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Critical group identification via a radiological habit study of members of the public potentially exposed to radiation from the Koeberg Nuclear Power Station

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Framework document

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Radiological Habits Survey: Pathways and sources near Koeberg Nuclear Power Station

Revision 2

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ANNEX A : QUESTIONNAIRE

1. INTRODUCTION

A radiological habits survey is proposed to identify the consumption and consumption rates of local terrestrial and aquatic foods in the survey area. The results of this site-specific programme may be applied by Industry and Regulator(s) for prospective and retrospective improvements to:

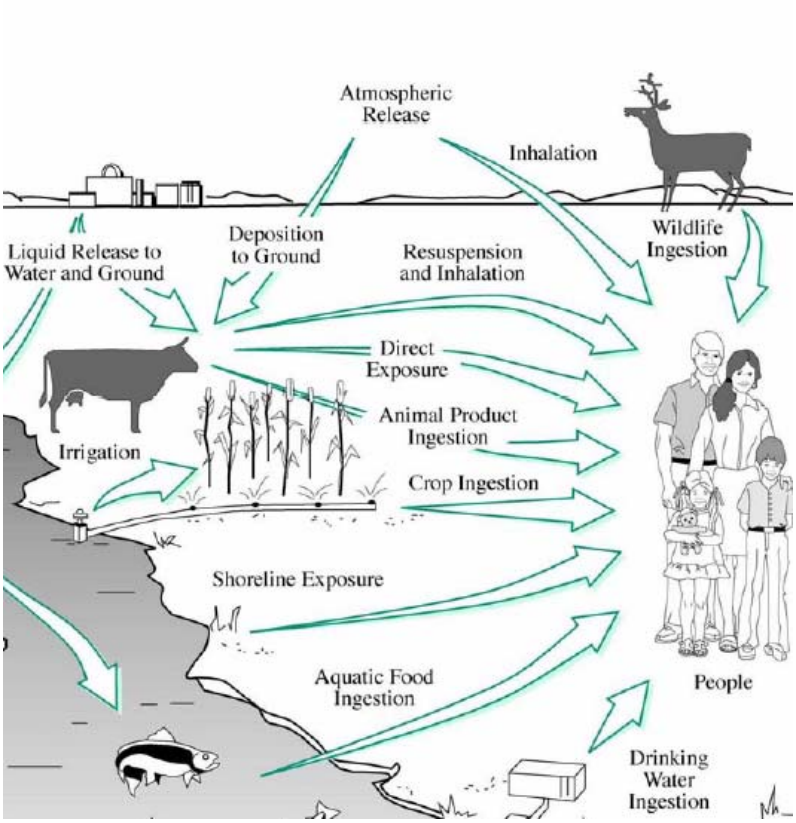
- Assumptions and methodologies applied in public dose assessments;
- The environmental monitoring programmes relating to the Koeberg site;
- The effluent management programmes relating to the Koeberg site;
- Emergency preparedness and response plans relating to the Koeberg site;
- The identification of changes to the critical group;

Members of the public may potentially be exposed to radiation from practices at Koeberg Nuclear Power Station because of their location or eating and recreational habits. They may be exposed directly or indirectly from discharges of liquid or gaseous radioactive wastes into the local environment, or from radiation emanating directly from the site. In order to assess such exposures, information on the eating and recreational habits of individuals living in the survey area is required. Figure 1 depicts some of the primary potential radiation exposure pathways and sources to the public namely:

- Direct plume exposure from inhalation and external exposure due to gaseous releases;
- Gamma exposure due to deposition of gaseous releases;
- Resuspension and inhalation of deposition from gaseous releases;
- Movement through groundwater and seawater;
- Ingestion of contaminated food from contaminated soils, plants and live stock;
- Consumption of locally sourced aquatic and terrestrial foods;
- Occupancy of inter-tidal areas and in/on marine water;
- Handling fishing gear and sediment;
- Consumption and/or use of seaweed and groundwater; and
- Occupancy of buildings and the surrounding areas relating to direct radiation.

Figure 1

Potential radiological exposure pathways to the public

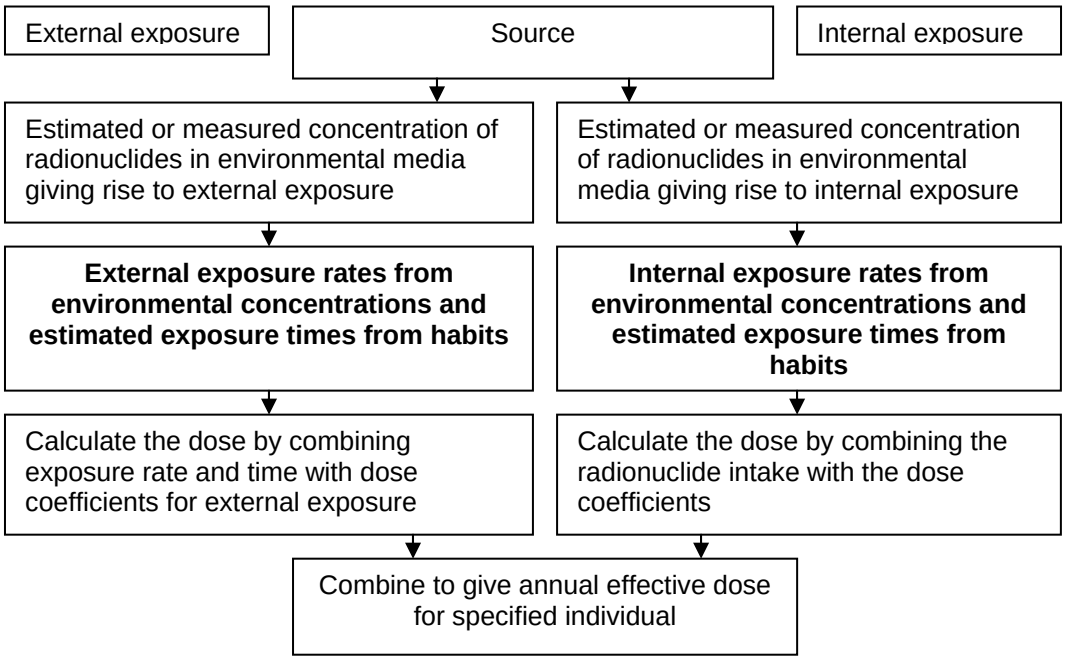


2. OBJECTIVES

The initial radiological habits survey [1] was performed around Koeberg Nuclear Power Station in 1988, by the Atomic Energy Corporation of South Africa, Ltd. The survey was site specific, and took into account groups residing in Melkbosstrand, Blaauwbergstrand, Mamre and Atlantis. Since then the land-use and demographics in the survey area have changed. A new radiological habits survey is required in the vicinity of Koeberg Nuclear Power Station in order to obtain relatively realistic site specific radiological habits survey data for prospective and retrospective application in the public dose assessment process as depicted in Figure 2.

Figure 2

The public dose assessment process



The objectives of the radiological habits survey are to:

- identify the agricultural production in the survey area;
- identify the land-use in the survey area;
- identify potential public exposure pathways due to the agricultural production and land-use;
- develop a questionnaire to obtain information on eating and drinking habits and recreational activities of the local population, including transient population present in the study area;
- obtain regulatory approval for the radiological habits survey;
- obtain integrated habits survey data related to the aquatic, terrestrial and direct radiation pathways; and
- consolidate and report the habits survey data.

3. METHODOLOGY

3.1 Overview

The radiological habits survey will be subdivided into three phases: planning, fieldwork and reporting.

During planning phase a preliminary desk study of the vicinity of the Koeberg Nuclear Power Station will be undertaken. Maps and information from the Koeberg Site Safety Analysis Report will suggest the locations and centres of population and topography relevant to particular activities. The results of previous environmental monitoring will be considered and the results of the original radiological habits survey [1] will be considered. Locally produced food and potential critical groups will identified. A questionnaire will be developed to help field workers with interviews during the fieldwork phase.

During the fieldwork phase approximately 40 senior students from a local university will be trained to perform interviews and collate information on consumption rates of locally produced foods, the typical number of meals per week, the size of the portions and methods of preparation. Similar information will be requested for other members of the household noting their age and sex. Information as to whether a fish is filleted or eaten on the bone and which parts are discarded, for example skin will be noted. Habits giving rise to external exposure will be investigated especially the time spent outdoors and over intertidal areas. Where possible, during interviews, questions will be phrased so as to avoid common sources of error. One such source is the tendency of the interviewee to bias the answers on the prevailing situation and further enquiry is needed to relate this to a yearly pattern.

During the reporting phase the raw survey data will be summarized in tables and the conversion of standardized units such as gram per day of edible portions for consumption of foods and hour per year for occupancy will be applied. The data will be verified and classified into different food categories described in [2]. The critical group selection procedures will be applied in accordance with methodologies addressed in [3].

Reports will be generated during the planning, fieldwork and reporting phases.

3.2 The radiological habits survey reporting requirements

The following reports will be developed during the planning, fieldwork and reporting phases:

- A Framework Document RP 5.294 which outlines the framework for the radiological habits survey will be compiled and send to the National Nuclear Regulator for review during the planning phase;

- A Report RP 5.295 which contains information identified during the preliminary desk study to identify the locations, centres of population, topography relevant to particular activities, locally produced foods for local consumption, potential critical group(s) and potential questions for interviewees will be compiled and send to the National Nuclear Regulator for review during the planning phase;

- A Questionnaire RP 5.296 to help interviewees to obtain relevant information relating to the radiological survey will be compiled and send to the National Nuclear Regulator for review during the planning phase;

- All original questionnaires will be consolidated in Report RP 5.297 during the fieldwork phase; and

- The final radiological habits survey report RP 5.298 will be compiled and the results will be presented to the NNR during the reporting phase.

The scope of the radiological habits survey process and reporting is limited to the planning, fieldwork and above reports. The critical group(s) will be identified from data collected during the fieldwork in accordance with methodologies discussed in [2]. The dose assessment aspects and application of the radiological habits survey data in practice are excluded from the scope of the radiological habits survey.

The requirements listed below will be addressed in the final radiological habits survey report RP 5.298.

3.2.1. Regulatory requirements

The radiological habits survey will be performed in accordance with the relevant South African statutory requirements prescribed in legislation. The relevant statutes and regulations will be identified and addressed in the report.

3.2.2. Radiological protection framework

The radiological habits survey will be implemented and performed in accordance with this Framework Document and relevant radiation protection requirements prescribed by the National Nuclear Regulator and Directorate: Radiation Control, Department of Health.

3.2.3. The radiological habits survey

A short introduction will be presented on the radiological habits survey for the Koeberg Nuclear Power Station site which relates to the site activity, survey area and survey methodology.

3.2.3.1 The site activity

The waste pathways and types of wastes (solid, liquid and gaseous waste) generated on the Koeberg site will be addressed. This will include likely arisings from the proposed PBMR nuclear plant. Brief extracts from the Koeberg Site Safety Report [4] will be presented.

3.2.3.2 The radiological habits survey area

The radiological habits survey area will be divided into three areas for survey purposes to address the dominant activities expected for the aquatic (sea) environment, terrestrial (land) environment and external exposure (direct radiation or non-food) pathways.

The evaluation of different survey methodologies, the advantages, disadvantages and application of results addressed in [5] were used to determine the survey area. The choice of the survey area is a management decision taking into account cost and the likely extent of the radiological effects of the site.

The aquatic surveys will be performed in the same marine areas and coastal zones addressed in [1], from Eerstesteen to Bokpunt. The marine area will be subdivided into 6 coastal zones, defined on maps and the surveys in these zones will target people fishing within the area or consuming fish from it, and people undertaking water-based activities (e.g. windsurfing, diving) In addition, inter-tidal activities such as angling, bait digging, shellfish collection or beach related activities will be identified. Retail and wholesale outlets trading in sea foods obtained from the survey area are also covered.

Complete terrestrial surveys will be performed within a 5 km radius around Koeberg Nuclear Power Station site and additional surveys will be performed at two controlled sites approximately 40 km from Koeberg Nuclear Power Station and at the locations defined in [1] i.e. Melkbosstrand, Atlantis, Tableview, Mamre and Blaauwbergstrand. The terrestrial survey strategy is based on the original survey addressed in [1] and the scope of radiological habits surveys performed by the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) for UK nuclear utilities and facilities and discussed in [5].

The advantages of this type of survey are:

- Habit data for highly exposed individuals are likely to be obtained;
- A clear definition of the limits of the survey is possible for atmospheric and direct-shine pathways;
- A link to consumption rates for local foods should be obtained;
- This survey is less expensive than a full population survey;
- The extent and cost is in proportion to the risk/dose;
- The focus is on populations around Koeberg Nuclear Power Station are likely to identify sub-populations who are subjected to the highest exposures; and
- The results of the survey may be compared and benchmarked against the results in [1].

Direct radiation surveys are currently performed monthly and quarterly at various distances up to 45 km from Koeberg Nuclear Power Station. The direct radiation surveys are performed in residential areas, at leisure areas and business areas not directly related to the operation of the nuclear site.

The survey methodology and fieldwork

In the past aquatic pathways surveys were separate from terrestrial surveys. The recent trend in the main programme of surveys has been towards providing data for integrated assessments across all relevant pathways. Current surveys around nuclear establishments are based on 3 defined areas in their vicinity which reflect where liquid and gaseous discharges and direct radiation, respectively, may be considered to influence radiation exposure.

During the planning phase information from the previous survey, the weather data, demographics and environmental monitoring reports relating to the survey area will

be reviewed in order to identify the land-use and possible areas where the habits surveys must be performed. Information will be obtained from local and national bodies and from the Koeberg Site Safety Report [4]. The information obtained from this review will be used to define the scope, design the survey and compile a questionnaire for application during fieldwork.

The fieldwork component of the survey will be carried out by at least 40 trained university students, 3 supervisors and an Administrator. The survey will be performed over a two week period. The students will perform the habits survey in accordance with the relevant questionnaire in the identified areas. The primary objectives are to cover all possible pathways and obtain information from people of different age groups in accordance with the questionnaires. The survey will exclude workers on site at Koeberg as the concern is only with exposure of members of the public. However, the eating and recreational habits of workers when not at work may be included in the survey, as they are then considered members of the public. In undertaking the surveys, attention is concentrated on those who are likely to be most exposed from the site under consideration and the surveys can be considered to be 'targeted'. The focus will be on the sub-populations around Koeberg that are likely to be subject to the highest exposures. However, as this identification is necessarily subjective, it should be presented explicitly, so that it can be readily scrutinised by interested parties. Account will be taken of seasonal variations in consumption rates and occupancy factors in deriving data from the survey for use in assessment calculations. In terms of food consumption data, the surveys are directed to determining the consumption of locally produced or sourced food. Thus, individuals are asked whether the produce they eat is local, farm or home-produced, or locally caught i.e. fish, shellfish or game.

Although the surveys are carried out in these 3 separately-defined areas, each interviewee is asked about all eating and recreational habits, whether aquatic, terrestrial or related to direct exposure. The area in the survey area will be divided into three areas for survey purposes to address the dominant activities expected for the aquatic (sea) environment, terrestrial (land) environment and external exposure (direct radiation or non-food) pathways.

3.2.3.4 The quality assurance programme

The radiological habits survey will be subjected to the Eskom Quality Assurance Programme. Eskom representatives will participate in the survey to perform quality

assurance checks during the habits survey, on the survey results, on the data management aspects and reporting. The Administrator and 3 Supervisors participating in the survey will be implementing a quality control function as required.

3.2.4 Methods of data analysis

Information obtained during surveys will be processed to obtain, wherever practicable, quantitative information that can be used to assess doses. Data will be processed into annual rates (i.e. consumption in kg/y, occupancy in h/y) by the use of established conversion factors, edible fractions, etc, and categorised into age and pathway groups.

The age groups are from 0 to 1 year of age (called 3 months); more than 1 year to 2 year (called 1 year old); more than 2 year to 7 year (called 5 year old); more than 7 year to 12 year (called 10 year old); more than 12 year to 17 year (called 15 year old); more than 17 years (called adults).

Data will include consumption of aquatic foods (fish, crustaceans, molluscs, marine plants and wildfowl) and terrestrial foods (milk, green vegetables, root vegetables, other vegetables, potatoes, domestic fruit, cattle meat, pig meat, sheep meat, poultry, eggs, wild/free foods, honey, fungi, rabbits/hare and venison). Freshwater aquatic foods in the terrestrial survey area will also be included.

External exposure pathways cover occupancies and handling. Inter-tidal occupancies will be grouped according to sediment type (i.e. sand) and handling is grouped into sediment and fishing gear. Occupancies in water and on water will be grouped separately, as are occupancies indoors and outdoors that are relevant to direct radiation.

The information will be considered during the assessment stage and indicative calculations will be used to make preliminary assessments. Quantitatively defined data will be presented as annual rates in report tables.

3.2.4.1 Data recording

The data collected during the field work will be recorded in logbooks. The raw data will be entered into a habits survey database where each individual for whom information will be obtained will receive a unique identifier (the observation number) to assist in maintaining data quality.

3.2.4.2 Data analysis

The data will be analysed using a consistent set of conversion factors. The data will be stored in a database in order to minimise transcription and other errors. Draft reports and data tables will formally be reviewed by an experienced person in radiological protection.

Two methods may be applied for data analysis. The first one analyses all the data for a given age and pathway group to give the 97.5th percentile rate. The second method averages all the values from the highest observation down to one third of the highest. This approach is called the 'cut-off' method and is related to the homogeneity criterion of ICRP.

The habits survey data will be analysed to give rates of consumption typical for those people most exposed by analyzing all the data for a given age and pathway group to give the 97.5th percentile rate. All data will be rounded off to 1 decimal point. Figures less than 0.05 will be rounded off to 2 significant digits. External exposure data will be quoted as integers.

3.2.4.3 Determination of the critical group

The concept of the critical group was developed by the ICRP during the 1960's. In ICRP Publication 9 [6] it was recommended that: "in practice, it is feasible to take account of these [age, size, metabolism and customs] sources of variability by the selection of appropriate critical groups within the population, provided the critical group is small enough to be homogeneous with respect to age, diet and those aspects of behavior that affect the doses received. Such a group should be representative of those individuals in the population expected to receive the highest dose…" The concept was introduced by ICRP in order to take account of the variation in dose which may arise due to differences in age, size, metabolism, habits and environment.

In ICRP Publication 26 [7] the statement was somewhat modified: "With exposure of members of the public it is usually feasible to take account of these sources of variability by the selection of appropriate critical groups within the population provided the critical group is small enough to be relatively homogeneous with respect to age, diet and those aspects of behavior that affect the doses received. Such a group should be representative of those individuals in the population expected to receive the highest dose equivalent.

The concept is developed further in ICRP Publication 43 [8] which addresses, among other things, the homogeneity criteria that should be used in choosing a critical group. The Commission suggests that if the ratio of the mean critical group dose to the appropriate limits is “less than about one tenth, a critical group should be regarded as homogeneous if the distribution of individual dose equivalents lies substantially within a total range of a factor of ten, i.e., a factor of about three either side of the mean. At higher fractions, the total range should be less, preferably no more than a factor of three”. Therefore, it is accepted that some individuals in the critical group will receive doses somewhat higher than the mean dose.

ICRP Publication 60 [9] does not provide any further modification to the critical group definition but does comment that the dose constraint should be applied to the mean dose in the critical group from the source for which the protection is being optimized.

The ICRP definitions addressed in Publication 26 [7] and Publication 43 [8] relating to the critical group will be applied for the identification of representative individuals defined as being reasonably homogeneous with respect to age, diet, and recreational activities. This will be achieved via statistical methodologies applied in [1] and [3] to determine the critical group. The cut-off based on homogeneity method and the top-thirty method will be applied for establishing the critical group from the survey data collected. The ratio between the maximum and minimum consumption will be set not to exceed a value determined by a trend in the log plot of the number of consumers exceeding a stated consumption rate versus the consumption rate.

The consumption data will be tabulated to show the number of observations in each 50g per week interval over the full consumption rate range of locally produced foods for different age groups. The average and peak consumption rates will be determined for the critical group.

Other statistical and arbitrary methods described by Hunt [3] may also be applied to the survey data to determine the critical group.

3.2.5 The aquatic radiation pathways

The aquatic radiation pathways relates to the aquatic survey area, commercial fishing, angling and hobby fishing, wholesalers and retailers within the survey area.

3.2.5.1 Aquatic survey area

The aquatic survey will cover the coastline and intertidal areas addressed in [1] between Eerstesteen and Bokpunt. The same coastal zones identified in [1] will be demarcated on survey maps.

3.2.5.2 Commercial fisheries

Information on pelagic fisheries (near-surface), demersal fisheries and inshore fisheries in the survey area will be covered in the report.

3.2.5.3 Angling and hobby fishing

Information on recreational angling within the survey area will be covered in the report.

3.2.5.4 Wholesalers and retailers

Information on fish processing establishments in the survey area will be covered in the report.

3.2.5.5 Other pathways

The collection and harvesting of seaweed as fertilizer will be covered in the report.

3.2.6 Internal exposure

The internal exposure will be assessed from the consumption of aquatic foods and consumption rates derived for adults, children and infants.

3.2.6.1 Adult consumption rates

Adults older than 17 years consuming the greatest quantities of different foods and seafood will be identified. The predominant species of fish, crustaceans and molluscs consumed will be covered in the report.

3.2.6.2 Children consumption rates

The consumption rates for children in the age group 2 year to 7 year (called 5 year old); 7 year to 12 year (called 10 year old); more than 12 year to 17 year (called 15

year old) consuming the greatest quantities of different foods and seafood will be covered in the report.

3.2.7 External exposure

The external exposure will be determined by intertidal occupancy on rock and sand will be covered in the report.

3.2.7.1 Handling

The handling of sediment during bait digging and mollusc's collection and handling of angling gear will be covered in the report.

3.2.7.2 Gamma dose rate measurement

Ambient gamma and beta radiation dose rate measurements (1 meter from the ground) will be performed in areas where high occupancy rates are observed.

3.2.8 Water based activities

Activities based in and on water may result in ingestion of water and/or inhalation of spray. Occupancy rates for activities in water and on water will be covered in the report.

3.2.8.1 Activities in water

Activities in water within the survey area i.e. diving and swimming will be covered in the report.

3.2.8.2 Activities on water

Activities on water within the survey area i.e. commercial fishing, hobby fishing, sailing and canoeing will be covered in the report.

3.2.9 Terrestrial survey area

The terrestrial survey area will cover all land and watercourses identified in the survey area. The farming and agricultural activities will be covered in the report.

3.2.9.1 Wholesalers and retailers

Farm-stalls in the survey area will be visited and the local produce and home-made food products on sale to the local population will be covered in the report.

3.2.9.2 Internal exposure

The internal exposure will be assessed from the consumption of terrestrial foods potentially affected by gaseous discharges and consumption rates derived for adults, children and infants.

3.2.9.3 Adult consumption rates

Adults older than 17 years consuming the greatest quantities of different foods i.e. green vegetables, other vegetables, root vegetables, potato, domestic fruit, milk, cattle meat, pig meat, sheep meat, poultry, eggs, wild/free foods, rabbits/hares, honey, wild fungi and freshwater fish will be covered in the report.

3.2.9.4 Children consumption rates

The consumption rates for children in the age group 2 year to 7 year (called 5 year old); 7 year to 12 year (called 10 year old); more than 12 year to 17 year (called 15 year old) consuming the greatest quantities of different foods i.e. green vegetables, other vegetables, root vegetables, potato, domestic fruit, milk, cattle meat, pig meat, sheep meat, poultry, eggs, wild/free foods, rabbits/hares, honey, wild fungi and freshwater fish will be covered in the report.

3.2.10 Direct radiation pathways

Activities in the survey area which may result in direct radiation exposure will be covered in the report.

3.2.10.1 Direct radiation survey area

The ambient integrated dose measured in the survey area using thermoluminescent dose meters will be covered in the report. The occupancy factors relating to recreational activities i.e. hiking and angling will be covered in the report.

3.2.10.2 Residential activities

Residential activities which may lead to direct radiation exposure will be covered in the report.

3.2.10.3 Leisure activities

Leisure outdoor activities i.e. visits to the Koeberg Visitors Center which may lead to direct radiation exposure will be covered in the report.

3.2.10.4 Commercial activities

Commercial activities i.e. farming and which may lead to direct radiation exposure will be covered in the report.

3.2.10.5 Occupancy rates

Information on indoor occupancy, outdoor occupancy and total occupancy for adults and children within the survey area will be covered in the report.

3.2.11 Combined pathways

In determining habits survey data for the purposes of assessing radiological doses to the public, it may be necessary to consider a combination of pathways. Data will be provided so that the full effect of combining pathways can be assessed for individuals.

3.2.12 Conclusions and suggestions

The findings of the survey will be presented and will be compared with the results of the previous survey. Suggestions will be made for application i.e. environmental monitoring.

4. RESPONSIBILITIES

It is the responsibility of Eskom to perform the radiological habits survey and to carry out the analyses and to produce a final report for submission to the NNR and subsequent approval before application in the public dose assessment and possible inclusion into the Koeberg Safety Analysis Report.

5. QUESTIONNAIRE

The questionnaire listed in Annex A to this document will be used for collection of data:

6. PROJECT SCHEDULE

The following project schedule is proposed:

Project item	Date
Compilation, review and formal submission of Framework Document to NNR.	August 2006
Review information from the previous survey, the weather data, demographics and environmental monitoring reports. Identify the land-use and possible areas where the habits surveys must be performed. Obtain relevant information to the survey from sources and define the scope, design the survey and compile a questionnaire for application during fieldwork.	September 2006
Compile a report and questionnaire on the scope of the habits survey and submit to the NNR for approval.	September 2006
Obtain approval from the NNR to use the questionnaire and perform the radiological habits survey	April 2007
Identify and provide training to university students to perform the radiological habits survey.	May 2007
Perform the field work relating to the radiological habits survey	June 2007
Compile a draft survey report for review. Consolidate review comments and finalise the radiological habits survey report.	August 2007
Present the radiological habits survey results to the NNR as required.	September 2007
Submit final radiological habits survey report RP 5. 298 to the NNR	November 2007

7. REFERENCES

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