1. Executive Summary

1.1 This report was commissioned by Earthlife Africa, Cape Town Branch, in response to their receiving a set of Annual Reports from 1983 to the Second Quarter of 2003, produced by the Environmental Survey Laboratory (ESL), Koeberg Nuclear Power Station (KNPS), as well as a similar batch of loose-leaf photostats from 1984 onwards, tabling the gaseous and liquid effluents from KNPS.

1.2 The first section of this report starts with an apology for the method used in compiling its contents, immediately followed by a short summary of the public health arguments for and against the civilian use of nuclear power stations. It then goes on to discuss the basics of nuclear physics, nuclear chemistry, nuclear engineering, and radiobiology, with particular reference to the long-lived radioactive waste products: Strontium-90, Iodine-131, and Cesium-137, These are of particular concern to environmental activists and public health authorities alike, since they are well-known carcinogens. This section concludes with a short refutation of the argument that higher levels of Strontium-90 and Cesium-137 in the vicinity of KNPS are attributable to above-ground nuclear weapons testing in the 1960s and 1970s.

1.3 The next section examines the data contained in the reports themselves and attempts to show how the criteria for reporting changed dramatically over the last two decades. In the 1980s the internal reports focused extensively on beta activity in air and foodstuffs, but still denied any connection between the appearance of radio-activity from ambient Strontium-90, Iodine-131, and Cesium-137 to actual emissions from KNPS, even while demonstrating extensive emissions by operational gaseous and liquid releases.

1.4 We will then show how these same emissions and appearances outside the confines of the nuclear reactor building complex were systematically under-reported, or obfuscated through a repeated and undifferentiated appeal to external causes. Having earlier dismissed the above-ground nuclear weapons testing theory, we focus on the spurious argument in favour of radio-therapy among local Melkbosstrand residents. Finally, we show how the actual, regular and deliberate release of carcinogenic, long-lived radioactive isotopes was further drowned by an overwhelming flood of irrelevant and meticulously argued data of no consequence.

1.5 We will further show that the authorities saw fit to manipulate the data by substantially increasing the levels of Annual Authorised Discharge Quantities (AADQs), and by averaging the discharges over twelve-month periods - even though the bulk of emissions took place in the last quarter of the year. In some cases, where the actual threats appear to become increasingly alarming, the authorities simply stopped reporting on the problem altogether -- at least in the public domain.

1.6 This must be understood in the context of increasing mobilisation among anti-nuclear structures and the perceived threat of local and national challenges to the hegemonic rule of Eskom, and other organs of State, in support of the current regime's new and aggressive nuclear energy policy. Thus a cursory examination of the Annual Reports of Eskom, the Department of Mineral & Energy (DME), and the National Nuclear Regulator (NNR) will show a similar paucity of relevant and pertinent detail on the emissions of the long-lived radio-isotopes to Strontium-90, Iodine-131, and Cesium-137 from KNPS.

1.7 Apart from the obvious problems relating to solid waste and the yet greater unsolved problem of spent fuel storage (with its related problems of nuclear weapons diversion), the extraction and tabulation of various readings that do penetrate the murk will show that there has been a consistent pattern of rising emissions from Koeberg Nuclear Power Station, through routine and officially sanctioned releases in the last quarter of the year, every year since inception.

1.8 In a nutshell, the cold and calculated addition of ANY amount of the long-lived isotopes Strontium-90 (28.1 years half-life) and Cesium-137 (30 years half-life) means that, effectively, these radio-toxic and carcinogenic substances will remain in the South-Western Cape for over 200 years from the date of their release. In terms of Section 26 of the Constitution this is morally and politically unacceptable.

1.9 The last section of this report will deal with recommendations and suggestions for further research as follows:

(a) a more thorough interrogation of the levels of Iodine-131, Strontium-90 and Cesium-137 released by KNPS over the last twenty years by closer scrutiny of documents still held by Eskom, NECSA and the NNR in terms of the National Nuclear Regulator Act No. 47 of 1999, section 40 (a)-(d) [attached as Appendix I of this report];

(b) a thoroughgoing examination of all records pertaining to airborne, liquid- and solid-medium beta activity that may be held by various municipalities and provincial health authorities;

(c) an examination of all records pertaining to beta activity in sewage effluent and sewage sludge on the Atlantic Seaboard;

(d) an examination of all records pertaining to beta activity in meat, leafy vegetables, milk and dairy products produced within a radius of 30 km of KNPS;

(e) an examination of all records pertaining to beta activity in filter feeders and crustaceans found within 500 metres of the shoreline of the South-Western Cape Coast between Saldanha Bay and Cape Point;

(f) a thoroughgoing and independent review of all scientific assumptions, sampling techniques methods, and error detection methods relating to existing reports on radioactive waste products released by KNPS, with particular reference to:

(i) the linear low-dose hypothesis;

(ii) the National Nuclear Regulator's Annual Authorised Discharge Quantities (AADQs);

(iii) statistical sampling of exposure to ionising radiation based on thermo-luminescent dosimeters (TLDs);

(iv) the "background radiation", "depleted Potassium-40 levels", "nuclear weapons fallout", "radio-therapy" hypotheses as applied to the following sites:

(a) Sea Point
(b) Blaauwbergplaas
(c) Melkbosstrand Sewage Works
(d) Yzerfontein
(e) Camphill Village
(f) Mamre
(g) Atlantis
(h) Malmesbury
(i) SAP Durbanville

(g) an independent and repeated random sample of beta activity and the presence of Iodine-131, Strontium-90 and Cesium-137 in airborne particulates, freshwater, marine life, foodstuffs, and Melkbosstrand sewage sludge;

(h) a comprehensive and independent audit of all bone, breast and soft tissue cancers within a 30-km radius of Koeberg, with particular emphasis on the age-group 0-14 for leukemia, and within the urban clusters of Milnerton, Table View, Melkbosstrand, Atlantis and Malmesbury;

We trust that potential donors, funders and well-wishers will see fit to further support these further enquiries financially so that the public's right to know, their ability to make informed choices concerning policy decisions, and their ability to engage with policy makers with regard to public expenditure in support of such decisions is enhanced. We also foresee that this information will be publicly disseminated in such a way as to make adequate public participation in the forthcoming second Environmental Impact Assessment into the proposed Pebble Bed Modular Reactor (PBMR) at the Koeberg site.

We believe that evidence drawn from the Koeberg Nuclear Power Station's Environmental Laboratory Survey Annual Reports over the last twenty years makes it abundantly clear that a renewal of Eskom's licence over another 40 years or more is in direct contravention of Section 26 of our Constitution and should be opposed by all citizens of the South-Western Cape in the interests of environmental justice and inter-generational equity.

2. An Apology for Method

This paper will assume no intimate knowledge on the part of the reader of nuclear physics, nuclear chemistry, radiobiology, nor of epidemiology. Although the writer is not a graduate in any one of these fields, he has been forced by circumstance to try and understand the nature and difficulties of nuclear power since first being exposed to the arguments in 1982. No apology is therefore offered for any shortcomings in the scientific method, since the writer makes no pretence at being (or wanting to be) a "scientist".

We will start with an attempt at some basic understanding of the field, before proceeding to examine the data provided by Eskom to the National Nuclear Regulator (NNR, formerly Council for Nuclear Safety, or CNS) over the last twenty years. Some conclusions will then be offered, together with recommendations and suggestions for further research. In order to place the position of this paper in its proper context, however, we will first examine the basic arguments on either side of the debate.

3. The Standard Pro-Nuclear Argument

The argument most often presented by supporters of nuclear power is that it is a "clean, safe and reliable" source of energy. Indeed, contemporary proponents of the Pebble Bed Modular Reactor (PBMR) have been at pains to emphasize that their new global offering is "inherently safe", as if the use of the adverb "inherently" (repeated endlessly in all media to date, globally) somehow linguistically makes redundant and superfluous any scientific or rational enquiry as to the truth of the assertion.

Similarly, the proponents often turn on their head the anti-nuclear activists' assertion that radio-toxic particles such as Cesium-137 and Strontium-90 might be injurious to human health by "comparing" such internally consumed radioactivity with "background", external radiation, thereby creating a mischievous and misleading distraction from the very real dangers to human health under consideration. This is coupled with a multitude of red herrings as to fission products from Koeberg Nuclear Power Station, such as Silver-110 or Cobalt-60 (which only serve to distract from the substantive issues), or by dealing at length with background readings in microSieverts attributable to a variety of sources other than Iodine-131, Strontium-90 and Cesium-137.

This report will therefore focus only on those aspects peculiar to measurable beta radiation in emissions from Koeberg proper and foodstuffs produced in the immediate vicinity. By using Ockham's razor judiciously, the report will therefore exclude entirely any questions pertaining to "background radiation", or any other irrelevant source of man-made radiation and focus exclusively on three long-lived radioactive by-products of the Koeberg Nuclear Power Station, namely the radioactive isotopes Strontium-90, Iodine-131, and Cesium-137. It is intended precisely to assist ordinary (but well-informed) members of the public to understand the problem of emissions from that particular power station and nowhere else. This understanding, we believe, is vital to the full exercise of democratic choice in the arena of participatory decision-making on matters of public interest regarding workers' health and public health.

We will therefore try to address one question and one question only:

> What is the precise measure of beta activity in air particulates, foodstuffs and emissions of the ionising radioactive nuclides Strontium-90, Iodine-131, and Caesium 137 in particular as a direct result of the conventional operation of the Koeberg Nuclear Power Station?

This very naturally brings us to the standard anti-nuclear argument.

4. The Standard Anti-Nuclear Argument

The standard anti-nuclear argument consists of a range of assertions which are beyond the scope of this paper: excessive costs relative to other sources of energy; technical safety issues; the horrifying consequences of a large-scale accident such as Chernobyl (Ukraine, 26 April 1986); or the ultimate storage of radioactive waste. As far as the impact on human heath is concerned, however, the anti-nuclear argument further suggests that we should be concerned about the conventional operations in an ordinary nuclear power station, since they routinely emit particularly long-lived radioactive particles such as Cesium-137 and Strontium-90. They further allege that such emissions are carcinogenic and that there is fairly good evidence available that these emissions are actually causing sufficient cancers above the norm with a particular emphasis on the higher-than normal levels of leukaemia and breast cancers.

It is these allegations which this paper seeks to investigate in the light of recently released reports by Eskom - the licensed operator of Koeberg Nuclear Power Station (KNPS), 28 km NNE of Cape Town, South Africa. These reports were first mandated in 1983 by the then Council for Nuclear Safety (CNS) and later, after the passage of the National Nuclear Regulatory Act of 1998, by the National Nuclear Regulator (NNR).

In order to understand all of these arguments, however, and to be able to interpret the reports with a reasonable degree of understanding, it will be necessary to take the reader on a little excursion into the Wonderland of sub-atomic physics and nuclear chemistry, before proceeding with a whistle-stop at that branch of radio-biology where radioactivity interacts with different cells inside the living human body.

5. Sub-Atomic, or Nuclear Physics

(The following description is taken largely from the website for the United States' Agency for Toxic Substances and Disease Registry http://www.atsdr.cdc.gov/toxprofiles/. *Although some editorial changes have been made in the interest of greater lucidity, the essential arguments remain unchanged. Where an alternate source has been used it is indicated accordingly.)*

To explain what ionizing radiation is, we will start with a discussion of **atoms,** how they come to be radioactive, and how they give off ionizing radiation.

Atoms are the basic building blocks of all **elements** (by "elements" is meant the simplest chemical structures such as the pure **gases** of oxygen, nitrogen and hydrogen; or the pure **metals** of gold, silver and tin).

We understand what atoms themselves are made of because we can measure their performance in space and time and in certain laboratory conditions. An atom of hydrogen, for example, consists of one very small central **nucleus** with one **electron** orbiting around it - just as the planets or comets are seen to orbit the sun.

The nucleus itself, however, can be further divided into two even more tiny bits: the **protons** (which are positively charged) and the **neutrons** (which carry no electrical charge). The number of protons in an atom's nucleus will tell you which of the elements it is. Oxygen, for example, has eight protons, and all the existing elements can thus be arranged in order of their number of protons in their nuclei to get the **Periodic Table** (attached as Appendix II)

Since each of the eight protons in the nucleus of an atom of oxygen has a positive charge, the positive charges try to push away from one another. The neutrons prevent this action by acting as a kind of glue that holds the protons together in the nucleus.

Now, while the number of protons in an atom of a particular element is always the same, the number of neutrons may change. Neutrons thus add to the weight of the atom, so an atom of carbon that has six protons and six neutrons is called Carbon-12 (6+6 = 12).

If two more neutrons were added to this atom, it would be called carbon-14 (6+6+2 = 14), which is used for dating fossils and is called an **isotope** of carbon. Isotopes are forms of the same element, but which have different numbers of neutrons within the nucleus.

5.1 How Does an Atom Become Radioactive?

The ratio of neutrons to protons within any nucleus of an atom determines whether that atom is stable or unstable. If there are too many or too few neutrons, the nucleus becomes unstable, and seeks stability by giving off **radiation** in the form of neutrons, alpha particles, beta particles, or pure energy in the form, of gamma rays - a process called disintegration or **radioactive decay.** This process of decay is normally measured in disintegrations per second (dps) or Becquerels (Bq). We can thus measure the activity of such unstable atoms in the environment or inside people by measuring the **radioactivity** of an atom in Becquerels. This will be vitally important later on in this report when we try to make sense of the Eskom data-sheets.

Another critical term in nuclear physics is the **half-life.** Since an unstable atom is busy disintegrating at a steady rate until it reaches a stable level, we can say that every time a particular mass of atoms reaches half the level of its original radioactivity the time it has taken to reach that level is the half-life. So, for example, polonium-210 has a half-life of 0,00016 seconds, while Uranium-238 has a half-life of 4,5 billion years!

There are several ways an atom can become radioactive: an atom can be naturally radioactive, it can be made radioactive by natural processes in the environment, or it can be made radioactive by humans. Naturally occurring radioactive materials such as potassium-40 and uranium-238 have existed since the earth was formed. Other naturally occurring radioactive materials such as carbon-14 and hydrogen-3 (tritium) are formed when radiation from the sun and stars bombards the earth's atmosphere.

Those elements which are heavier than lead (^{82}Pb on the Periodic Table) are naturally radioactive because they were originally formed with too many neutrons. The heaviest atom in nature is uranium-238, which is about 99,7% of naturally occurring uranium. The isotope which is most useful for nuclear power, however, is the isotope uranium-235 which is about 0,3% in nature. This is normally enriched to above 3% percent for use in a nuclear power plant.

In a nuclear reactor such as the two at Koeberg Nuclear Power Station, atoms of 3.2 % Uranium-235 in the nuclear fuel (Uranium Dioxide, or UO_2) are bombarded with slow-moving neutrons so that they absorb one neutron (Uranium-236) and then immediately split into two radioactive fragments plus two or three neutrons. This is called **nuclear fission.**

One of these "fission neutrons" is then captured by another uranium atom and the fission process is repeated under controlled conditions to generate heat inside the primary coolant water. This heat is transferred to the surrounding pipes of water under pressure (the secondary coolant, thereby creating steam to drive the turbines, which create electricity. This configuration is known as a **Pressurised Water Reactor**, or PWR, and is one of the most common forms of civilian power reactors found around the world. The famous Three Mile Island in Pennsylvania, USA, where an accident occurred in 1979 is one such PWR. Koeberg Nuclear Power Station is of a similar Westinghouse design, supplied by Framatome in France in the 1ate 1970s.

5.2 What are the By-products of Uranium-235 Fission?

If we want to make good our assertion that Strontium-90 and Cesium-137 are directly related to the normal operation of a nuclear power station, it must be shown that they are by-products of the nuclear fission of Uranium-235, or **daughter products**. Luckily, there is plenty of evidence from the history of nuclear power plants throughout the world to show that these products are guaranteed to be there. An early textbook (*Nuclear Chemical Engineering*, courtesy of Professor Philip Lloyd of the Energy Research Institute at the University of Cape Town) reveals a fascinating set of curves, which predict the likely daughter products from the fission of Uranium-235 by the introduction of slow-moving thermal neutrons (p.46, Table 2.6: see Appendix III).

Starting at a low 0,0079% for atomic mass number 77 on the left-hand column, the curve peaks at mass numbers 93 and 94 at 6,4%, before tapering off at mass number 115 (0,011%). On the right-hand column the mass number starts at 117 (0,010%), peaks at mass number 134 (7,5%) and tapers off at 157 (0,0074%). From this reliable data-set, therefore, one may easily predict that two sets of fission products are more than likely to occur in association with a nuclear power station: one set in the range of mass number 89 to 100; and one set in the range of mass number 132 to 144 - and these are precisely the ranges in which the radioactive isotopes of Strontium-90 and Cesium-137 do occur.

Even more conveniently, however, the textbook shows at Fig. 2.1.4a on page 47 that - of the 5,8 percent of likely products having an atomic mass of 90 (namely the isotopes Selenium-90, Bromine-90, Krypton-90 and Rubidium-90) all decay very rapidly (maximum 33 seconds) to Strontium-90, which has a half-life of 29,1 years.

5.3. Why are Strontium-90 and Cesium-137 so important?

Iodine-131 is singled out by the Eskom reports for special attention. According to an American University website, however, its short half-life of eight days ensures that it will soon be gone (http://hyperphysics.phy-astr.gsu.edu/hbase/pertab/sr.html). The website suggests that Strontium-90 and Cesium-137 are isotopes which should be much more closely guarded against release into the environment since their half-lives of around 30 years are the longest for radioactive contaminants from Uranium-235 and ensure that they will be around for well over a hundred years.

Besides its persistence and high activity, Cesium-137 has the further insidious property of being mistaken for potassium by living organisms and taken up as part of the fluid electrolytes. This means that it is passed on up the food chain and re-concentrated from the environment by that process. Of the fission products, Strontium-90 is most accessible to plants via uptake from the soil and that uptake is roughly ten times greater than that of Cesium-137. This has a direct implication for the grazing lands of the Darling dairy farms downwind from Koeberg Nuclear Power Station and we will have to see whether adequate monitoring has been performed on Darling dairy products in the Eskom reports.

The Environmental Protection Agency in the United States indicates a summary of the health effects of Strontium-90 (http://www.epa.gov/radiation/radionuclides/strontium.htm):

> People may inhale trace amounts of Strontium-90 (Sr-90) as a contaminant in dust. But, swallowing Sr-90 with food or water is the primary pathway of intake. When people ingest Sr-90, about 70-80% of it passes through the body. Virtually all of the remaining 20-30% that is absorbed is deposited in the bone. About 1% is distributed among the blood volume, extra-cellular fluid, soft tissue, and surface of the bone, where it may stay and decay or is excreted.

> Strontium-90 is chemically similar to calcium, and tends to deposit in bone and blood-forming tissue (bone marrow). Thus, Strontium-90 is referred to as a "bone seeker." Internal exposure to Sr-90 is linked to bone cancer, cancer of the soft tissue near the bone, and leukaemia.

Much has been written on the health effects of ionizing radiation, so we won't exhaust the topic now. Interested readers may refer to papers submitted to the PBMR EIA process by Earthlife Africa in 2004 (Appendix IV) and the *2003 Recommendations of the European Committee on Radiation Risk*, Brussels 2003 (available from Earthlife Africa, Cape Town Branch). One of the key statements, for example, is given by an abstract of Mangano et al ("Infant death and childhood cancer reductions after plant closings in the United States" in *Archives of Environmental Health*, Jan-Feb 2002, vol.57 no.1, pp 23-31):

> Subsequent to 1987, eight US plants located at least 113 km from other reactors ceased operations. Strontium-90 levels in local milk declined sharply after closings, as did death among infants who had lived downwind and within 64 km of each plant [Note that Cape Town itself is 28 km downwind from Koeberg in the prevailing North-westerly wind of winter, so that a epidemiological study of the 0-14 age group would be appropriate as well.] These reductions occurred within the first two years that followed closing of the plants, were sustained for at least six years, and were especially pronounced for birth defects. Trends in infant deaths in proximate areas not downwind, and more than 64 km from the closed plants, were not different from national patterns. In proximate areas for which data were available, cancer incidence in children younger than five years of age fell significantly after shutdowns. Changes in health following nuclear reactor closings may help elucidate the relationship between low-does radiation exposure and disease.

In *New Scientist* (9 September 1983) an outbreak of leukaemia occurred three kilometres from the Sizewell PWR in Suffolk, United Kingdom. Eleven fatal cases were discovered among a small town population of Leiston. Again in *New Scientist* (3 November 1983) it was reported that a study of children in the vicinity of the Sellafield nuclear reprocessing plant in Cumbria had revealed 14 cases of leukaemia, where the national norm would have been three. In *Nature*, vol.283 of February 1980, it was further reported that 13 hypothyroid babies had been born in the wake of Three Mile Island as against an expected three cases.

Finally, Table 11.1 on Page 104 of the ECCR 2003 Report gives three further examples of elevated leukaemia cases in the vicinity of nuclear power plants: Hinkley Point, UK (1988), Kruemmel, Germany (1992) and Barsebaeck, Sweden (1998). As a result of this comprehensive study of all the data from all sources of long-lived radioactive isotopes, the Committee recommends that the maximum permissible dose to members of the public should be kept below 0,1 mSv, while exposure limits to workers should be 5 mSv (p.138).

At the beginning of Section 5.1 above we explained that radiation is normally measured in Becquerels, or disintegrations per second. When the radioactive nuclide gets inside the human body, however, we need to measure what the dose will internally to the bone marrow or soft organ tissues (such as the insides of breasts, gonads, or livers, and so on). This measure is called the Sievert and is worked out for different radioactive nuclides and their ability to work their way through to a specific organ. For a fuller discussion, see Section 5.5. below.

For the record, the expected rates of cancer for South African children were provided by the Medical Research Council in their National Burden of Disease Report, 2000 (courtesy Dr Debbie Bradshaw, Director: Burden of Disease Unit, MRC):

All Cancers per 100 000 Children

0-4 years	< 45 males	< 41 females
5-14 years	< 87 males	< 43 females

All Leukaemia's per 100 000 Children

0-4 years	< 1.7 males	< 1.6 females
5-14 years	< 1.8 males	< 0.9 females

WHO estimated latencies are 5-10 years for children, and 10-15 years for adults.

5.4. How does Strontium-90 and Cesium-137 get out of the Nuclear Reactor?

Apart from the mere existence of reports to the CNS and the NNR that suggest that the radioactive isotopes Sr-90 and Cs-137 do get outside (otherwise why report on it?) and that the levels are measurable (but are often dismissed), it has been confidently asserted by pro-nuclear lobbyists such as Andrew Kenny that no such emissions exist, or that they are insignificant.

Yet in her contribution to the Conference on Nuclear Policy for a Democratic South Africa Conference in February, Cape Town 1994, Dr Rosalie Bertell wrote ("Health Implications of Nuclear Development: The International Experience", Appendix V p.2):

> Nuclear fission produces some 500 different radioactive chemicals [isotopes] either by splitting a large atom like uranium 235 ... or by activation of materials in the surrounding medium [water at Koeberg]. Non-radioactive [atoms of] molecules in the air, water, pipes, or other material in proximity to nuclear fissioning are violently bombarded by the neutrons released [through fission], becoming radioactive. At the temperature of the reaction some of these radioactive chemicals [isotopes] are [suspended in] gases, some liquids, and some solids. Some gases are held up temporarily to "cool" down to a liquid or solid state. The gases and liquids are all released to the environment....

Dean E. Abrahamson presents a more convincing argument in "Ecological Hazards of Nuclear Power Stations", Chapter 42 of the book *The Careless Technology* (www.iucn.org/themes/ceesp/ Publications/ SL/CT/Chapter%2042%20-%20The%20Careless%20Technology.pdf - at page 801 following (given as Appendix V(a) in this report):

> Some of the fission products escape into the primary coolant and are available for release into the environment. In addition, the bulk of the activation [or decay] products is formed [in], or can diffuse into, the primary coolant. It should be emphasized that not all of the fission products which are produced are available for local release. Also, those radioactive wastes which are released are done so deliberately.
>
> They are released because release is cheaper than retention; the only gain is a slightly (and to date) unspecified reduced power cost to the consumer.
>
> The fission products are produced in the uranium oxide fuel pellets. The cladding surrounding the fuel is 0.02 to 0.04 inches thick and is surrounded by the primary coolant water ... Fission products can pass through intact cladding by diffusion and other processes, or they can pass through defects in the cladding. There may be 500,000 linear feet of cladding in a reactor core. It is difficult to fabricate this amount of thin-walled tubing without leaks either initially or after prolonged exposure to high temperatures and high neutron flux.

Indeed, very early on in the construction of the Koeberg Nuclear Power Station, it was revealed that there had been "ferritic inclusions" in the manufacture of some of the piping (*Cape Times* 25 February 1985), meaning an excess of iron in an otherwise perfect blend of stainless steel. Other sources of leakage can include faulty valves, seals and incompetent or careless welds.

The current Dean of Research at the Witwatersrand Technikon, Professor Thomas auf der Heyde, used to be a nuclear activist in his youth. In a photocopied handout for activists in Koeberg Alert ("An introduction to the physics and chemistry which 'happens' in a nuclear reactor, or How does it work?" Koeberg Alert, June 1983, p.6: see Appendix VI), he suggested that -

> ... the water which bathes the [nuclear fuel] pile becomes highly radioactive as well, and I am sure it is just poured away in some deserted place. Finally ... pressure often builds up in the containment vessel [of the nuclear fuel reactor] due to a build-up of radioactive hydrogen gas and radioactive water vapour (steam). The only way in which this pressure maybe relieved is by releasing the gas into the atmosphere.

Professor Auf der Heyde must also have been psychic in his youth because, in a lawsuit brought against Florida Power & Light in 2003 for negligence at its nuclear power plant on Hutchinson Island in St. Lucie County, a mother alleged that her son had contracted brain cancer from exposure to the release of sewage sludge that was accidentally contaminated with radioactive waste in the late 1970s and early 1980s. The following instructive extract is from the story published by journalist Sarah Prohaska ("Parents question 2 boys' cancer: St. Lucie Nuclear Plant emissions have never posed a risk, FPL says" in *Palm Beach Post*, 10 August 2005):

> One aspect of their cases will focus on the sludge incident in the early 1980s, which began with a sink that workers thought drained into the plant's radioactive waste system but instead drained for nearly four years into its regular sanitary sewage system, according to court documents. Not realizing that, workers used the sink to wash contaminated items such as respirators, mops and rags.
>
> Managers at the time blamed the mix-up on a staff turnover of nearly 100 percent between 1976 and 1978, according to FPL documents. In September 1982, the sink's drain clogged, and officials realized the mistake.
>
> At the time, FPL officials publicly acknowledged the sink problem and said two truckloads of sewage sludge from the plant's on-site treatment center, which included contaminated waste from the sink, had been shipped for disposal to a 2,000-acre cow pasture in western St. Lucie County, just west of Glades Cut-off Road. Official say they removed 6 inches of soil from the contaminated area and shipped it to a nuclear waste facility in South Carolina.
>
> An FPL spokeswoman said air, soil and water tests at the time showed the site was not a public health risk. "It was contaminated with extremely low radiation levels," FPL's Scott said.
>
> But La Vista disputes the finding and said that besides those two shipments from the on-site treatment plant, records show the sink also drained into a septic tank that was pumped out daily between 1978 and 1980. The waste from that tank was taken to the municipal Fort Pierce sewage treatment plant, according to FPL documents. Those shipments also could have sent radioactive material into the air, water and ground, she argues. She said the Fort Pierce plant no longer has any documents that could show how that waste was handled or where it went. "We have no clue where that went," she said.

A similar situation was revealed by *Business Day* 2 June 2002 where Eskom had accumulated 18 years' worth of radioactive sludge mixed with waste water from the Koeberg laundry, where protective clothing is washed after exposure to radiation. Mercifully, permission to dump the toxic sludge was declined by the city officials at the time, but one would still want to examine closely the levels of long-lived isotopes in all waste streams associated with the plant over the twenty-year period in question.

The reference to the *Business Day* article comes from the Earthlife Africa, Cape Town Branch: "Safety Issues in the South African Nuclear Industry: Koeberg and the PBMR", Nuclear Energy Costs the Earth Campaign Briefing Paper no.2, April 2004, p.8. (see Appendix VII). This very useful paper also outlines a range of technical safety issues, including the difficulties with embrittlement of metals owing to continuous bombardment by neutrons in the reactor vessel. The paper draws attention to the enforced shutdown of the Yankee Rowe power plant for this very reason, as reported in the *Washington Post* of April 1999. I would further recommend this paper for its overview of the public health issues in relation to nuclear power plants, radiological issues and difficulties in trusting the existing regimes in South Africa to both police and sanction breaches of the regulations with regard to unreported incidents and excessive levels of contamination both inside and outside the plant.

The most definitive evidence for Strontium fallout in the vicinity of Koeberg, however, was provided by independent monitors Gerry Kuhn Environmental & Hygiene Engineering cc in a report to Morning Star residents near the municipal chemical waste dump at Vissershok, outside Cape Town, dated 19 March 2003 (see Appendix VIII). They write on page 2:

> Radioactive Monosites are found within west coast sands (red sands) to the north but in this regard the Strontium levels are considered too high in our opinion.

Kuhn's highest reading for Strontium was 654,4 ppm at Waterloo Bridge.

A final blow to the rhetoric of the pro-nuclear spin doctors, moreover, comes from the proponents of the new Pebble Bed Modular Reactor themselves in their Final Report on the Environmental Impact Assessment (See Appendix IX). Table 36 on page 247 gives the projected release in liquid effluent of Cesium-137 (55 percent of mixture) as 5.2×10^{9} Bq p.a., (that is 5,2 billion Becquerels a year, where "p.a." means *per annum* or "in a year" in Latin) and Strontium-90 (0.5 percent) as 4.9×10^{7} Bq p.a., or 49 million Becquerels a year! The point here is not to compare or contrast such emissions with any local or international standards but merely to concede that such emissions do, in fact, exist and that they must be accounted for in the surrounding environment, or preferably contained entirely within the reactor building, before being sealed and packaged as hazardous waste products.

Using Dose Conversion Factors drawn from Koeberg, the proponents calculate a potential dose rate of 2.3×10^{-2} µSv for Cesium-137 and 8.1×10^{-5} µSv for Strontium-90 (Table 37, page 248).

On the question of gaseous releases, the proponents write as follows (p.251):

> The release of gaseous [radio-] activity from the [PBMR] plant has been based on a loss of 0.1% of the volume of the primary helium-containing systems per day. [The reference to helium is because the PBMR design incorporates helium gas as a coolant, instead of water.] The concentration of [the radio-] activity in the gas was derived values calculated for the HTR [High-Temperature Reactor] Modul, which in turn was based on the AVR [Advanced Gas-Cooled Reactor] experience. [These are all basically Federal German experiments in the 1980s which both failed and were rejected by the German Government and sold to Eskom in the 1990s by ABB-Siemens.]
>
> All releases are routed via the reactor building ventilation system and released at a height of 20 m above ground level and the dilution factors are specific to the design of the ventilation system …
>
> The primary coolant leak rate from the [United States] Peach Bottom nuclear plant was 1% of the inventory per day and from the AVR and Dragon reactors it was 0.2% To achieve lower [p.252] leak rates, very high demands will be made on the impermeability of components and systems.

In other words, to support Dean E. Abrahamson's earlier contention, it will cost more money to entirely contain the more dangerous, long-lived radiotoxic isotopes. By this argument the proponents are quite content to reveal the quantities of isotopes to be released every year at

Tables 40, 41 and 42 on pages 252-255. Compared to the amount released in liquid effluent, Strontium-90 in airborne particles is confined to 870 Bq a year but Cesium-137 weighs in at 230 000 Bq a year. So much for "inherently safe"!

In order to counteract the worst effects of this freely admitted quantity of emissions, the eagle-eyed National Nuclear Regulator recommends in Footnote (b) on page 430 that "If Cs-137 activity in air is detected, Sr-89 and Sr-90 analysis shall be performed." Again they suggest at Footnote (k) that "If gamma isotopic analysis indicates Cs-137, an analysis for Sr-89 & 90 shall be performed." In essence, the NNR recognises the direct link between the two isotopes as interlinked daughter products of fission in a nuclear reactor.

Finally, with the benefit of hindsight, the NNR demands at Footnote (l) that -

> The NNR shall be informed if the total gamma activity I sewage sludge at the Melkbos sewage works exceeds 100 Bq/kg or if the activity of any single nuclide exceeds 50 Bq/kg (both requirements exclude natural radioactivity).

Broadly speaking, then, the evidence for conventional releases of Strontium-90 and Cesium-137 from an operating nuclear power plant is unequivocal and should not detain us any further in debate now and nor should it do so in the future. What remains is to be vigilant when it comes to existing and future solid waste, effluent and nuclear fallout from Koeberg and Pelindaba.

5.5 But what about Fallout from Above-Ground Nuclear Weapons Testing?

Despite the clear and unambiguous evidence that Strontium-90 can and does find its way into the environment from a normally operating nuclear power station, much was made in the Eskom reports that evidence of Strontium-90 in the environment surrounding Koeberg Nuclear Power Station is as a direct result of above-ground nuclear weapons testing in previous decades. The current Koeberg Public Safety Information Forum dominated by industry stakeholders has also publicly rehearsed this convenient excuse more recently. (See Appendix X: "Minutes of the Koeberg Public Safety Information Forum held at the Melkbosstrand NG Church on 23 June 2005", photostat)

In Table 7.3 on page 53 of the European Committee on Radiation Risk study cited above, it states that fallout from global weapons tests peaked in the 1960s with a cumulative dose of 1000 to 2000 μSv and is now worth about 10 μSv per annum.

Given the cessation of such testing some decades ago, however, and a decline in radio-activity over a 30-year period, we will need to examine whether these levels of Strontium-90 have decreased (which would be predictable, since above-ground nuclear weapons testing ceased some time ago), remained the same, or increased in Becquerels.

In a very old paper by J.R. Moroney of the Australian Radiation Laboratory (see Appendix XI: "Radioactive Fallout in the Southern Hemisphere From Nuclear Weapons Tests", an invited paper to the International Symposium on Environmental Radiation Research Society of Japan, Commonwealth Department of Health, November 1979), the author painstakingly reviews the literature on above-ground weapons testing in the preceding period. On page 2 he states that –

> Of the total 188 Mt of fission products to the atmosphere, 160 Mt went into the stratosphere of the northern hemisphere [rarely penetrating below 10^{O} S] and 18 Mt into the northern troposphere. The corresponding releases to the atmosphere of the southern atmosphere were 8 Mt and 2 Mt, respectively.

He goes on to state on page 3 that "For the southern hemisphere all injections into the stratosphere, and most of the total release to the troposphere, occurred into the two periods 1966-1970 and 1971-1974." Table 3 on page 6 indicates that Strontium-90 was released mainly to the stratosphere, which would be part of the total of 8 Mt of releases in the southern atmosphere mentioned above, compared to the overall total of 188 Mt - a mere 4.25 percent of all releases. Disproportionately, however, the dose commitment to bone marrow and bone lining cells given in Table 4 on page 7 (derived from UNSCEAR 1977) is 24 and 33 mrad (millirad) respectively.

Here we get into a terrible muddle about measurements in radiobiology, because each step in calculation requires greater and greater complexity and more and more variables, all subjected to intense dispute. The following departure by way of further explanation is drawn from The Institute of Energy and Environmental Research: *Energy and Security*, no.4 1997p.7 (Appendix XII).

The traditional unit of externally measured radioactivity is the **Curie (Ci)**, which is equal to the radioactivity of one gram of pure radium (^{88}Ra on the Periodic Table). The **Becquerel (Bq)** is the newer standard international (SI) unit of radioactivity equal to one disintegration per second. It is equivalent to 27 picoCuries, or one Curie is equal to 37 billion Becquerels.

When the radioactive particle enters the human system, however, we have to measure the impact on the living cells. The **rem (radiation equivalent man)** acknowledges the different impacts of the three different kinds of radiation: alpha, beta and gamma. The **Gray (Gy),** defines the impact on the cellular matter as 1 joule per kilogram of 100 rems. When the dose has been laid down in the tissue, moreover, we still need to know what precise biological damage has occurred and that is given in **Sieverts (Sv),** which is the impact of 1 gray or 100 rems.

Thus the impact of above-ground nuclear weapons testing may be given as an expected internal dose of Strontium-90 in the southern hemisphere of 0.24 mSv to the bone marrow but 0.33 mSv to the bone lining cells.

When one studies the actual depositions in Australia in Table 9 on page 17, however (0.31 mSv to bone marrow; 42 mSv to bone lining cells), one can see from Figure 3(b) on page 27 that there is a movement to the west from the greatest deposition at the time of a nuclear test in the South Pacific Ocean in 1975. Correspondingly, there is a spike in deposition to ground of short-lived Zirconium-95 measured in Pretoria, South Africa, with no detectable levels after 1980. Similarly, in Figure 8 on page 32 we see a spike in Sr-90 levels at roughly 500 kCi in 1976 in the northern hemisphere and then a rapid descent to below 100 kCi at the time of writing. Again the calculations for the southern hemisphere Sr-90 inventories given in Figure 10(a) on page 34 are only above 10 kCi by 1979, while for the latitudes 20^{O} to 40^{O} S, they are below one mCi per km^2 by 1979. Finally, the results in Argentina are significantly lower than those for Australia. As the fallout drifted west from the Pacific and Australian tests, therefore, the amount of Strontium-90 available for possible uptake by humans becomes progressively less in volume.

The conclusions that may be drawn from this impeccably argued paper are as follows:

1. The maximum possible value of fallout for Strontium-90 in the southern hemisphere from above-ground nuclear weapons testing is one mCi per km^2 (37×10^6 Bq per km^2).

2. The maximum possible value for ground-level radioactivity in **one square metre** of Strontium-90 in the southern hemisphere from above-ground nuclear weapons testing is therefore 37 000 Becquerels (37×10^6 Bq per km^2 divided by 10^3).

3. Given the decline in radioactivity westwards of the nuclear testing sites, the value in South Africa for ground-level radioactivity of Strontium-90 in one square metre in the southern hemisphere from above-ground nuclear weapons testing should be **roughly 10 percent less at peak,** giving a maximum value of 33 300 Becquerels.

4. Given that Strontium-90 has a half-life of 28.1 years and that the last above-ground nuclear weapons tests were carried out in the 1970s, the level of radioactivity for Sr-90 from those tests should be **half** of what it was then, namely 16 650 Becquerels.

5. The predicted peak values in all units for ground-level radioactivity of Strontium-90 over one square metre in the vicinity of Koeberg Nuclear Power Station attributable to above-ground nuclear weapons testing in the 1970s should therefore be 16 650 Becquerels in the year 2000. Anything above that level cannot be attributable to above-ground nuclear testing.

6 Analysis of the Environmental Survey Laboratory Reports

The first report issued by the Environmental Survey Laboratory was completed by C Chichiarelli, Head of Environmental Surveillance and issued on 1 December 1983. According to the report, fuel loading for Koeberg-1 had taken place but the reactor had yet to go critical. The report thus forms a vital pre-operational baseline study for comparison with later discharges and environmental impacts and should be used accordingly, although one always needs to take into consideration errors of commission and omission in the collection of the relevant data.

The report mentions in its abstract that it contains the results of the second year of the Operational Radiological Environmental Survey Programme, so presumably there is a report on the first year of this programme, which ought to be made available. Reference is also made to ESCOM Standard OPS 7016/26-8, which we would need to see in order to test the allegation that "requirements of the abovementioned Standard were met and exceeded."

Tables I-IV in Appendices XIII-XVI of this report summarise the findings to date, so we will merely mention a few observations. Note that in all cases, we have highlighted those results which demonstrate a maximum value in a given month for a sample, since the tabulation of a mean averaged over an entire year is not conducive to an understanding of risk. The linear low-dose threshold approach, which starts with a massive dose to atomic bomb survivors in Hiroshima and extrapolates in a straight line to low levels of internal exposure does not meet with our view of public health safety standards. As far as we are concerned, ANY dose of internal beta-emitting, long-lived isotopes - especially Strontium-90 and Cesium-137 - represents a serious challenge to soft tissue and bone marrow, and should therefore be avoided at all costs. While we would accept the challenges of a minimal influx of these isotopes due to weapons fallout and intermittent discharges from Koeberg Nuclear Power Station, it is our contention that the quantity of Cesium-137 in particular, and its obviously associated risk from Strontium-90, pose an unnecessary threat to the population of the South-Western Cape.

6.1. Annual Authorised Discharge Quantities

In the loose, photocopied sheets supplied with the reports, and summarised in Table I in Appendix XIII of this report, the Annual Authorised Discharge Quantities (AADQs) were inflated on numerous occasions, with the biggest shift coming on the eve of the establishment of the new democratic State in 1993. A cynic might argue that these wildly inflated AADQs were designed to coincide not only with a more open order of society, but also to shield the authorities from the discovery that existing emissions and environmental impacts were of too high an order for comfort. A comparison of the original AADQs provided for liquid effluents in 1984 with the actual emissions for the 1990s will show that - in many cases - the authorised levels were exceeded, especially in the last quarter of the year. It will be necessary, therefore, to examine closely the origins of the AADQs of October 1993 in terms of: the issuing authority; the scientific method used to justify these inflated figures; and to what extent they were justified in retrospect, owing to the repeated excessive tolerance of increasing quantities of effluents and gaseous emissions within a cosy network of nuclear industry officials.

6.2. Levels of Strontium-90, Iodine-131 and Cesium-137 in Gaseous Emissions from KNPS

Notwithstanding point 6.1 above, the 1990 ESL Report for KNPS (pp.18-20) gives the following Annual Authorised Discharge Quantities for the relevant isotopes in gaseous format:

Strontium-90:	1.000E+08,	where	nE+08 = n X 10^8	or	100 000 000 Bq
Iodine-131:	2.000E+10,	where	nE+10 =n X 10^{10}	or	20 000 000 000 Bq
Cesium-137:	4.000E+10,	where	nE+10 =n X 10^{10}	or	40 000 000 000 Bq

We feel that any amount of extra long-lived radioactive isotopes is too many, so 40 billion extra Becquerels of Cesium-137 annually is unacceptable. With a half-life of 30 years, this amount can quickly accumulate to hundreds of billions of Becquerels over 20 years.

The actual gaseous emissions from KNPS between 1984 and 2002 are given in Table II in Appendix XIV of this report. The highest value for gaseous emissions of Iodine-131 was achieved in 1988 (2.619E+09, or 2.6 billion Bq) with another whopper in 2001 (1.031E+09, or 1.031 billion Bq), while the highest value for Cesium-137 was in 2002 (3.544E+06, or a modest 3.544 million Bq).

6.3. Levels of Strontium-90, Iodine-131, and Cesium-137 in Liquid Effluent from KNPS

The actual emissions from KNPS between 1984 and 2000 are given in Table III, Appendix XV of this report. One emission of Strontium-92 (2.951E+04, or 29 510 Bq) is noted for 1984, and one of Strontium-90 (3,023E+05, or 302 300 Bq) for 1988. This climbs steadily to 952 800 Bq in 1990, before leaping to a bumper new democracy present of 53.35 million Becquerels in 1994. Yet another dose of 25.78 million Becquerels is recorded in 2002.

Iodine-131 emissions in liquid format are consistently recorded above the million-Becquerel mark from the very beginning. Starting at 1.247 million Becquerels in 1984, the record was achieved also with the new democracy in 1994 (3.482 billion Becquerels) and excelled in time for the first local government elections in 1995 (3.901 billion Becquerels).

Cesium-137 also only kicked in with a vengeance in the transition to democracy. Starting with a petite 568 400 Bq in 1985, it peaked at 16.46 billion Becquerels in 1994, fell back to 3.901 billion Bq in 1995, and settled down to a quiet 25.18 million Bq in 2002.

So much for residues from above-ground nuclear weapons testing!

Perhaps the excitement of an open society was all too much for the new Government of National Unity, because the new, “improved” AADQs kicked in just in time by October 1993. Eskom was granted permission to release any quantity under 7 710 000 000 000 Bq a year of Iodine-131 and 11 900 000 000 000 Bq a year of Cesium-137. Is that a trillion? A gazillion? As

P J O'Rourke wrote of arms expenditure, it was a "jet-stream of zeros". By way of contrast, Strontium-90 permissible levels are set at only eight zeros: 586 500 000 Becquerels a year.

6.4. Levels of beta activity in foodstuffs

Given the vast quantity of releases from KNPS over the last two decades, one would expect some sort of impact on the environment, no matter how many times the nuclear authorities say there are none. From an earlier zealous approach to measurement in foodstuffs in the 1980s, however, the ESL Reports quietly die down with regard to measurements in the 1990s, preferring to rely heavily on thermo-luminescent dosimeters (TLDs) and "effective dose in microSieverts" (a highly suspect mathematical calculation) to tell their side of the story. In other words, the actual presence of long-lived isotopes **inside** human beings was of far less importance in the reporting procedure over the decades than such trivia as the trace elements remaining from above-ground weapons testing and garbage about background radiation from granite rocks in Paarl. The need for public assurance and public relations spin always exceeded by far in the sheer volume of output the need for scientific rigour and accurate, publicly accountable reporting of the true facts. For what it's worth, however, their own figures are summarised for selected foodstuffs in Table II in Appendix XIV) and are merely highlighted below.

(a) FRUIT
From a baseline of 800 Bq/kg in 1983 to 1 126 Bq/kg in 1984 for **green figs.**

(b) GRAINS
From a baseline of 427 Bq/kg in 1983 to 658 Bq/kg in 1987 for **oats.** From a baseline of 391 Bq/kg in 1983 to 596 Bq/kg in 1984 for **wheat**, with a consistently higher reading from 1984 onwards.

(c) LINE FISH
Line fish would normally be very difficult to correlate with emissions from a nuclear power station, owing to the distances they are able to travel, but nevertheless a baseline figure of 1 121 is provided in 1983, compared to a maximum of 1 348 at Ou Skip in 1348.

(d) FILTER FEEDERS
Given their sedentary status and their known ability to concentrate radionuclides, filter feeders make for excellent canaries in the dark underworld of nuclear production at coastal sites. Two species are used for radiotoxic pollution at Koeberg Nuclear Power Station: **the black mussel** (*choromytilus meridionalis*) and **the white mussel** (*donax serra*). The baseline for the black mussel is given as 980 Bq/kg in 1983, rising to 1 281 Bq/kg at Ou Skip in 1987. The baseline for the white mussel is given as 937 Bq/kg, rising to 1 874 at Ou Skip in August 1988.

No further data of any significance is offered hereafter, except for a lengthy disquisition on the levels of Ag-110 in white mussels in the ESL Report for 1993, which is later dismissed on the grounds that "some people do eat white mussels, but this is very limited" (covering letter

K-16696-E addressed to Manager: Koeberg Project, National Nuclear Regulator, dated 27 March 2002; signed by Marc Maree from Generation Safety and Assurance on behalf of Peter Wakefield, Generation and Safety Assurance Manager, Eskom, Duynefonteyn; enquiries to Tertius Karsten, Radiation Protection ph 021-550-4624).

The main point is that - on observing elevated levels of beta activity in mussels - one ought to conduct a thoroughgoing survey of unscheduled and excessive releases retrospectively to determine the cause of the elevated levels of activity, and to take timely remedial action. If a canary dies in the coal-miner's underground birdcage, the miner does not light a match to determine whether the bird is edible, but leaves without further delay.

(e) MILK
Baseline of 115.7 Bq/l in 1983, rising to 140Bq/l in 1989, after which no data is given.

6.5. Presence of Strontium-90 and Cesium-131 in Foodstuffs

Starting with the baseline study of 1983, the ESL Annual Reports make a brave attempt to analyse the quantities of beta activity in may foodstuffs in various places, detecting very usefully trace elements of Strontium-90 and Cesium-137 in a variety of foodstuffs and which provide further baseline reference points for the later argument in favour of nuclear weapons fallout. Given the facts, however, that above-ground nuclear weapons testing stopped some decades ago; that a far smaller volume of releases were available in the Southern Hemisphere; and that the highest half-life is 30 years for Cesium-137; one would expect a gradual decrease in the trace quantities detected in foodstuffs. Nevertheless, the ESL Reports show increasing evidence of higher levels of Cesium-137 and Strontium-90 in local foodstuffs, not to mention the clearly tabulated huge releases of Cesium-137 in both gaseous and liquid forms. We know from the evidence, moreover, that these two isotopes are directly related to the production of electricity from nuclear reactors.

(a) FRUITS
The baseline for Strontium-90 was less than 0.30 Bq/kg in 983 for **green figs**, but rose to 3.9 Bq/kg for **wild guavas** in 1986. Whether this is an adequate correlation, however, remains to be proven. After this date, no further data is presented.

(b) GRAINS
The baseline for Strontium-90 in **wheat** was 0.91 but rises to 22.8 in 1986, which correlates with the high levels of Strontium-90 in wild guavas given in 6.3 (a) above. This would automatically suggest a closer inspection is required for all data for the year 1986, and casts substantive doubt on the "above-ground nuclear-weapons testing fallout" hypothesis, since one would expect the levels of Strontium-90 to be fairly constant or falling.

(c) MILK
Levels of Strontium-90 in milk samples were barely detectable at 0.08 Bq/l in 1983, but jumped to 0.214 Bq/l in 1985 and again to 0.37 in 1987, before receding again. If these spikes were attributable to above-ground nuclear-weapons testing, as is claimed, then one would expect

them to stay constant or decline, as they did in 1986 and 1989. No data is provided from 1990 onwards.

At Camphill Village, where the cows graze off the land, Strontium-90 levels start equally at 0.08 Bq/l in 1983 but jump five times to 0.41 Bq/l in 1989, before the data disappears from sight altogether. Clearly there is a need for independent testing of milk samples produced in the South-Western Cape.

6.6. Levels of Iodine-131 in Melkbos Sewage Sludge

Finally, we come to the vexed question of elevated levels of Strontium-90, Iodine-131, and Cesium-137 in sewage sludge at Melkbosstrand. Given the long and cosy relationship with their nearest neighbours, it would be perfectly understandable for the Eskom authorities to want to put the community at ease when it comes to the presence of radioactive isotopes in their collective ablutions. One of the ingenious methods of doing so, the above extraordinary figures for emissions notwithstanding, was to conduct an intense and feverish search for the perpetrators of this contaminated sludge.

Starting with the hypothesis that it must be someone other than the Eskom authorities in command of the giant nuclear power station on their doorstep, the authorities quickly latched on to the use of mild radioisotopes in radiotherapy. Voila! The unfortunate few who were being radiated for therapeutic reasons must be responsible for the elevated levels.

For those whose science is more hazy, however, we show that Iodine-131 started with a modest 105 Bq of activity in October 1990 and then rose above 3 000 Becquerels on three occasions: 18 October 1996 (3 870 Bq); 20 May 1998 (3 640 Bq); and 7 June 2000 (3 730 Bq). The highest level ever was on 17 November 1999 (9 220 Bq). We would very much like to have access to the method by which these specific occurrences were tied to radiotherapy among Melkbosstrand residents, because we do not believe that the vast quantities of Iodine-131 emerging every year in gaseous and liquid format from KNPS is immune from entering the Melkbos Sewage Works.

We have already noted above how radioactive particles can pass out of the reactor pile into the primary coolant water and then further afield. In the ESL Report for 1987, however, it expressly states on page 4 at 1.3 that – as part of an attempt to investigate the origins of elevated levels of radioactivity in Melkbosstrand sewage sludge –

> ... a vacation student was given the task to design and install a temporary system whereby waste water from the ISI hall (a known source of contamination) could be pumped into drums which are then emptied into the TEU system on site. The water from the hand basins in this area would normally drain into the 6 SEU system, which is connected to the Melkbosstrand sewage system.

In other words, the route to contamination of the Melkbosstrand most likely would travel from the reactor pile, via the liquid cooling systems, to the interior of the plant, and then be washed out one way or another via the 9 SEU and 6 SEU outlets via the sewer system to the local environment in liquid effluent form. We have already seen what quantities of Iodine-131 and other long-lived radioactive isotopes are present in liquid effluents. The only question that remains, therefore, is: where exactly do all those effluents go?

What we see, in effect, is a major breach in our understanding between masses of effluents on the one hand and paltry appearances of radioactivity on the other. Is it being suggested by default, for example, that all the effluents are swept out to sea, never to enter the human environment ever again? Or does the blowback to human ingestion and inhalation represent such a small dilution as to be "undetectable"?

We are fairly suspicious that these unscientific and spin-related assumptions are behind the motivation to "investigate" the causes of elevated levels in the Melkbosstrand sewage. This process began in 1988 (Executive Summary, page i, ESL Report 1988), as well as one for elevated levels of Strontium-90 and Cesium-137 in Camphill Village milk, based on the hypothesis that this was due low levels of potassium in the soil. Despite the unique direct grazing methods used by the Camphill Village dairy, no admission was made that these elevated levels may just as possibly have been due to the gaseous emissions from Koeberg.

In 1989 (p.12 at 2.7, ESL Report 1989), it is stated that Melkbos sludge (6 SEU) showed the presence of Cobalt-60 – a known waste product of nuclear power stations – but "the presence of Co-60 is not explained". In 1990, however, we find a new departure mentioned in the Executive Summary:

> The origin of I-131 which was detected in the sewage sludge during October and November is considered to be of radio-pharmaceutical origin. Therapeutic use of activities in the order of 1-3 GBq was employed on a regular out-patient basis by several local hospitals prior to detection.

Thus – despite the reported effluents of Iodine-131 in both gaseous and liquid media – the cause for the elevated levels is not sought within its own boundaries by the Eskom authorities, but by looking elsewhere. The excuse for this oversight is given boldly at 2.7 on page 5:

> There is no reason to suppose that this can be attributed to the operation of the power station particularly as no other fission products were detected.

Amazingly, on the very next page 6 at Figure 4 the presence of Cobalt-60 is shown in the same weeks that the high levels of Iodine-131 were detected. Nevertheless, the authorities are determined at all costs to pursue the "radiotherapy" hypothesis. In their Introduction on page 1 they state:

> The unusual occurrence of this isotope [Iodine-131], it is believed, can be attributed to the presence of a patient in the area undergoing radiotherapy, although this supposition cannot be proven despite the co-operation of the medical authorities.

So we go from "belief" to "supposition" to "hypothesis" to "proof" in a few easy steps. All that remains "with the co-operation of the medical authorities" is the proof. Any one single patient will help to prove the hypothesis, as long as we can find one. Meanwhile the gaseous effluent from KPNS has risen from 73.9 million Bq in 1984 to over 2 billion Bq in 1988, 1989 and 1991, while the liquid effluent levels have gone from 12 500 Bq in 1984 to over 10 million Bq in 1986, 1987, 1988, and 1989, dropping back to over one million Bq in 1990, before climbing back to a record 3.9 billion Bq in 1995 (see Tables II and III, Appendix XIV and XV of this report).

No mention is made of Iodine-131 in the ESL Report for 1991and in 1992 the occurrence was said "to be attributable to a non-Koeberg source" (Abstract, page 1). Once again the Abstract on page 2 of the 1993 ESL Report states:

> I-131 was detected at activities above the reporting levels on 12 occasions [in Melkbos sewage sludge], but this phenomenon may be attributable to a non-Koeberg source.

Paragraph 3.5.1 on page 3 mentions that elevated levels occurred "especially in the last four months of the year" and this is shown on Table 1 of the report at page 4. This is not surprising, considering the liquid releases from September 1993 given in Appendix 2 of the ESL Report, which bears the hand-written comment: "(Due to the release via SEC old AADQs ... assumed)" (see Appendix XVII of this report). Thus the percentage by which the isotopes associated with nuclear reactors exceed the original AADQs as follows:

Mn-54	125%	
Ag-110		175%
Sb-124	490%	

No wonder, then, that the Council for Nuclear Safety saw fit to introduce revised AADQs in October of the same year.

Moreover, on 28 March 1995, barely one year into the new democratic order, the ESL Report for 1994 announces:

> A very positive development was the resolution of the Iodine-131 in Melkbosstrand sewage sludge issue.... A joint investigation by ESKOM, the Council for Nuclear Safety (CNS) and the Department of Health was successfully concluded when the latter [i.e. the Department of Health] traced two residents who were receiving radiotherapy. Treatment dates were consistent with the two most-recent occurrences of I-131 in the sludge.

And what a relief that must have been!

7. A Brief Examination of Recent Annual Reports from the Nuclear Authorities

As might be expected, the authorities tasked with managing the nuclear industry are very brief in reflecting all the above information.

In its Annual Report 2005, Eskom has a short reference to nuclear safety on page 30 (all extracts given in Appendix XVIII). It mentions three tiers of nuclear safety governance:

(i) a Sustainability Committee of the Board;

(ii) a Nuclear Management Committee, chaired by the Managing Director of the Generation Division; and

(iii) the Safety Review Group -

> ... a forum that brings together nuclear expertise from different parts of Eskom for the purposes of meaningfully debating and evaluating nuclear safety issues, and making appropriate recommendations to senior management and the higher tiers of committees.

On page 112 of Eskom's Annual Report it is mentioned that –

> Eskom's nuclear safety performance continues to meet world standards as measured against the latest available information on pressurised water reactors of a similar design. Koeberg performance is calculated monthly using the performance indicator procedures of the World Association of Nuclear Operators (WANO), and benchmarked against the latest results available from WANO which are published quarterly.

Again, it would be useful to get access to these performance indicators and benchmarks.

In the Director's Report on page 119, the only performance indicator revealed at 4.2 is Radiation exposure, milliSieverts per annum with a footnote that this is calculated as a twelve-month moving indicator. Nevertheless, this is indicated as having been 0.0079 mSv in March 2005, with a target of 0.25 mSv, the limit set by the National Nuclear Regulator. Since this is a dose rate calculated from actual releases reduced by multi-factoral mathematics (whose method is not open to scrutiny) and then averaged over twelve months, it is hardly revealing, and could mean anything you want it to, provided you knew how to manipulate the different factors. These figures are repeated at Table 1 on page 185 and run pretty uneventfully back to 1995 on page 186 - and that is all.

In the Department of Minerals and Energy (DME) Annual Report of 2003 (extracts supplied as Appendix XIX of this report), there is no information supplied whatsoever, except for an allusion to a directorate called "Nuclear Safety" in the Nuclear sub-programme described on page 18. On page 18 of the DME Annual Report, however, it does refer to the National Nuclear Regulator Act, 1999 (Act 47 of 1999, or NNRA, of which excerpts are provided in Appendix I of this report), which "... provides for the protection of persons, property and the environment against nuclear damage ...". One therefore relies exclusively on the National Nuclear Regulator (NNR) for information in the public domain.

Indeed, the very wording of the above statement by the DME is drawn verbatim from the NNRA at section 5 (a) (see Appendix I of this report). In section 6(1) there is an appeal to co-operative governance as contemplated in Chapter 3 of the Constitution, read together with section 239 of the Constitution, in order to "ensure the effective monitoring and control of the nuclear hazard;" [NNRA, section 6(1)(a)]

The National Nuclear Regulator is further instructed in the NNRA, section 7(1)(g) to "advise the Minister on matters associated with any action or condition which – (i) is capable of causing nuclear damage;". At section 7(1)(j) of the NNRA, the regulator –

> ... must produce and submit to the Minister an annual public report on the health and safety related to workers, the public and the environment associated with all sites including, but not limited to, the prescribed contents.

Again in section 7(2) of the NNRA –

> The Minister must table to Parliament the annual public report submitted to him or her in terms of subsection 1(j) within 14 days after it is so submitted if Parliament is in ordinary session or, if Parliament is not in ordinary session, within 14 days after the commencement of its next ordinary session.

Although we have not yet established whether the NNR Annual Report was in fact tabled in Parliament, we were sufficiently gratified to discover (albeit with a little difficulty) that the report itself was in fact obtainable and is further discussed below. A copy of the NNR Annual Report 2004/2005 is also now obtainable from the Cape Town Branch of Earthlife Africa, while relevant extracts are provided in Appendix XX of this report.

Section 8 (1)(a) of the NNRA describes the composition of the Board of Directors. In the NNR Annual Report 2004/2005, the mandatory twelve Board members are given on pages 4 and 5:

(i) two nuclear physicists: the Chairperson of the NNR Board, Professor Bharuth-Ram, and Dr Simanga Tsela, who also sits on the International Committee for Radiological Protection;

(ii) one representative from the Office of the Presidency (Goolam Aboobaker, a medical physicist);

(iii) two representatives from the Department of Environmental Affairs and Tourism: Thembisile Khumalo, who specialises in environmental science and hazardous waste issues; and Dr J M Matjila, who is Chief Director: Environmental Quality and Protection;

(iv) three representatives from the Department of Minerals and Energy: Dr Schalk de Waal, Director: Nuclear Safety; H Motaung, Deputy Chief Inspector, Mine Health and Safety (as well as president of the African Mining Association and CEO of Pelawan Investment (Pty) Ltd); and Mrs T Zungu, Chief Director: Audit Services;

(v) three representatives from business: one who is mandated to represent organised business, Dr J M Stewart, formerly employed by the Chamber of Mines and currently consulting to the mining industry on sustainable development; Ms T Mgoduso, CEO of Freight Dynamics, a subsidiary of Transnet; Ms T Mashanda, Executive Finance Manager for Africa from Multichoice (Africa) (Pty) Ltd; and Dr T Lesoli, manager of a health products distribution company, Mother Earth Distributors;

(vi) a representative of the Health Professions (but a lawyer by training), Adv B M Mkhize, CEO of the Health Professions Council;

(vii) one representative of organised labour, Derek Elbrecht, National Treasurer of the National Union of Mineworkers;

(viii) one representative of civil society, Ds Pieter Groves, formerly of the Namakwaland Aksie vir die Gemeenskap en die Omgewing, based in Kommaggas, Namaqualand, but not mentioned on pages 4 and 5 of the NNR Annual Report for 2004/2005.

The strangest part of this Board line-up is that the NNRA expressly confines the numbers to a maximum of twelve members, at section 8 (4)(a)(vi). One suspects that the Board has been artificially loaded in favour of the South African Government and the mining industry, while marginalising interested and affected parties in civil society, since only one representative each is mandatory from the two Departments and organised business. One is also surprised to see the absence of representatives from the Departments of Health, and Water and Forestry, as well as those from local and regional government, especially the City of Cape Town, whose public health is directly threatened by the continued existence of KNPS and the threat posed by the new Pebble Bed Modular Reactor.

In the Chairman's Forward to the NNR Annual Report2005/2005 at page 6, the Chairman expresses his gratitude to "interaction ... with public organisations such as Earthlife Africa", but makes no mention of the newly released Draft Regulations, which seeks to amend the NNRA to exclude members of the public from voting or holding office in the Koeberg Public Safety Information Forum. It also seeks to similarly exclude all members of the Namaqualand community beyond the waste facility at Vaalputs from its own mandatory public forum. The Chairman's Forward is also silent on any unscheduled and excessive releases from KNPS.

With regard to the Chief Executive Officer's Forward, however, the following paragraph is included at page 8:

> The results of the NNR's monitoring of ongoing operations at Koeberg are that, while a total of 345 problem notifications/occurrences were reported, none of them was significant in terms of occupational and public safety as defined in the NNR Act.

This is not the place to interrogate the entire report, since a full analysis of the NNR Annual Report itself is beyond the brief issued to this consultant by Earthlife Africa. Nevertheless, a copy of the relevant section on KNPS is to be found in Appendix 000. A further reference is made on page 17 of the NNR Annual Report to the 345 Problem Notifications, which are broken down as follows:

Category One	immediate notification of the NNR	14
Category Two	24-hour notification of the NNR	12
Category Three	notification of the NNR < five working days	319

No further details are given and this concludes the section on Koeberg.

What is relevant, however is section 2 of the NNR Annual Report 2004/2005 (“Public Exposure to Radiation”) at pages 11-12, as well as section 3 (“Environmental Safety”) on page 12. Section 2 begins as follows:

> Various gaseous and liquid radioactive emissions and effluents are produced during the process of nuclear generation. These emissions are treated by dedicated clean-up systems, which remove most of the radioactivity from them prior to discharge to the environment. Public exposure is controlled within strictly defined limits through the implementation of a radiological emissions and effluent management programme. This ensures that the discharges of radioactivity from Koeberg result in no significant risk to the public.

The key phrase here is “dedicated clean-up systems”. What we need to know in order to properly assess the effectiveness of these measures is the amount of radioactivity in Becquerels before treatment inside the reactor building compared with the same measure outside the reactor building in terms of the long-lived radioactive isotopes Strontium-90, Iodine-131 and Cesium-137. The headings “Before” and “After” above the relevant columns in the loose photostatted sheets currently held by Earthlife Africa, Cape Town Branch cannot possibly refer to these “dedicated clean-up systems, since – in all cases – the quantity of Becquerels increase from those listed under “Before” to those listed under “After”, so no assurance is provided at all.

The first paragraph under section 2 of the NNR Annual Report 2004/2005 continues as follows:

> A key feature of this programme is the control of radioactivity in effluent discharges to within the Annual Authorised Discharge Quantities (AADQ). In addition to continuous monitoring of radioactivity in effluent, radiological surveillance of the environment is also carried out. In this way, independent and strict control is maintained on public exposure to radioactive releases.

The difficulties with AADQs have already been explained above, in that the AADQs were all inflated by several orders of magnitude in October 1993 by the old Council for Nuclear Safety immediately prior to the advent of the new democratic order. No attempt has yet been made by the NNR to re-assess the appropriateness of these AADQs since inception. In order to compare the true value of their efforts, therefore, the NNR should be reporting strictly on the amount of radioactive isotopes in gaseous and liquid effluents relative to 1984, when the KNPS first came on stream.

The first gaseous releases of Iodine-131 in 1984 were of the order of 73.9 million Becquerels, while the liquid effluent releases were 12 400 Becquerels. The highest recorded level for gaseous releases of Iodine-131 was recorded as 2.6 billion Becquerels in 1988 and levels have never dropped below the original mark in 1984 up to, and including 2002. The highest recorded level for liquid effluent releases (a more likely source of radioactive Iodine-131 in Melkbos sewage sludge) was 3.9 billion Becquerels in 1995 and the levels have never dropped below 10 million Becquerels up to, and including, 2002. Surely these figures should be given in unadulterated format in the NNR Annual Reports?

Unfortunately, however, in the immediately following paragraph on page 11 of the NNR Annual Report 2004/2005 the NNR sees fit to further obfuscate the matter by referring only to "a projected total individual dose of 8.72 microSieverts to the hypothetically most exposed group". More mumbo-jumbo, less science. We will not detain the benighted reader further by trying to unpack the horrors of radiobiology, for which see Section 5.3 above.

In the Table that follows on page 12 and in Section 3 of the NNR Annual Report 2004/2005 there is no mention of Strontium-90 whatsoever and only one brief mention is given on Cesium-137 as follows:

> Very small amounts of Koeberg effluent could be identified in sewage sludge, while reportable activities of 131-I(iodine), originating from therapeutic or diagnostic medical treatment of local residents, were detected on various occasions in Melkbosstrand sewage sludge. Trace quantities of Co-60 and Cs-137 were also detected in the effluent sample from the Melkbos sewage works.

The Iodine-131 appearance in Melkbos sewage sludge is discussed in this report at Section 6.6 above, so we will merely note the reappearance of this hypothesis in the NNR Report. We are mightily relived, however, that no reference was made to above-ground nuclear weapons testing with the appearance of Cesium-137 in sewage effluent and await further explanation from Eskom and the NNR with interest.

We further note a reference to the French CP-1 family of nuclear power plants further down on page 12 of the NNR Report, while on page 13 reference is made to the "USA Davis Besse Nuclear Power Plant incident" and Belgian Tihanhge-1, which was also mentioned in the Earthlife Africa Campaign Briefing Paper #2: "Safety Issues in the South African Nuclear Industry: Koeberg and the PBMR" (p.11 at bottom).

From all of the above, therefore, it is our contention that – based on the understanding that the substantive risk to public health is posed by the internal ingestion or inhalation of the long-lived radioactive isotopes Strontium-90, Iodine-131 and Cesium-137 which are directly attributable to the production of electricity by nuclear fission at Koeberg Nuclear Power Station – the current threat to public health is both under-reported and obfuscated by Eskom, the National Nuclear Regulator and the Minister of Minerals and Energy. We thus firmly believe that they are collectively and severally in breach of Section 26 of the Constitution in that they have failed to exercise their minds in the fulfilment of their statutory duty to protect the general public and the environment from the harmful effects of man-made ionising radiation, consumed internally.

8. Recommendations and Suggestions for Further Research

[TO BE FINALISED IN CONSULTATION WITH ALL CADRES IN NOVEMBER]

(a) a more thorough interrogation of the levels of Iodine-131, Strontium-90 and Cesium-137 released by KNPS over the last twenty years by closer scrutiny of documents still held by Eskom, NECSA and the NNR in terms of the National Nuclear Regulator Act No. 47 of 1999, section 40 (a)-(d) [attached as Appendix I of this report];

(b) a thoroughgoing examination of all records pertaining to airborne, liquid- and solid-medium beta activity that may be held by various municipalities and provincial health authorities;

(c) an examination of all records pertaining to beta activity in sewage effluent and sewage sludge on the Atlantic Seaboard;

(d) an examination of all records pertaining to beta activity in meat, leafy vegetables, milk and dairy products produced within a radius of 30 km of KNPS;

(e) an examination of all records pertaining to beta activity in filter feeders and crustaceans found within 500 metres of the shoreline of the South-Western Cape Coast between Saldanha Bay and Cape Point;

(f) a thoroughgoing and independent review of all scientific assumptions, sampling techniques methods, and error detection methods relating to existing reports on radioactive waste products released by KNPS, with particular reference to:

(i) the linear low-dose hypothesis;

(ii) the National Nuclear Regulator's Annual Authorised Discharge Quantities (AADQs)

(iii) statistical sampling of exposure to ionising radiation based on thermo-luminescent dosimeters (TLDs);

(iv) the "background radiation", "depleted Potassium-40 levels", "nuclear weapons fallout", "radio-therapy" hypotheses as applied to the following sites:

(a) Sea Point
(b) Blaauwbergplaas
(c) Melkbosstrand Sewage Works

(d) Yzerfontein
(e) Camphill Village
(f) Mamre
(g) Atlantis
(h) Malmesbury
(i) SAP Durbanville
(g) an independent and repeated random sample of beta activity and the presence of Iodine-131, Strontium-90 and Cesium-137 in airborne particulates, freshwater, marine life, foodstuffs, and Melkbosstrand sewage sludge.

(h) a comprehensive and independent audit of all bone, breast and soft tissue cancers within a 30-km radius of Koeberg, with particular emphasis on the age-group 0-14 for leukaemia, and within the urban clusters of Milnerton, Table View, Melkbosstrand, Atlantis and Malmesbury.

We trust that potential donors, funders and well-wishers will see fit to further fund these enquiries so that the public's right to know, their ability to make informed choices concerning policy decisions, and their ability to engage with policy makers with regard to public expenditures in support of such decisions is enhanced. We also foresee that this information will be publicly disseminated in such a way as to make adequate public participation in the forthcoming second Environmental Impact Assessment into the proposed Pebble Bed Modular Reactor (PBMR) at Koeberg, 28 km NE of Cape Town.

We believe that evidence drawn from Koeberg Nuclear Power Station's Environmental Laboratory Survey Annual Reports over the last twenty years makes it abundantly clear that a renewal of Eskom's licence over another 40 years or more is in direct contravention of Section 26 of our Constitution and should be opposed by all citizens of the South-Western Cape in the interests of environmental justice and inter-generational equity.