept of the representative person applies to the different exposure situations [11]:

a) normal situations (or planned situations [12]),

b) existing situations, and

c) emergency situations.

This study is a prospective assessment of future exposures from the current facilities including the introduction of a new source. A basic screening model based on the IAEA guidelines [7] was developed for the normal situations and PC-Cosyma was utilised to study potential emergency situations (no countermeasures were considered). The accident scenario is an atmospheric release, so the Tourist group is not exposed. In both models, average weather conditions for the Pelindaba site were used. For this study only adults were investigated, other age groups are important and will be addressed in future studies.

Pelindaba houses many different facilities for uranium processing, isotope production and the research reactor. Most of them do not discharge significant quantities of radioactive material into the environment. Only two discharge pathways from Pelindaba are significant: atmospheric releases and discharges to the Crocodile River via the liquid effluent management systems. The two pathways are reported separately in Necsa's environmental monitoring reports. So they will be discussed separately here.

A set of nuclides were chosen that are representative of the typical releases from the different facilities. Doses were calculated from unit releases to provide an indication of representative person and whether that representative person is in fact representative for any facility on the Pelindaba site. This creates a tool for a new facility to assess which group will be most affected based on the composition of the facility's source term.

The groups are ranked based on the dose calculated. Table 1 and Table 2 show the ranking per nuclide for normal situations discharges. Table 3 and Table 4 provide the ranking per nuclide for emergency situations.

Table 1: Group Ranking based on Normal Situations Atmospheric Discharges

	Sr-90	**U-235**	**Pu-239**	**I-131**	**Cs-137**	**Xe-135**
1	Farmer	Farm Worker	Farm Worker	Farmer	Farm Worker	Farm Worker
2	Farm Worker	Informal Farmer	Informal Farmer	Farm Worker	Informal Farmer	Informal Resident
3	Informal Farmer	Farmer	Farmer	Informal Farmer	Farmer	Informal Farmer
4	Resident	Informal Resident	Informal Resident	Resident	Informal Resident	Resident
5	Informal Resident	Resident	Resident	Informal Resident	Resident	Farmer
6	Worker	Worker	Worker	Worker	Worker	Worker

Table 2: Group Ranking base on Normal Situations Liquid Discharges

	Sr-90	**U-235**	**Pu-239**	**I-131**	**Cs-137**
1	Informal Farmer	Informal Farmer	Informal Farmer	Informal Farmer	Informal Farmer
2	Informal Resident	Informal Resident	Informal Resident	Informal Resident	Informal Resident

3	Tourist	Tourist	Tourist	Tourist	Tourist

Table 3: Group Ranking based on Accident Releases: Short Term (7 day integration time)

	Sr-90	**U-235**	**Pu-239**	**I-131**	**Cs-137**	**Xe-135**
1	Resident	Resident	Resident	Resident	Resident	Farm Worker
2	Farm Worker	Farm Worker	Farm Worker	Farm Worker	Farm Worker	Resident
3	Farmer	Farmer	Farmer	Worker	Worker	Informal Resident
4	Worker	Worker	Worker	Farmer	Farmer	Informal Farmer
5	Informal Resident	Informal Resident	Informal Resident	Informal Resident	Informal Resident	Farmer
6	Informal Farmer	Informal Farmer	Informal Farmer	Informal Farmer	Informal Farmer	Worker

Table 4: Group Ranking based on Accident Releases: Long Term (50 year)

	Sr-90	**U-235**	**Pu-239**	**I-131**	**Cs-137**	**Xe-135**
1	Farmer	Resident	Resident	Farmer	Farm Worker	Farm Worker
2	Farm Worker	Farm Worker	Farm Worker	Farm Worker	Farmer	Resident
3	Informal Farmer	Farmer	Farmer	Informal Farmer	Informal Farmer	Informal Resident
4	Resident	Worker	Worker	Resident	Resident	Informal Farmer
5	Informal Resident	Informal Resident	Informal Farmer	Informal Resident	Worker	Farmer
6	Worker	Informal Farmer	Informal Resident	Worker	Informal Resident	Worker

The ranking of the groups for normal situations atmospheric pathway (Table 1) is dominated by the role that ingestion pathway plays, refer to Table 5; except in the case of Xe-135 which is purely based on the shielding factors. Secondary effects are seen for nuclides U-235, Cs-137 and Sr-90, where the groundshine dose becomes significant, prioritising those groups where more time is spent outdoors and the housing provides less shielding i.e. the Farm Worker and Informal Farmer. The inhalation pathway for Pu-239 increases the rank of groups with higher breathing rates i.e. the Farm Worker.

Table 5: Consumption of locally produced foodstuffs

Group	**Fraction of fresh food locally produced**
Farmer	1
Farm Worker	1
Informal Farmer	1
Resident	0.1
Informal Resident	0.1
Worker	0
Tourist	0

Similarly for the liquid pathway (Table 2), the ingestion dose is the most significant followed by the time exposed. Only those groups that have non-zero doses are reported.

In terms of accident releases, the short term results (Table 3) are clearly linked to the distance to the representative person and the time exposed (see Table 6). The distances are measured from the Emergency Control Centre (ECC) at the centre of the Pelindaba site. The results are roughly independent of the nuclide considered except for the noble gas (which is again dominated by the shielding factors). The Resident group is the nearest to the ECC of all the groups that are present in the area for 100% of the time, then the Farmer and the Farm Worker. The Farm Worker's housing provides less shielding than the Farmer. Although the Worker group spends only 23% of the time in the area, because it is the nearest of all the groups, it is an important group to consider for short term effects.

The dominant short term dose pathways follow the same trend across the different groups. For Sr-90, U-235 and Pu-239 almost 100% of the dose is inhalation dose. For Xe-135 the whole dose is cloudshine. For I-131 the dose is roughly evenly distributed between groundshine and inhalation. For Cs-137, approximately a third of the dose is from groundshine with most of the remainder inhalation dose.

Table 6: Groups' Distance from the ECC and Time in the Vicinity

Group	Distance to ECC [km]	Fraction of time in vicinity
Worker	1.85	0.23
Tourist	1.98	0.034
Resident	2.06	1
Farmer	2.61	1
Farm Worker	2.61	1
Informal Resident	3.1	1
Informal Farmer	3.1	1

The long term results (Table 4) are more dependent on the nuclide considered, particularly with respect to the ingestion pathway. Those groups where their total fresh food consumption is local are most significant for nuclides I-131, Sr-90 and Cs-137 (see Table 5).

For U-235 and Pu-239 the dominant pathway is inhalation so the ranking is practically the same as the short term effective dose, i.e. the dose is mostly dependent on distance and time exposed. Similarly, since cloudshine is the only pathway associated with noble gases, the ranking of groups for Xe-135 is the same for the long and short term effective doses.

3.3 Cumulative Assessment

Although it is useful to be able to predict the representative person for a new facility as described above, a new facility needs to be integrated onto an existing site. Thus the representative person for the current facilities on site is assessed.

The model used above measures the distance from the ECC. The ECC is in the centre of the Pelindaba site. The site stretches almost 4 km across, and some of the facilities are up to 2 km from the ECC. The offset of the facilities from the ECC was considered such that the distances from each facility to the group position were used in the dose analysis. Table 7 provides the ranking of the groups for the atmospheric normal situations discharges. Each facility was addressed in turn and the doses summed together to determine the representative person for the site as a whole (refer to the last column in Table 7).

Table 7: Group Ranking of the Existing Facilities and the Site as a Whole for Normal Situations (Atmospheric Discharges)

	Safari-1	**Isotope Production**	**U Facilities (West)**	**U Facilities (East)**	**Whole Site**
1	Farmer	Farmer	Farm Worker	Resident	Farmer
2	Farm Worker	Farm Worker	Farmer	Farm Worker	Farm Worker
3	Informal Farmer	Informal Farmer	Informal Farmer	Informal Farmer	Informal Farmer
4	Resident	Resident	Informal Resident	Informal Resident	Resident
5	Informal Resident	Informal Resident	Resident	Farmer	Informal Resident
6	Worker	Worker	Worker	Worker	Worker

The trend seen in the single nuclide cases is repeated here. Ingestion plays an important role in the selection of the representative individual for the site. It is interesting to note that the Resident group becomes more significant for the U Facilities on the East side of the Pelindaba site. This is directly related to the proximity of the group to the facilities, since the dominant dose pathways in this case are inhalation and groundshine.

An accidental release is usually from one facility at a time, so the groups are ranked for the existing facilities and not the site as a whole, refer to Table 8 and Table 9. A common cause event is still to be investigated.

Table 8: Group Rankings of Existing Facilities for Accident Scenarios: Short Term Dose (7 days)

	Safari-1	**Isotope Production**	**U Facilities (West)**	**U Facilities (East)**
1	Worker	Farm Worker	Farm Worker	Farm Worker
2	Informal Farmer	Informal Resident	Informal Resident	Informal Resident
3	Farm Worker	Informal Farmer	Informal Farmer	Informal Farmer
4	Resident	Resident	Resident	Resident
5	Farmer	Farmer	Farmer	Farmer
6	Informal Resident	Worker	Worker	Worker

Table 9: Group Rankings of Existing Facilities for Accident Scenarios: Long Term Dose (50 years)

	Safari-1	**Isotope Production**	**U Facilities (West)**	**U Facilities (East)**
1	Informal Farmer	Farmer	Farm Worker	Farm Worker
2	Worker	Farm Worker	Informal Resident	Informal Resident
3	Informal Resident	Informal Farmer	Informal Farmer	Informal Farmer
4	Farmer	Informal Resident	Resident	Resident
5	Farm Worker	Resident	Farmer	Farmer
6	Resident	Worker	Worker	Worker

It is notable that the ranking seen for the single nuclide is not consistent with the ranking for the existing facilities. This indicates that measuring the distance to the receptor from the actual source is more important for the accident scenario than normal situations. This is apparent from the difference seen in the U Facilities (West) and U Facilities (East), where the source is predominantly U, compared to the U-235 unit release ranking in Table 4. This is also seen from the ranking of the Worker group for Safari-1 as the Worker is the closest group to the source, despite the fact that the Worker group spends only a fraction of the time in the region.

4 Concluding Remarks

Siting a new nuclear installation on an existing multi-facility site is largely beneficial. The bulk of the data required to characterise a site for a new installation exists already. However, the South African siting regulations call for a cumulative radiological impact assessment. Thus it is important to study the effect of a new installation on the public dose and this entails a good understanding of the representative person used to demonstrate compliance to the regulatory criteria.

Different groups were identified from amongst the public surveyed around the Pelindaba region. A dose analysis was performed to identify the representative person for the site and a tool developed for anticipating how a new facility may affect the selection. It was shown that the most significant characteristics for the groups are the proximity to the source and the consumption of local foodstuffs. Currently, for normal operation the representative person would be characterised as a Farmer. The representative person for accident scenarios is facility specific. Additionally, it is clear that the representative person for normal situations is not necessarily the same as the representative person for accident scenarios.

The annual survey performed by Necsa is a crucial tool to obtain habit data of the population around Pelindaba. This valuable engagement with the public assists not only in public understanding and acceptance of nuclear technology but also in the assessment and protection of public health.

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