THE DECOMMISSIONING OF THE WATER BOILER REACTOR

Shin Chang, Shen-Yu Lai
Atomic Energy Council, Taiwan, China

ABSTRACT

Following completion of service, the Water Boiler Reactor (WBR) has been decommissioned by the Institute of Nuclear Energy Research (INER) under the Atomic Energy Council's (AEC) regulation. The WBR is a light water moderated and graphite reflected research reactor with peak thermal power of 100 kW. The unique feature of the WBR is that it is fueled with uranyl sulfate (UO_2SO_4) which is in liquid form. Since there is another research reactor owned by INER of megawatt scale in the planning stages for decommissioning, the WBR project was conducted with great care to accumulate experience. Extensive planning by INER and step-by-step regulative activities by AEC were followed regardless of the structural simplicity of the WBR. Valuable information was gathered in the task and will be useful for preparing future decommissioning needs. The major work in the WBR decommissioning project was finished within six months and the accumulated dose received during the work was 19.63mSv.

INTRODUCTION

Six research reactors and six nuclear power units have been built in Taiwan. The first nuclear facility to be decommissioned is the Tsing Hua Argonaut Reactor (THAR) owned by National Tsing Hua University (NTHU) (Shen & Chang, 1994). The THAR reactor was built in 1973 and decommissioned in 1993. With very complete planning of work and fully devoted personnel of NTHU, the THAR decommissioning project was carried out successfully and satisfactorily. Much useful experience was collected through that project and the most important lesson learned was regarding the planning of work. In order to reduce the amount of radioactive waste, to minimize the personnel dose and to confine the expanse within the budget, many decisions were made with great care during the planning stage.

The Water Boiler Reactor (WBR), which was constructed and operated by the Institute of Nuclear Energy Research, is the second nuclear facility to be decommissioned in Taiwan. The construction of WBR was finished by the end of 1982 and the first criticality was reached on February 23, 1983. The original design purpose of WBR was to generate pure neutron free gamma sources for irradiation purpose. However, due to the power oscillation problem, the operation of WBR has never been successful. Finally, the permanent shut down decision was made on April 29, 1991. The decommissioning of the facility was then planned.

FACILITY DESCRIPTION

Like the JRR-1 in Japan, WBR is an aqueous homogeneous solution reactor using enriched uranium fuel and light water as the moderator. A uranyl sulfate fuel solution fills the core, in cylindrical shape with 54 cm inner diameter and 38 cm in height. The core barrel is made of SS-316L plate with 0.48 cm in thickness and structure strengthening ring on the side. There are five control rod guide tubes penetrating the core vertically. Four rods are used for safety and one rod for regulating power. The control material is Cd and B_4C. The cooling system is made of ten layers of SS-316L tube (0.95 cm in diameter). It can be seen from Figure 1 that the overflow chamber (20 cm in diameter and 76 cm in height) is connected to the top of the core directly. The purpose of this tank is to provide expansion space for the fuel solution during temperature increases and power maneuvering. The reactor core and overfill tank are further placed in an aluminum container. Graphite plate is used to fill the space between the reactor core and the aluminum

aluminum container. Graphite plate is used to fill the space between the reactor core and the aluminum container as inner reflector design. Outside of the aluminum container is another layer of graphite of 30 cm thickness. This graphite layer works as the outer reflector. As the outer most area, the reactor is surrounded by a 3.5 m thick concrete biological shield.

There are two loops composing the cooling system of the WBR. The primary loop is a closed cycle design, which transfers fission energy to the heat exchanger, through which the thermal energy is transferred to the cooling tower on the building roof by the secondary system. The coolant is demineralized light water. In order to remove the H_2 and O_2 produced by radiolysis, the WBR is equipped with a gas recombiner. Other major components of the WBR are a control system, a ventilation system, a protective system and experimental equipment.

DECOMMISSIONING

According to the regulation issued by the Atomic Energy Council (AEC), dismantling is the only option for research reactors. Before the dismantling work actually took place, the aqueous fuel was first removed from the core. Since the proper way to store the uranyl sulfate, which is highly corrosive, is still under study by INER, the stainless steel tank together with leak detecting equipment was designed for temporary storage. These tanks are designed to store uranyl sulfate safely for at least 10 years under a highly corrosive environment. However, according to the schedule of INER, the acceptable method to treat uranyl sulfate should be available in two to three years. After the fuel was removed, the core system had a complete purge and was ready to be dismantled.

A complete field survey and contamination/activation analysis was performed right after the fuel was removed in order to prepare the detailed dismantling procedure. The reactor building area was measured by swipe tests with one sample per square metre. Water samples from the coolant system were analyzed to discover any radioactive nuclide embodied. Dose rates around the core region together with its peripheral structure were measured directly through the control rod guide tube and horizontal through tube. The data were taken every 10 to 20 cm and the measured results are shown in Figure 2. Since the largest amount of radioactive waste involved in a decommissioning project comes from concrete shielding, the contamination/activation of the biological shielding was further investigated by drilling a sampling hole. The data were also taken every 10 to 20 cm and the activity together with radioactive isotopes measured is shown in Figure 2. Based on those measured and analyzed data, it was confirmed that the reactor associated with its internal parts were significantly contaminated and activated. The de-iodine tank and recombiner system were significantly contaminated but almost not activated. The dismantling of those above-mentioned systems should be carried out with caution during decommissioning. Other systems, such as the graphite reflector and cooling system, also show slight contamination and/or activation. However, the contamination and/or activation is not serious so that special treatment does not seem necessary. Regarding the biological shield, it can be seen from Figure 2 that the contamination is limited to the 10 cm thickness from the inner-most surface. This information provides the basis for the decontamination of the biological shield.

Dismantling of the WBR was commenced after fuel was removed and the safety review process, which was performed by the AEC, was clear. In order to clear a space for the temporary storage of decommissioning waste, the experimental equipment and instrumental equipment were removed first because of its structural simplicity. The removal and disassembly of the reactor core was one of the major tasks for the WBR decommissioning. In order to protect the personnel, an under water cutting device with remote control ability was designed. This cutting pool was also equipped with airborne radiation monitors and gas treatment systems. The effluent gas was routed through a HEPA filter before it was ventilated to the atmosphere. In order to remove the released radioactive substances from the pool water, a water treatment system was also attached to the cutting pool. Another highly contaminated piece of equipment, which had to be dismantled in the cutting pool, was the gas recombiner system. In order to reduce the radioactivity, the gas recombiner tank together with the associated pipes were decontaminated by an ion exchange process.

The reflector layers, both inner reflector and outer reflector, are piled structures with blocks of graphite. Since those graphite blocks were also contaminated, a robot arm controlled from a remote panel was designed to remove it. Regarding the biological shield, since contamination extended to only a 10 cm depth from the inner surface, all the concrete up to the first 15 cm depth was scraped and stored as radioactive waste. Other components were mainly disassembled by a mechanical saw or electric arc, since they were either only slightly contaminated or not contaminated at all. Finally, the interior of the whole building was surveyed to make sure the radiation background was within predetermined levels.

RADIOACTIVE PROTECTION

Protecting the general public from radioactive hazard is the ultimate goal of nuclear facility decommissioning. Thus, environmental monitoring is one of the major tasks within the working scope. Three stages of environmental monitoring were requested by the AEC, namely, prior to, during and after decommissioning. The first stage was to establish the background level and the last stage was to provide long-term tracing. Monitoring items include water samples, soil samples, plant samples, air monitoring and TLD direct exposure, etc. Samples were taken around the reactor building based on weekly and/or monthly periods. It can be seen from Figures 4 and 5 that the WBR decommissioning project did not impose any adverse radiological effect on the environment, because all the measured data were within the fluctuations of the background level.

Protection of the participant workers from radiation exposure was another issue that needed intensive care. Obviously, personnel dosimeter and suitable working dress were strictly required. A health physics control station was set up at the entrance of the reactor building to perform daily radioactive protection and entrance control. Masks with respiratory devices were used in dealing with tasks that may involve airborne radioactive substances. The ventilation system of the reactor building was redesigned prior to the dismantling work for both heath physics and environmental protection purposes. Before any major dismantling work took place, such as reactor core dismantling or graphite block removal, a safety evaluation form had to be filled out by the field chief engineer and health physics representative jointly. The purpose of this evaluation was to point out potential radiological hazards involved and to find out the best working procedure. Also, in order to ensure that all the safety aspects had been considered, several hold-points at major decommissioning steps were established. Whenever a hold-point was reached, the site work could be continued only on approval of the field manger. With all those efforts aforementioned, the total accumulated dose of all 14 workers who participated in the WBR decommissioning project was 19.63mSv. The maximum accumulated dose among the workers was 3.62mSv, which is far below the regulatory threshold.

CONCLUSIONS

It can be seen from various articles published regarding the decommissioning project that the current technology is mature enough to carry out such kind of tasks, not only for research reactors but also on the scale of a nuclear power plant. Various cutting devices and field survey equipment are available to handle the complex geometry and radiation background in a typical nuclear reactor. However, it is obvious that advance technology can ease the problem but not remove the problem. To execute a decommissioning project successfully relies mainly on good planning and management. Even though the scale of the WBR was quite small, the decommissioning project was carried out with great care by INER and AEC. This project served as an exercise of the management ability and cooperation between the different parties. It also served as a practice program in preparation for the forthcoming TRR decommissioning project which is 40 MW scale and also owned by INER. In addition to the field survey and equipment dismantling techniques, the experience mainly gained from the WBR decommissioning project has reconfirmed that:

(1) Good planning work is an important factor to ensure the success of a decommissioning project.

(2) The weights and priorities in the field of project and site management are also key factors to the success.

(3) Skilled and well-trained personnel are essential to carry out a decommissioning project.

(4) Good field management can minimize the personnel doses and the amount of radioactive waste produced.

ACKNOWLEDGEMENTS

Authors greatly appreciate the help and the co-operation of Mr. W. M. Chia, Mr. W. L. Lo, Mr. K. C. Twu and colleagues of the AEC during the WBR decommissioning project.

REFERENCES

Shen, L. and S. Chang. “The Decommissioning of Tsing Hua Argonaut Reactor”: *Proceedings of the* Ninth Pacific Basin Nuclear Conference, Sydney, Australia, May 1-6, 1994, Volume 2, pp 1077-1082.

KEY WORDS

Decommission, Water Boiler Reactor, Research Reactor, Dismantling.

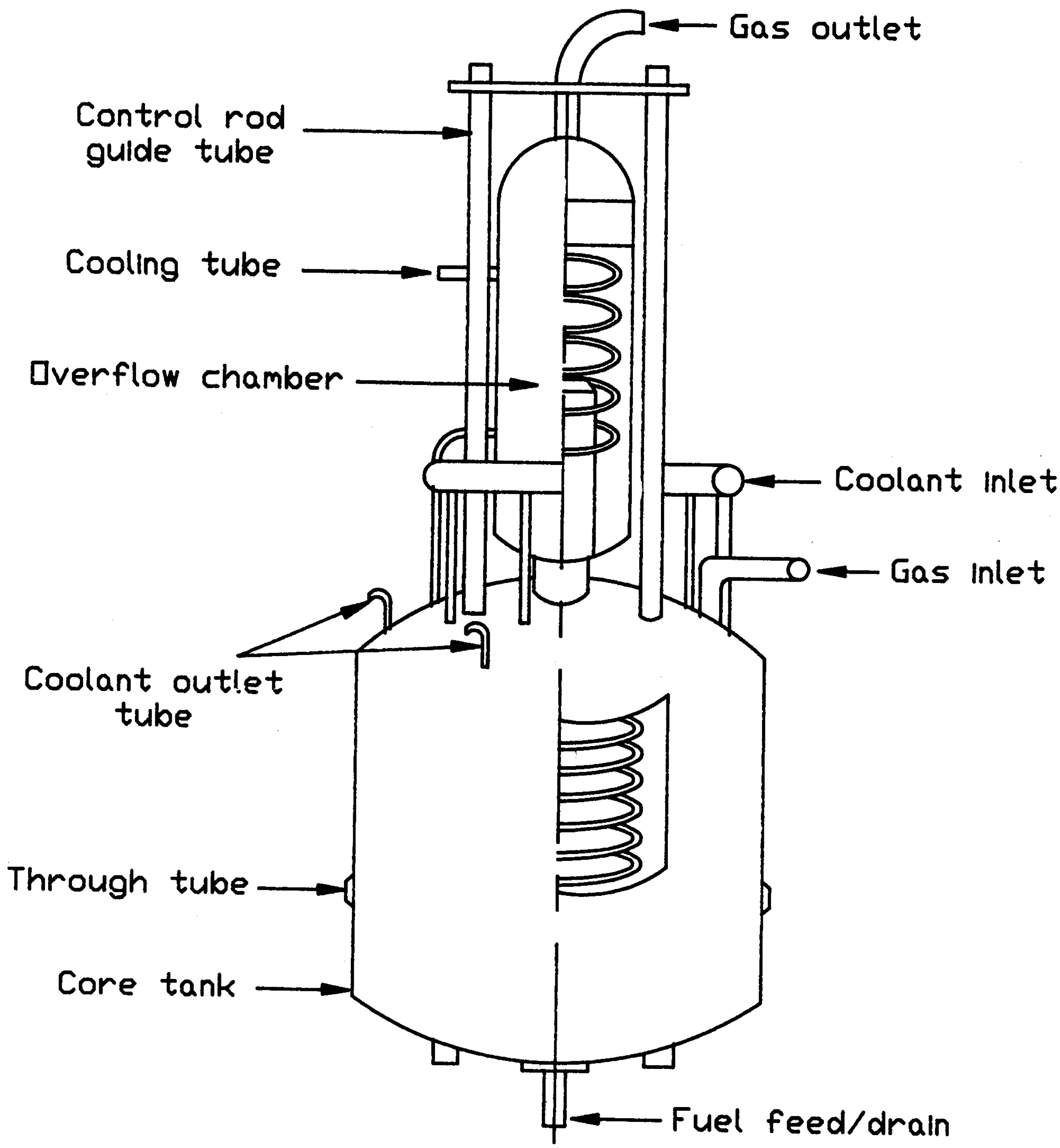

Figure 1 Main Components of WBR Core Design

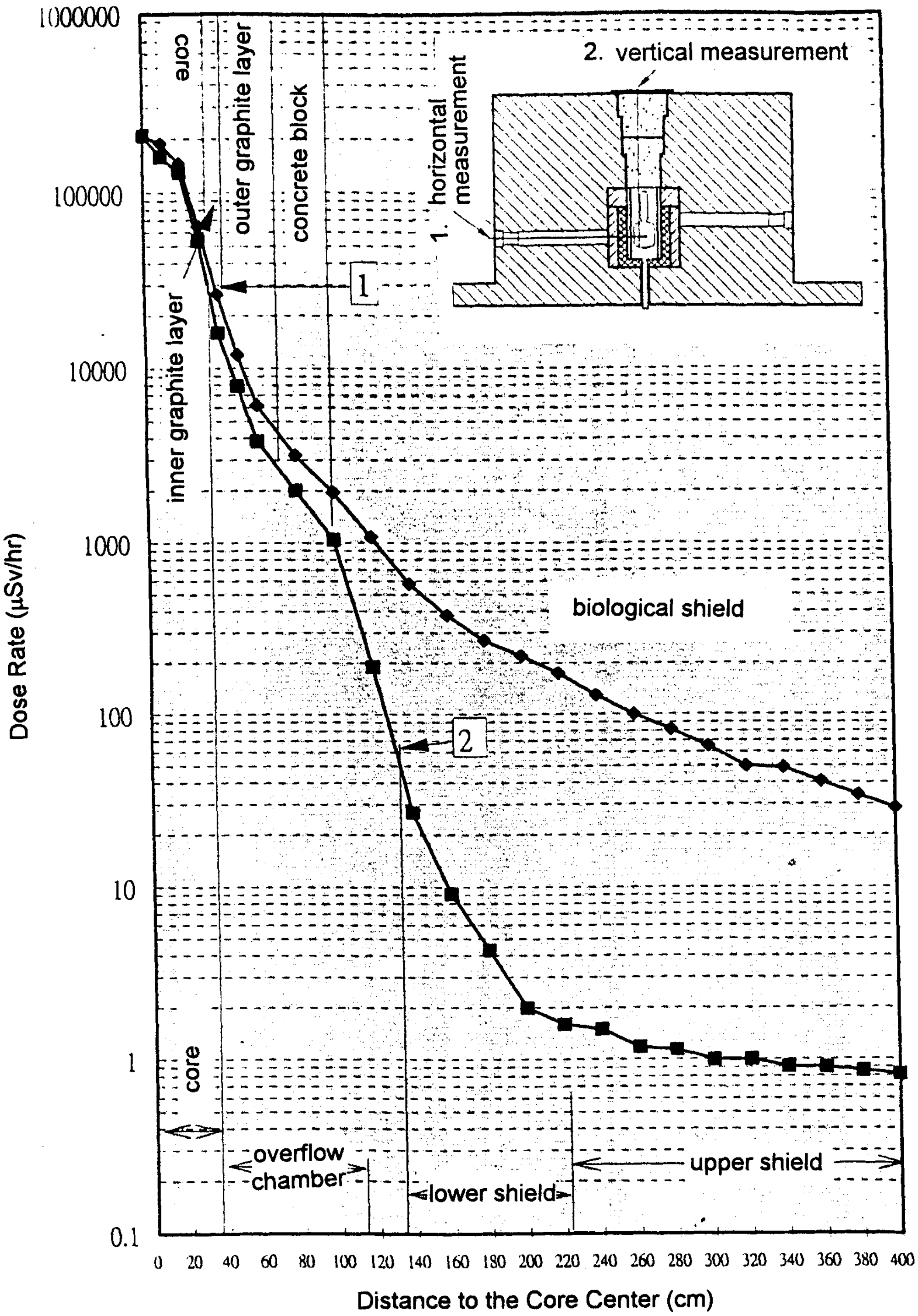

Figure 2 Dose Rate Measurement Results of the WBR

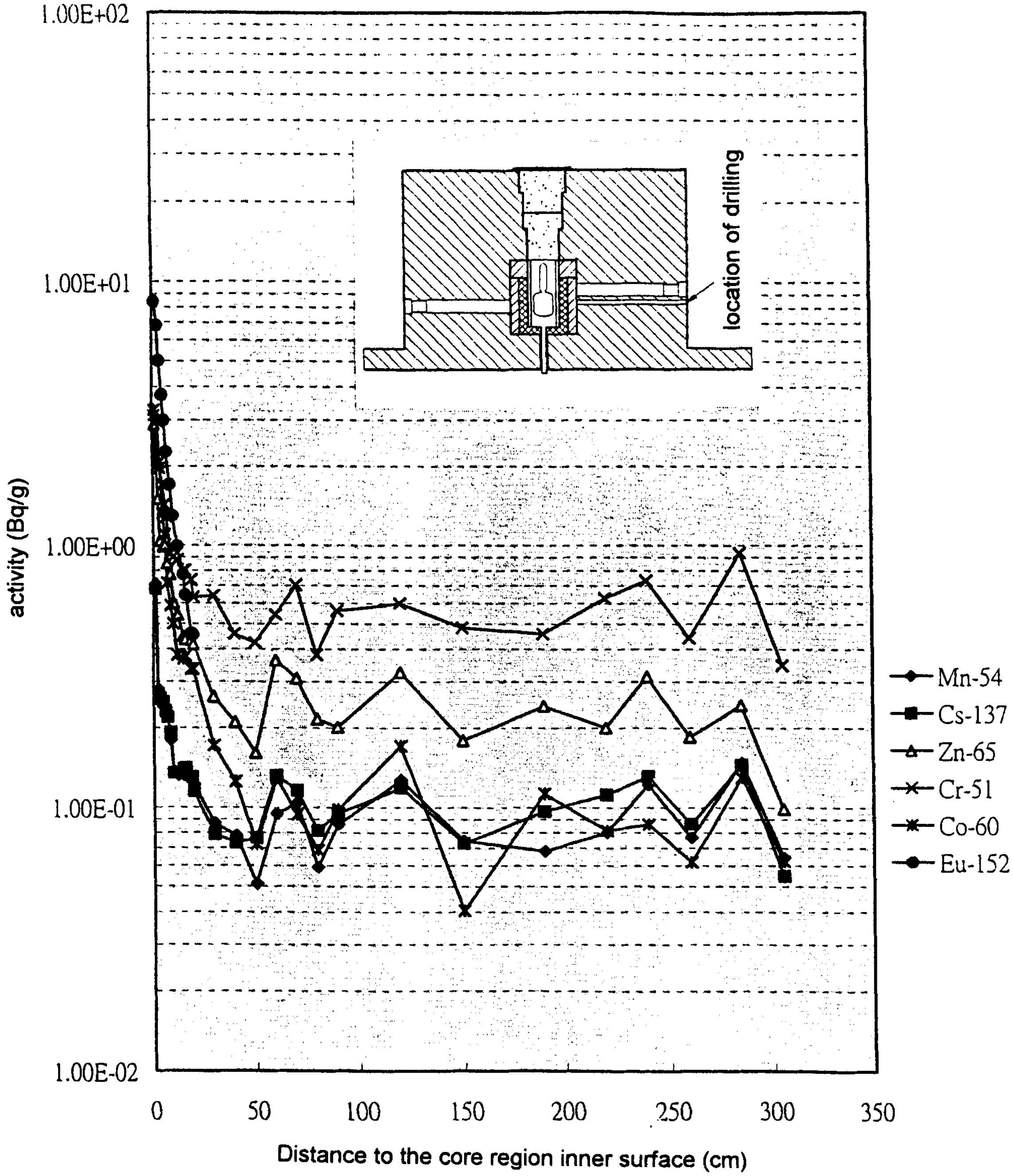

Figure 3 Contamination Analysis of the Biological Shielding Concrete

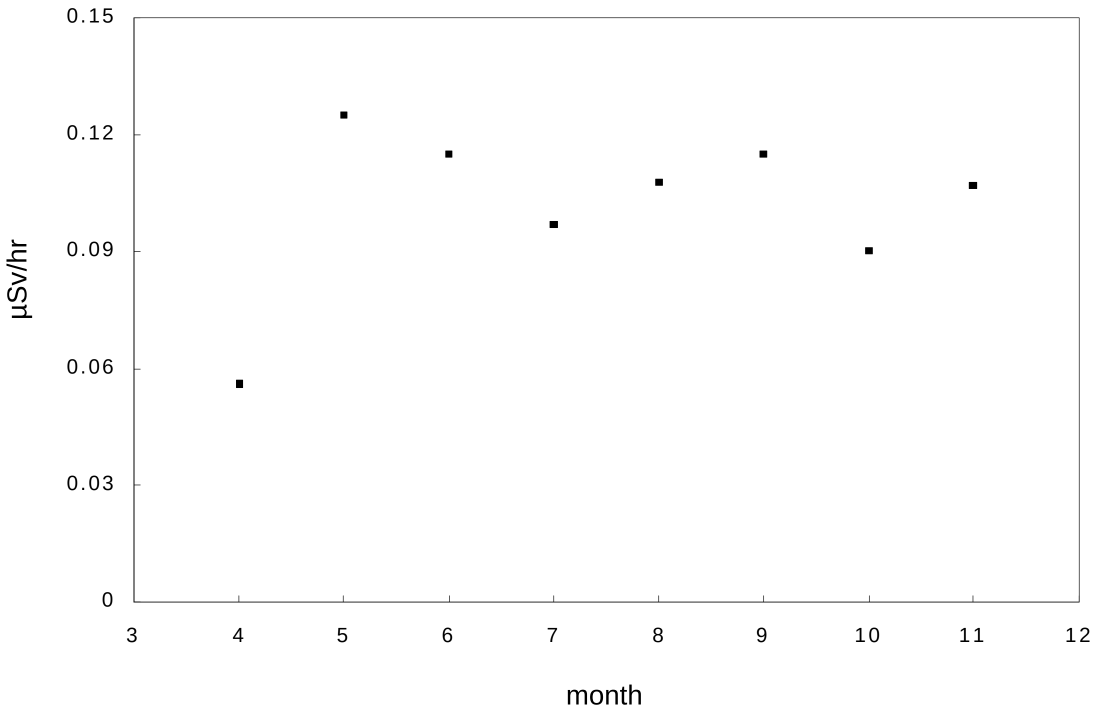

Figure 4 WBR Decommissioning Environmental Monitoring
Averaged TLD Records

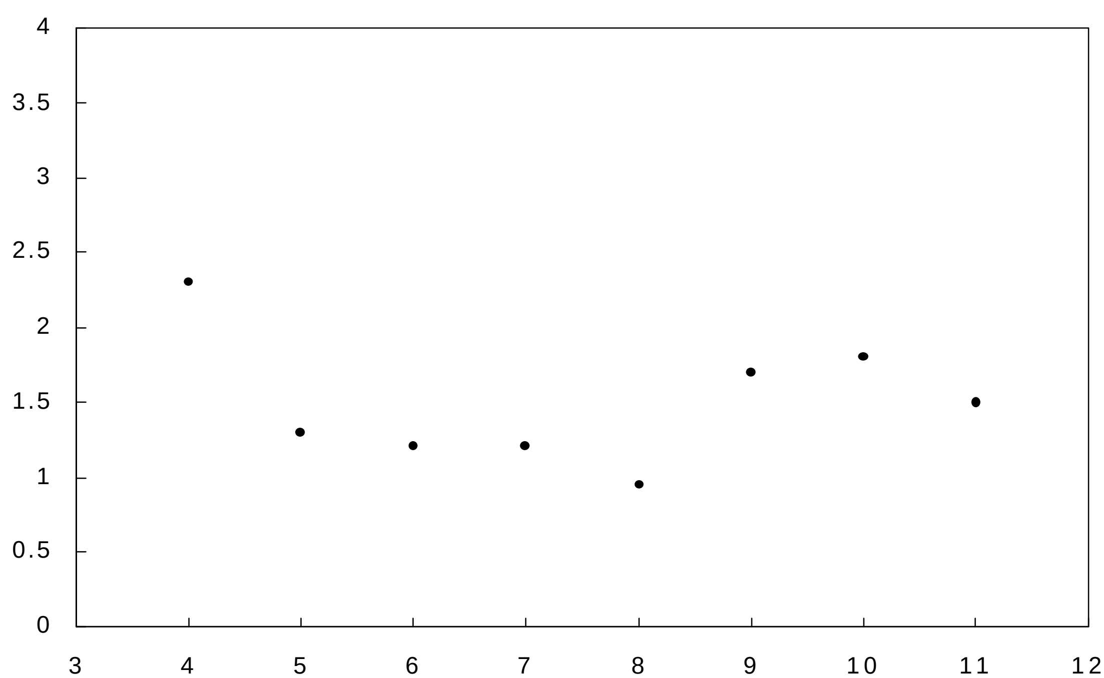

Figure 5 WBR Decommissioning Environmental Monitoring
Total Airborne ß Activity