Figure 3.14: Variation in total workforce numbers and percentage annual turnover in workforce at Rössing Uranium Mine, from 1980 to 1988. (Drawn from data provided by E. Ten Kate).

All Rössing employees are provided with extensive and intensive training to enable them to conduct their work competently, productively, safely and with regard for the environment. Frequent refresher training courses are provided, and employees are also trained to efficiently undertake the tasks required of them when they are promoted to the next job level.

3.8.3 Associated Projects

The Rössing mine continually upgrades its operations through the introduction of re-designed equipment and plant. This work is, however, of a batch nature, i.e. the annual acid plant overhaul requires a workforce of some 190 contractors for a period of approximately 4 weeks once per year only, a shovel overhaul requires people of different expertise for a period of 3 months once per year. To cater for this type of work Rössing uses up to ten different contracting companies who have the expertise and the workforce inside Namibia to allow them to move their people from different areas at short notice. Projects at Rössing vary enormously, and in the past have included: construction of hospitals, houses, roads and sewerage plants, the installation of computers and computer control systems, heavy electrical distribution systems, the construction of shovels, modifications to trucks, etc. Thus the number of contractors' employees can vary from ten to approximately 300 per month during any twelve month period.

3.9 Environmental Health and Safety

Most activities in a modern world involve some form of risk and uranium mining is no exception. Workers may be exposed to a wide range of potential hazards which can cause immediate and adverse effects or may lead to more subtle, less easily recognized and long-term adverse effects (Swiegers &

Jooste, 1987). Rössing is concerned about these activities and their potential effect on the workforce and environment, and has introduced a comprehensive preventative programme which conforms to standards that are consistent with the best practices in the world. Wherever possible, the best available technology is applied to reduce the impact of operations on the environment, and those conditions that are potentially hazardous to the employee or to the environment are carefully monitored.

Environmental health and safety programmes at Rössing are centralized in a single division, with the disciplines of environmental surveillance and environmental control grouped together within one department - "Environmental Health Services". The major goal of this department is to provide the safest, healthiest and most ecologically secure environment. Environmental medicine falls under the medical health services and reports to the Personnel Manager.

3.9.1 Environmental Health

All environmental health programmes at Rössing have been developed on a risk-based approach, taking into account the degree of exposure, the target organ involved, the type of work carried out, meteorological conditions and even the location of residential areas.

At Rössing, environmental health includes the studies that fall within the province of the Safety/Loss Control Officer, Occupational Hygienist, Environmentalist, Health Physicist and Engineer, for the recognition, evaluation and control of occupational and non-occupational hazards and environmental control (Jooste, 1990).

In the anticipation or recognition phase, use is made of all available information and knowledge regarding the occupational environment/workplace, as well as the operations and processes, to anticipate or recognize potential environmental hygiene hazards. In particular, assessments are made of the potential environmental health hazards due to the:

- raw materials used,
- processes used,
- materials added,
- equipment,
- operational procedures,
- suitability of building structure, and
- route of entry of toxic materials,

as well as the suitability of protective equipment required for the workforce. The variables that are considered when evaluating the degree of hazard to the workforce or the environment are:

- chemical concentration,
- route of exposure - (inhalation, ingestion, absorption),
- individual variations - (age, sex, etc.),
- frequency of exposure,
- previous work experience,
- chemical formulations,
- controls in use,
- environmental factors - (temperature, humidity, etc.),
- costs versus correction factor, etc.

The potential environmental health hazards which are carefully monitored on the mine include radiation (external and internal), dust, gasses, fumes and acid mist, noise, ergonomics, groundwater quality control and heat stress, as well as the impacts of these factors on the environment.

The Rössing Uranium Mine has a Health, Safety and Environmental Services Department, with a staff of between 17 and 24 people. The Head of this Department reports to the Assistant General Manager of the mine. The Department is structured into five sections, Namely: environmental surveillance, health physics, occupational hygiene, loss control/safety and first aid training (information supplied by A.W.J. Jooste).

3.9.1.1 *Radiation*

External radiation in a uranium mine arises from direct gamma radiation from the daughter products of uranium and thorium, and from radon gas emanating from the mine and tailings, (See Table 3.3). Because of the low grade of the Rössing deposits, radiation levels in the open pit and processing plant are usually low. Emphasis is placed on the prevention of internal radiation through ingestion or inhalation of radioactive dust, particularly where airborne uranium poses a dual threat as a toxic metal and a source of radiation.

Routine radiation monitoring programmes have been developed to monitor radiation in the air, water, soil and vegetation both on the mine property (Plate 7) and at strategic locations further afield. The final product area, where the U_3O_8 is roasted and packed, is recognized as an area where the workers have the greatest potential for exposure to radiation and radiotoxicity. This area is subject to special precautions to minimize employee exposure to radiation, and all employees undergo monthly urinalyses to check for possible internal exposure. All employees entering or leaving the final product recovery section are monitored with a portal radiation scanner to ensure that they are free from contamination (Swiegers & Jooste, 1987).

External radiation and radon measurements have been carried out extensively in all the operating areas as well as existing residences and in buildings. Extensive surveys at the mine have shown that radon levels are very low due to rapid dilution of radon and its daughter products in the atmosphere. Standards set by the International Commission on Radiological Protection (ICRP) and the South African Atomic Energy Act of 1967 are easily met (Dames & Moore, 1983b). No evidence has been found from direct measurements or from modelling studies that Rössing employees or the general public have ever been exposed to radiation levels above, or close to, limits recommended by the ICRP (Swiegers & Jooste, 1987).

To place the radiation levels at Rössing in perspective, the average annual radiation dose received by Rössing's production workers amounts to 3.3 mSv $year^{-1}$, made up of external plus internal radiation. The ICRP's recommended limit for additional radiation exposure of employees in the nuclear industry is 20 mSv per year. Thus the average annual radiation exposure of Rössing's production workers is well within the ICRP's limits (A.W.J. Jooste, personal communication).

3.9.1.2 *Dust*

Possible exposure to dust containing silica and radioactive materials is a potential health hazard at Rössing. Strict precautions are taken to minimize this problem, such as wetting down of rock piles and haul roads in the open pit, as well as dust collection in the crushing plant (See Section 3.6.3).

In Namibia, the Atmospheric Pollution Prevention Ordinance of 1976 regulates atmospheric pollution by noxious gases, dust, smoke and vehicle emissions within areas that have been declared to be controlled areas. Rössing operates a comprehensive air quality surveillance programme, with air samplers located at various locations on the mine and at the residential areas. Typical total dust levels average about 30 $\mu g\ m^{-3}$ at Arandis and 60 $\mu g\ m^{-3}$ at Namib Lodge (Swiegers & Jooste, 1987). These levels are well below the target levels of a maximum of 150 $\mu g\ m^{-3}$ set by the Air Pollution Control Ordinance in South Africa.

In the open pit, respirable dust levels can reach far higher levels than at other points on the mine, despite intensive wetting down of all rock piles and road surfaces. Where dust levels exceed 500 μg m^{-3}, all operators are required to use respirators and work within dust-proofed, air-conditioned control cabins. Respirable dust levels also exceed 500 $\mu g\ m^{-3}$ at certain points in the crusher circuits and all operators are required to wear respirators where respirable dust levels exceed 500 $\mu g\ m^{-3}$.

3.9.1.3 *Noise*

At Rössing a major effort is made to control this hazard. Standards are set at 85 dB(A) and, if noise levels exceed this standard, employees are provided with hearing protection. All areas where the noise level is 85 dB(A) or above are identified as noise zones and clearly demarcated, with warning pictograms exhorting employees to wear hearing protectors. Where practicable, noise levels in these zones are reduced by engineering means. All drills, shovels, haultrucks and field equipment are fitted with specially sealed and air conditioned cabins to reduce noise, dust and radiation exposure. All employees who are required to wear hearing protectors are examined and undergo routine annual hearing acuity tests.

3.9.1.4 *Gases*

Gases and fumes that occur in particular sections of the plant or workshops at Rössing consist mainly of sulphur dioxide, welding gases and exhaust fumes. The concentrations of these gases are closely monitored and appropriate measures to minimize contact or reduce the hazard are provided. Wherever necessary, employees are issued with, and required to wear, protective clothing and respirators (Jooste, 1990).

Anhydrous ammonia is stored in four tanks on the Rössing site. Since this represents a potential serious air pollutant in the event of an accidental release, air dispersion modelling has been conducted on various possible scenarios (Van Rensburg, 1990a). The mine has also instituted formalized emergency procedures designed to minimize damage in the event of accidental releases.

By far the biggest air pollutant emitted from the mine is sulphur dioxide from the acid plant. Both during normal operation and especially during start-up, SO_2 is released into the atmosphere. A detailed study has been carried out to determine the extent of the problem and define appropriate remedial measures (Van Rensburg, 1990b).

Monitoring of, and preventative measures against, the radioactive gas radon have been described in Section 3.9.1.1.

3.9.1.5 *Water quality*

The South African Water Act, Number 54 of 1956, as administered by the Namibian Department of Water Affairs, applies in Namibia. The Water Act authorizes the Minister responsible for Water Affairs to prescribe requirements relating to the purification of effluent and to specify steps to be taken by mining (and other) operations, in order to prevent the pollution of water by seepage or drainage from the area, both while operations are in progress and after the abandonment thereof (Swiegers & Jooste, 1987). Permit conditions issued by the Department of Water Affairs to Rössing require that water released at any point in the mining process must meet strict standards. Contaminated water is not released into the environment.

All aquifers across the mine site have been identified by means of extensive geophysical surveys, using both resistivity and electromagnetic techniques (Dames & Moore, 1981; 1983a). Seepage control from the tailings dam is achieved by monitoring seepage flows and by collecting and recycling seepage for re-use in the mine or in the plant (See Section 3.6.2.4). The primary objective is to prevent pollution of underground water in the Khan River and infiltration of seepage into groundwater off the mining grant (Swiegers & Jooste, 1987).

A comprehensive monitoring borehole system consisting of 95 boreholes, has been installed to the west, south-west, east and north-east of the tailings dam. These boreholes were sited to ensure that no seepage route existed that would allow contamination of the Khan River. The monitoring boreholes are arranged in three zones around the tailings impoundment and are supplemented with a cluster of 31 de-watering wells sited in the more permeable zones to the west and south-west, and a system of cut-off trenches and pumps in the bed of each gorge (Figure 3.11). Seepage and groundwater recovered in these wells and cut-off trenches is pumped back for re-use either in the metallurgical process or for dust suppression in the mining process.

Each month, the depth of water in each borehole is recorded and water samples are collected and analyzed for several variables of concern, such as chlorides, nitrates, sulphates, radium, etc. Duplicate samples are submitted to the Department of Water Affairs who conduct their own analyses to evaluate compliance with the company's Waste Effluent Permit (Swiegers & Jooste, 1987).

A computer programme TARFAR has been developed to predict the effects of tailings deposition on the flow of tailings solution and contaminants on groundwater regimes on the mine site (Dames & Moore, 1985; Swiegers & Jooste, 1987). Seepage flow and chemical data pertaining to the gorges and monitoring boreholes is recorded, collated and fed into the computer programme for analysis and evaluation. This data is used for seepage model prediction and has successfully predicted the migration of seepage plumes from the tailings impoundment (Swiegers & Jooste, 1987), which in turn has allowed appropriate action to be taken.

3.9.2 Environmental Medicine

General occupational diseases may be caused by physical, chemical, biological and ergonomical agents. The disease pattern varies from industry to industry and the target organ involved also differs from situation to situation. Health effects which are of special concern to the mining and milling of uranium bearing ores include those due to the inhalation of radioactive materials, as well as those associated with chronic exposure to low radiation levels (Swiegers & Jooste, 1987).

All Rössing employees are medically examined both prior to, and upon termination, of employment. In addition, all employees undergo regular medical examinations during employment, the frequency and extent of these examinations is determined by the type of activity each employee performs (Swiegers & Jooste, 1987). Special investigations are an integral part of the examination and supplement the conventional medical questionnaire and physical examination. Tests performed on a routine basis include: audiograms, visual acuity, colour and nightvision, chest X-Rays, lung function, sputum cytology, full blood count, blood glucose levels, serum creatinine, liver function and electro-cardiogram (ECG). Additional tests are conducted when indicated and all clinical data is computerized and correlated with environmental data such as dosimeter readings, uranium excretion in urine, and the levels of dust, radiation and noise measured on the mine. Group and individual analyses are conducted annually. The information obtained from cross-sectional studies enables the physicians to advise Rössing Management and also allows Operations staff to act appropriately when indicated (Swiegers & Jooste, 1987).

A fundamental part of any environmental medical surveillance programme is the timely identification of vulnerable individuals, the identification of occupational exposure and the screening of individuals for occupational and non-occupational diseases. The entire Rössing workforce is provided with a standard of health protection that is exceptionally high for any industry.

3.9.2.1 *Identification of vulnerable individuals*

Some people are more susceptible to particular diseases than others and it is therefore imperative to identify these individuals and to employ them in non-risk areas. Of special interest are the chronic obstructive pulmonary diseases which represent a spectrum of diseases which include asthma, bronchitis and emphysema. Atopic or extrinsic asthma based on IgE-dependent allergy is readily recognized and is often associated with eczema and allergic rhinitis and has a hereditary basis. Positive skin tests and high blood IgE levels identify susceptible individuals, who are then employed outside dusty and gas-laden areas (Swiegers & Jooste, 1987).

Genetic factors together with certain environmental agents may play a role in the etiology of lung cancer. This is of special significance in a uranium mine because ionizing radiation is known to cause lung cancer in both smokers and non-smokers, though the risk is substantially greater in smokers. It is therefore imperative to develop methods to identify individuals at high risk of lung cancer and limit their exposure (Swiegers & Jooste, 1987).

3.9.2.2 *Identification of occupational exposure*

Environmental monitoring has two main purposes. Firstly, the data allow appropriate actions to be taken so as to prevent the particular environmental agents which are monitored from exceeding safe limits. Secondly, individual exposure can be calculated through indirect methods such as the determination of annual limit intakes (ALI). The purpose of personal monitoring is to calculate the individual's exposure directly. Here, personal dust samplers are worn for a period of 8 hours and the respirable portion of the dust sampled is analyzed.

Dosimeters provide an indication of the external radiation dose received while the uranium level excreted in the urine is indicative of the exposure to the biologically soluble portions of uranium. At Rössing, these tests are conducted routinely and the quantity of natural uranium in the lungs of employees working in the uranium drying and packaging area is measured. External dose rates are on average less than 10 % of the maximum permissible dose of 25 μSv hr^{-1}. To date, the mean annual dose collected was 2.48 mSv per annum at the Final Product Recovery plant. None of the Final Product Recovery workers have had lung uranium levels in excess of the maximum permissible level of 26.5 mg uranium (Swiegers & Jooste, 1987).