# Radiological data from German Nuclear Power Plants During the Transition From Operation to Decommissioning – the Need for the Improved Data Acquisition Structure for Utilities under Decommissioning

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**Abstract**

During the last years, several nuclear power plants underwent the transition from the operational phase to the decommissioning phase. This transition typically results in a reduction of the received personnel doses, in changes of the work performed in the facilities and in changed requisites on radiation protection.

Although the existing data structure of the Information System on Occupational Exposure (ISOE) is able to document the doses and to account for the optimisation of radiological protection during the operational phase of nuclear power plants, this goal is more ambitious in the case of personnel in nuclear power plants during decommissioning. Exposure data from different decommissioning projects are presented and discussed to illustrate recent difficulties to collect appropriate data. It is explained why evaluations of data for nuclear power plants in operation, collected within the ISOE database, are much more promising than evaluations of data for nuclear power plants under decommissioning, collected within the current ISOE database. To solve the limitations ISOE is discussing an improvement of the ISOE data collection system for nuclear power plants under decommissioning; the current status of the improvement and first reflections by some decommissioning projects will be discussed, too.

## 1. Introduction

The Information System on Occupational Exposure (ISOE) of the OECD Nuclear Energy Agency (NEA) focuses on the occupational exposure of personnel in NPPs. Established in 1992 by the OECD-NEA, the overall goal of the ISOE is to facilitate the optimisation of radiological protection of personnel in nuclear power plants (NPPs) through collection and assessment of relevant data and the exchange of experiences on radiation protection in NPPs. The central database of ISOE contains data for a large number of NPPs in operation (401 NPPs) and under decommissioning (about 80). As such the ISOE database represents the largest database on data on the occupational exposure in NPPs under operation.

In general, the ISOE database reveals falling trends in occupational exposure in NPPs worldwide (see Fig. 1), reflecting the success of measures to reduce occupational exposure. Although the actual level of the annual collective effective dose is strongly depending on the type of reactor, it decreased in all types during the last 20 years. This dose reduction is a result of experiences gained, an experience feedback performed between vendors, operators and regulatory bodies and the application of the ALARA principle.

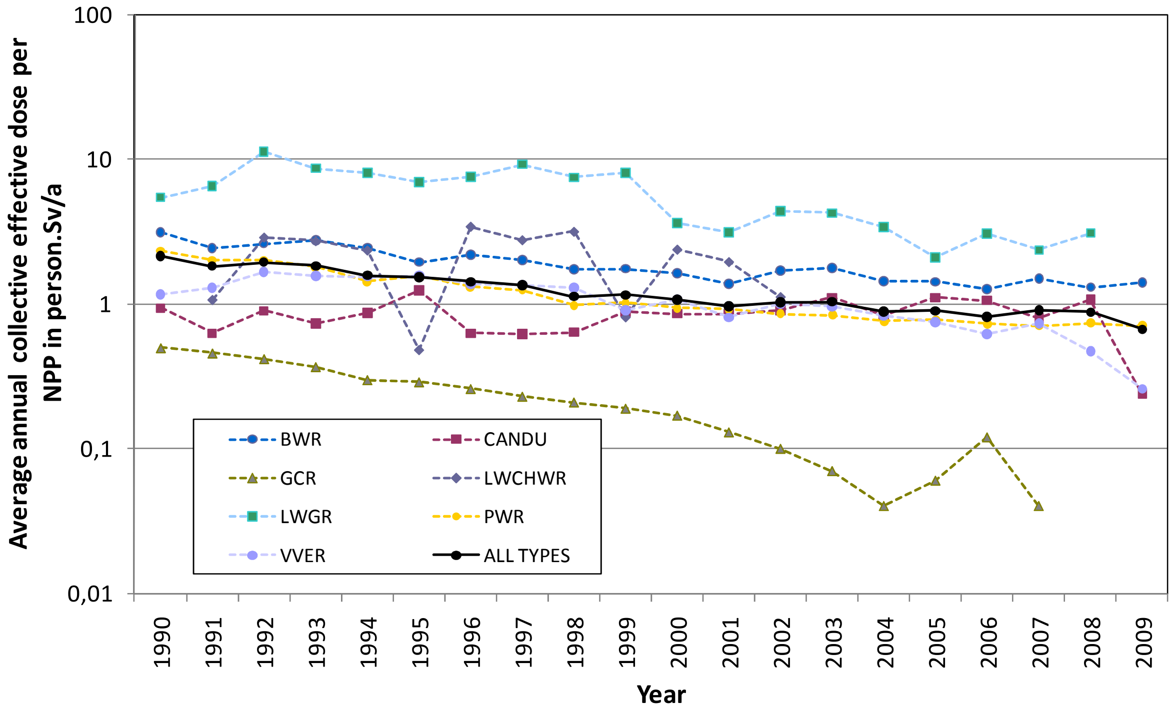


**Fig 1:** The average annual collective effective dose per (operational) NPP of a reactor type in person.Sv/a during the last 2 decades

The data from decommissioning NPPs are shown in Fig. 2. There is a still increasing number of decommissioning NPPs reporting to ISOE, related to the fact, that ISOE promotes the collection of decommissioning related data within the last years and that new decommissioning projects were started. The average annual collective dose is much lower than in case of NPPs in operation and it is decreasing. Nevertheless, it is not correct to interpret this as a trend due to improvements (as in the case of operational NPPs), because during decommissioning the exposure strongly depends among others on the type of reactor and its radioactive inventory and the kind and amount of decommissioning work of a year which change dramatically during the progress of a decommissioning project.

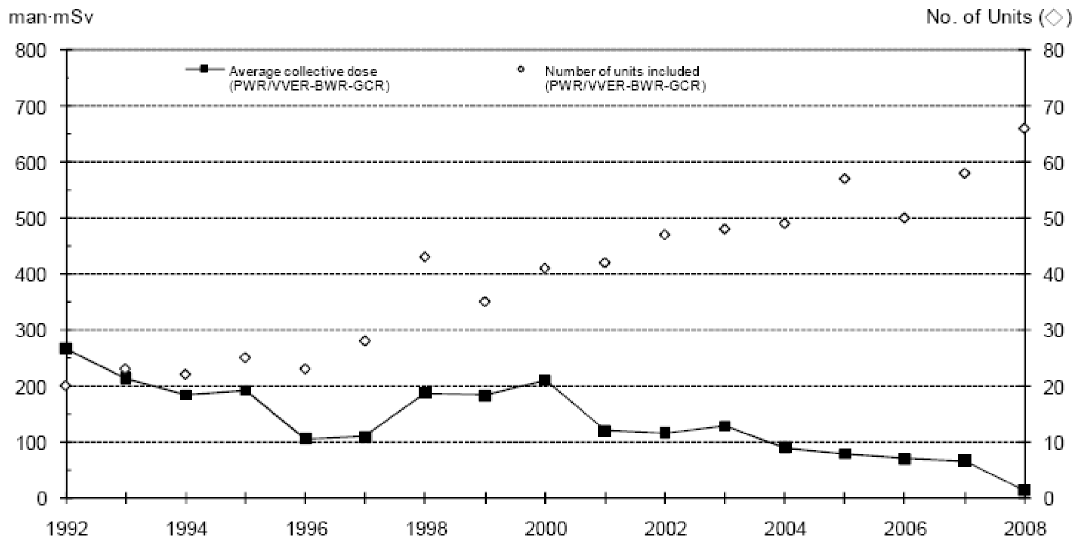


**Fig 2:** The average annual collective effective dose per (decommissioning) NPP in person.Sv/a during the last 2 decades

Although it can be reasonably assumed that also during decommissioning there are improvements in radiation protection due to experience feedback, it is relatively difficult to demonstrate this unambiguously on base of the ISOE data. The reason for this difficulty is that on the one hand the activity and hence the local dose rates will be decreasing during a decommissioning project, while on the other hand the dismantling of the most radioactive structures, systems and components -leading to higher collective dose- might take place during a later phase of decommissioning. Moreover, the most works during decommissioning are not performed repeatedly as during the operation. Instead most works (like dismantling works) are performed only once so that a comparison of a specific work activity typically will lack from data to compare. Thus, the collective dose or the average individual dose during decommissioning are complex entities which are the result of a sum of a number of highly variable tasks which by nature will differently contribute to the annual collective dose from year to year and thus do not allow an expectation of a decreasing trend.

Hence, to reach the central goals of the ISOE also for NPPs under decommissioning, i.e. not only to document the occupational exposure in NPPs under decommissioning but also to contribute to improvements in radiation protection by the promotion of experience feedback and experience exchange, it is not sufficient to analyse the evolution of the annual collective dose but to collect data in more detail.

## 2. Data on Occupational Exposure in Nuclear Power Plants Under Decommissioning – Examples from Germany

What can be learned from recent exposure data in ISOE can be illustrated for example by data for German NPPs under decommissioning. Today in Germany 17 NPPs (at 13 sites) are under decommissioning while 2 nuclear power plants were completely dismantled meanwhile. Depending on the individual decommissioning project more extensive or less extensive data are provided and available in the ISOE system or a database of Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH, which is based on these data.

## 2.1 The Occupational Exposure in German Nuclear Power Plants Under Decommissioning

The occupational exposure in German NPPs under decommissioning is presented in Fig 3 and Fig 4. As the international data, the average annual individual effective dose of German personnel is decreasing (with strong variations), but it is not possible to attribute this effect to specific improvements in radiation protection, because it is a sum of the effective doses from different projects in different stages of decommissioning. The total annual collective effective dose shows a similar pattern (Fig 4). Thus, to understand the development of occupational exposure in detail, it is necessary to evaluate the data on the level of a single NPP unit.

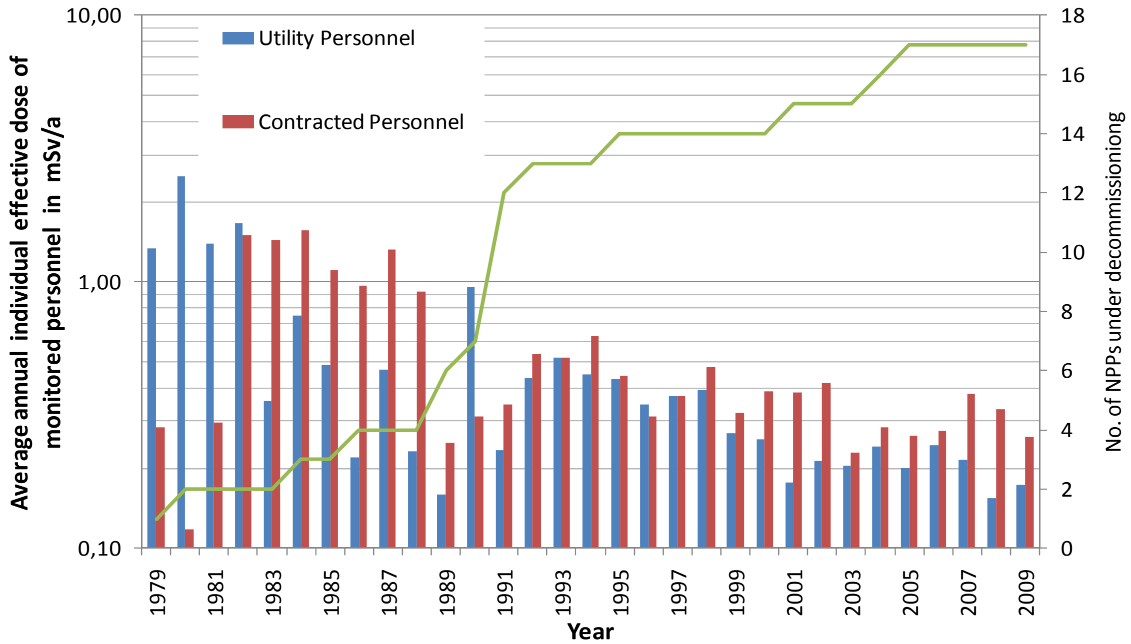


**Fig 3:** The average annual individual effective dose of monitored personnel in NPPs under decommissioning NPP in mSv/a during the last 3 decades

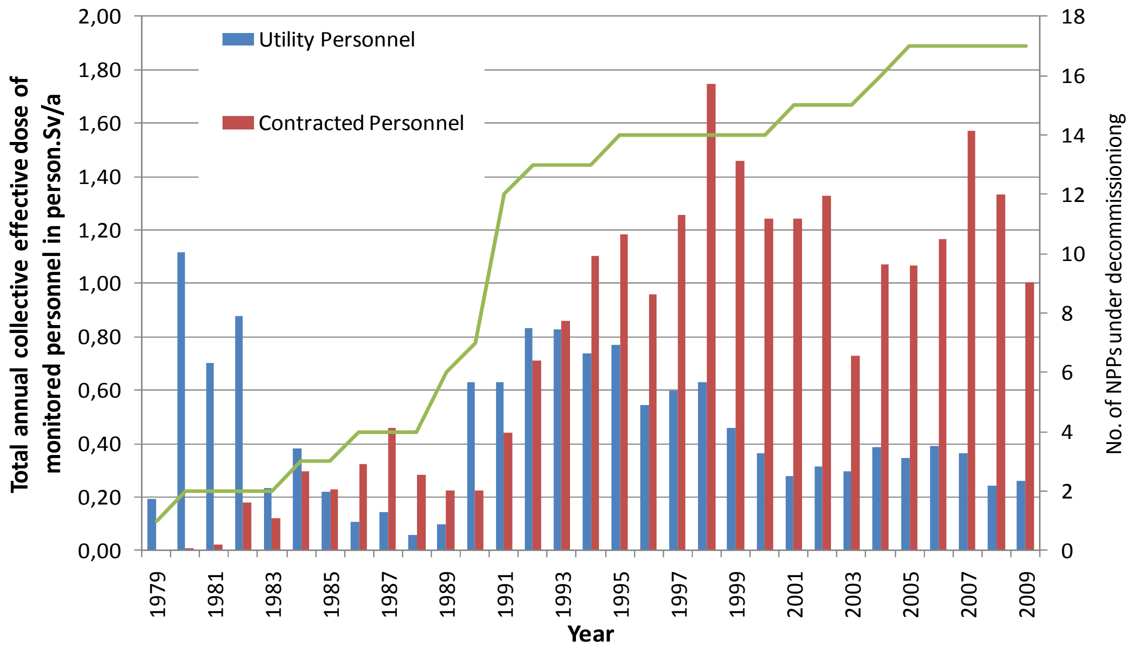


**Fig 4:** The total annual collective effective dose of all German NPPs under decommissioning in person.Sv/a during the last 3 decades

## 2.2 The Occupational Exposure of Single German NPPs During the Transition From Operation to Decommissioning

In Fig. 5 and Fig. 6, there is shown the development of the annual collective effective dose and the average individual effective dose in an arbitrarily chosen NPP for its whole life cycle. The data cover the period of operation, the transition from operation to decommissioning and the period of decommissioning, which is still ongoing.

During the operational phase, a clear decreasing trend can be observed since the end of the 1980s, reflecting improvements in radiation protection. This trend is superimposed by variations due to the different workload in different years, including back fitting activities to improve the safety level of the NPP. For example, in 1994, there was no refuelling and outage, resulting in a lower annual dose. Since 1995, there is obviously a 2-year pattern due to periodic works. The ISOE data base provides the data structure to document the performed works adequately, so these patterns can be understood.

Concerning the transition to the decommissioning phase, at least three observations can be made: First, there is an obvious dose reduction by a factor of (typically) 5 to 10 between operational doses and doses during decommissioning. This factor depends among others on the radiological situation of the NPP during operation and decommissioning, influenced e.g. by NPP design and the mode of operation. Secondly, this reduction is usually not sharp, because already shortly before the cessation of operation some works are not needed to be performed any more (e.g. specific maintenance activities, inspections). In the given example, the decision to cease the operation was made three years before the end of operation. Third, after the beginning of decommissioning, the doses are not necessarily decreasing further, because they are depending on the factors as the performed works and the planning and schedule of the decommissioning activities. In the given example, the maximum collective dose during decommissioning was reached 3 years after the end of operation, i.e. in 2007.

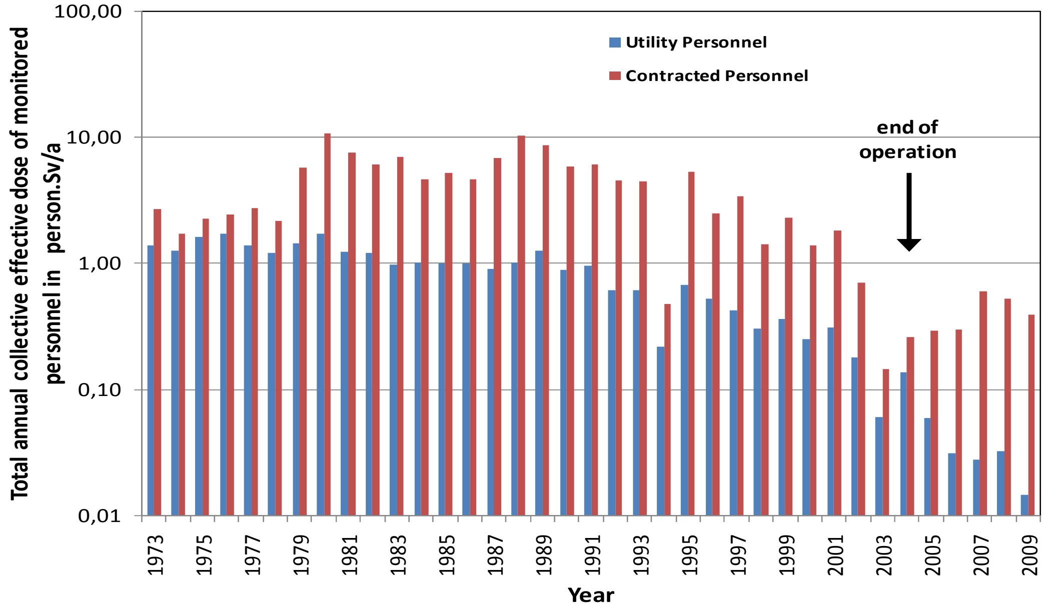


**Fig 5:** The annual collective effective dose in person.Sv/a during operation and decommissioning of an arbitrarily chosen German NPP

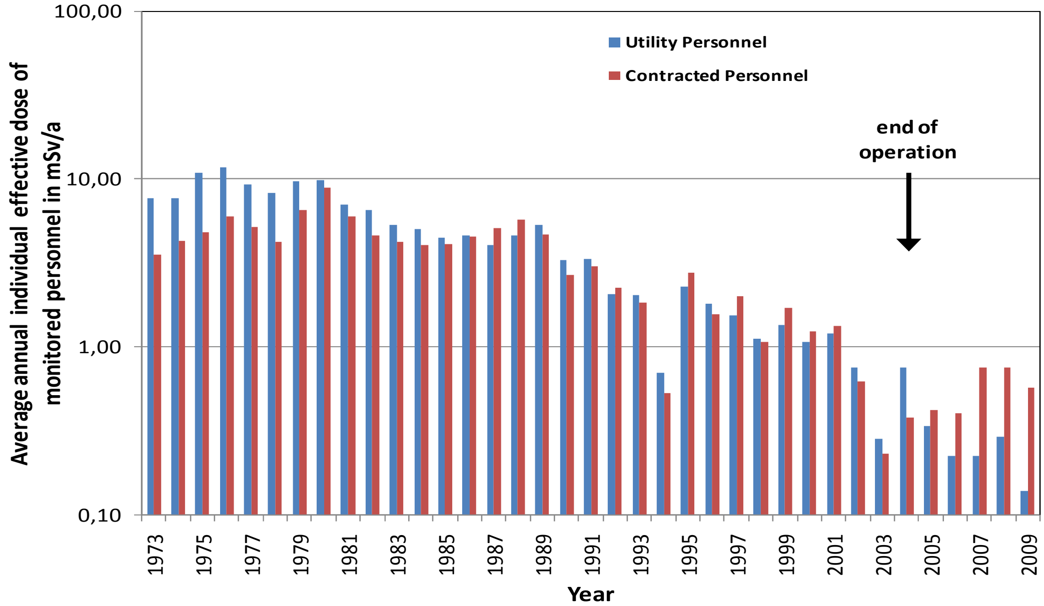


**Fig 6:** The average annual individual effective dose in mSv/a during operation and decommissioning of an arbitrarily chosen German NPP

These three developments described above can be seen – more or less pronounced – for different German NPPs in Fig.7, where the annual collective effective dose is plotted versus the time, with the year of the end of operations set to 0. It can be clearly seen that during decommissioning, the dose may vary strongly from year to year. There are also differences depending on whether the end of operation was following shortly after the decision shut down (blue and red lines) or whether this decision was made some years in advance (purple and grey lines). It is obvious that these differences can only be understood if the exposure data are analysed in more detail considering details on the NPP and decommissioning activities performed.

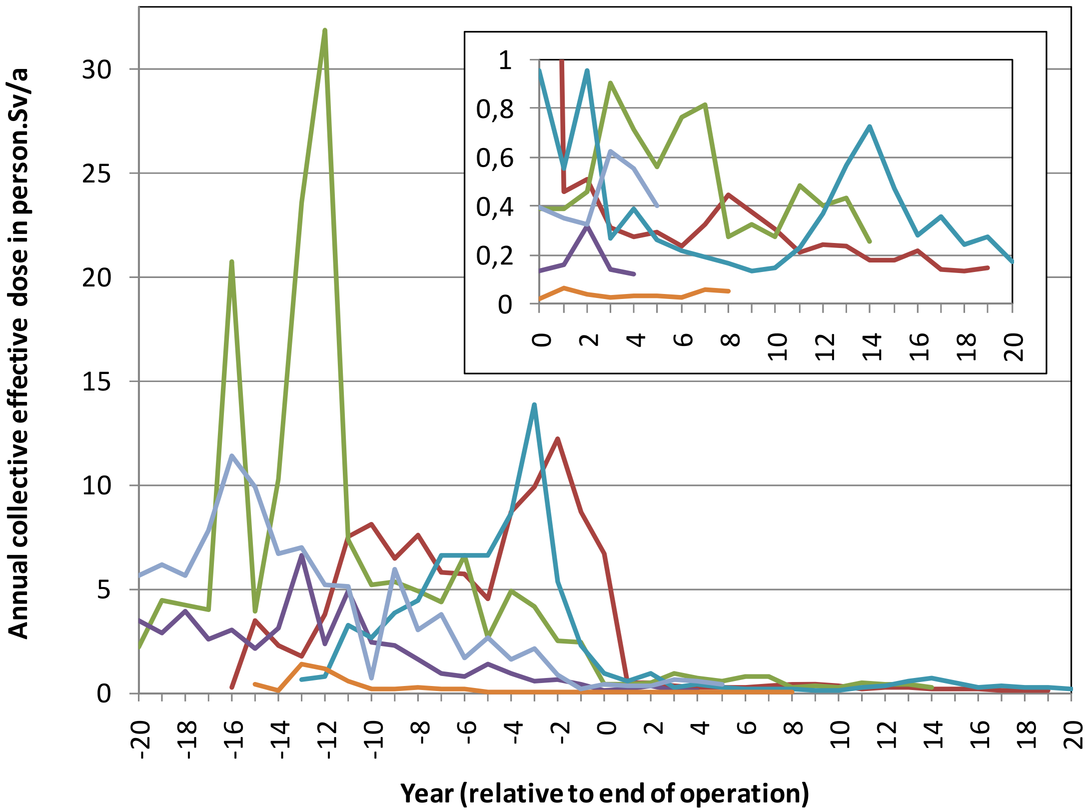


**Fig. 7:** The annual collective effective dose of several German NPPS, plotted relative to the end of the operation (insert: magnification of the decommissioning phase)

## 3. A Closer Look on Job, Task and Sub-Task Doses – Understanding the Origins of the Occupational Exposure

A detailed analysis of the occupational exposure is based on detailed data on the exposure situation and the related doses. This is the basic concept implemented in the ISOE Database on occupational exposure in NPPs.

The database provides a standardized structure to collect data for NPPs in operation and decommissioning. Up to now main emphasis is laid on the needs for NPPs in operation. The structure foresees a hierarchy of three levels of detail for the data. The highest level is the level of pre-defined jobs as “refuelling” or “main coolant pump work activities”. The medium level is the level of tasks, several tasks result in a job and as such can be used to provide more details on the exposure within a job. The third level is the level of sub-task, which – similar to the tasks – provides an option to collect further detailed exposure data for a task. Accordingly, provided a certain degree of data completeness, the ISOE database provides an adequate tools for such a detailed analysis for reactors in operation.

As an example for a job in Fig 8 it is plotted the refuelling dose and the annual collective effective dose since 1993 in an arbitrarily chosen NPP. Parallel with the reduction of the annual collective dose, the refuelling dose is shifting from about 80 mSv in the early 90s to around 60 mSv in recent years. The data show, that on a job level reductions can be identified and allocated to work conditions. The data show also, that additional work activities are influencing the overall evolution of the annual collective effective dose as the degree of reduction is different for the job data and the annual collective effective dose.

It is worth to mention, that understanding data on the job level requires that the work content for each year is more or less the same. If the work content varies too much, this variation should be reflected by the different tasks, which might contribution to the job (and similar: the different sub-tasks contributing to a task); it is a challenge for the practice, to provide these data on a sufficient detailed level.

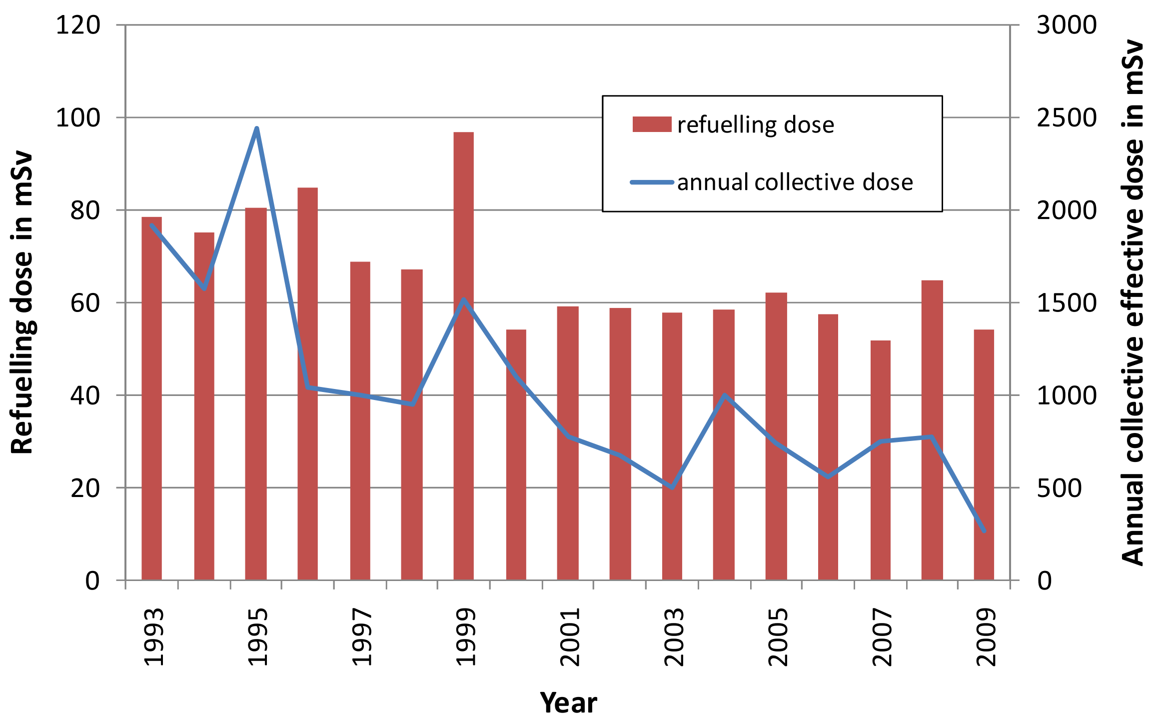


**Fig 8:** The refuelling dose (left scale) and the annual collective effective dose (right scale) in an arbitrarily chosen NPP since 1993

Looking at recently available data in the ISOE database for NPPs under decommissioning, for example in Fig 9 reveals several problems: First – as previously mentioned – the annual collective dose is changing from year to year, depending on the workload – the annual collective effective dose does due to the nature of decommissioning not follow a typical trend. Second, the reported data on jobs and task do not sum up in the annual collective effective dose – this is important to understand which work measures contribute by which dose. The reasons for the incomplete data are manifold – among others data are difficult to retrieve in practice (see later) and the current data structure for NPPs under decommissioning is limited with regard to the need for decommissioning. Third, even if the data was provided as complete as possible within the given structure, still more specifications would be needed than during operation. For example, to understand the job "decontamination", there would be needed not only the specification of the decontaminated structure, system or component, but also information e.g. about the radiological surrounding or the operational history.

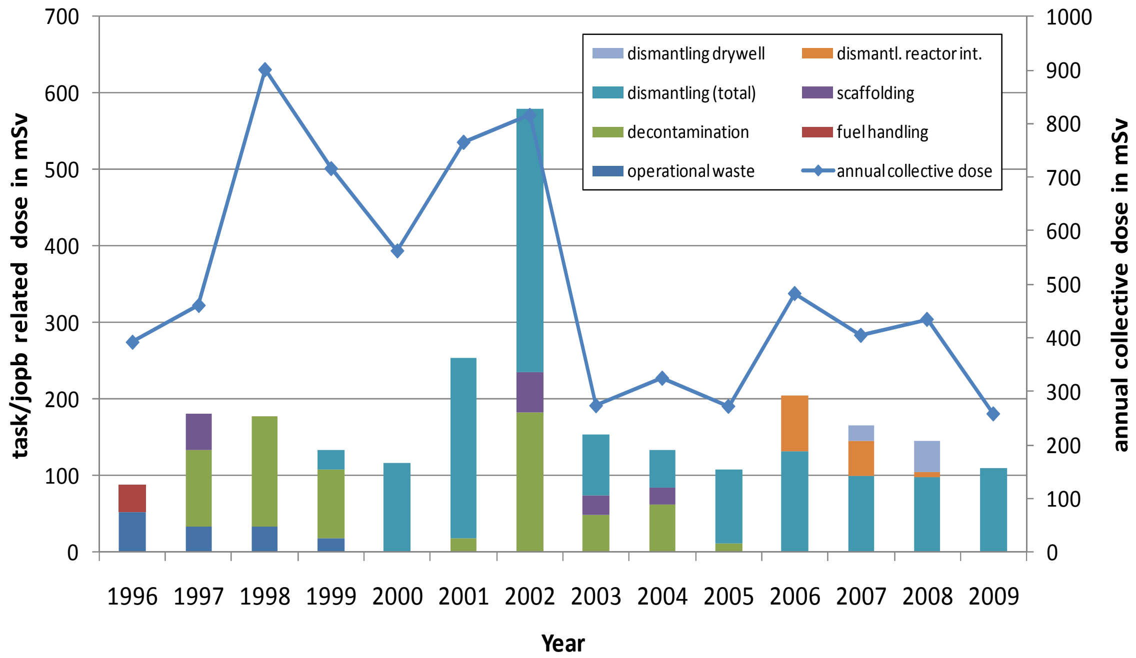


**Fig 9:** Different job and task doses (left scale) and the annual collective effective dose (right scale) in an arbitrarily chosen German NPP under decommissioning

To solve the technical limitations of the ISOE database, a proposal was prepared within ISOE to adapt the existing jobs and tasks to better fit to the decommissioning projects need. While the current structure provides only one job definition for all decommissioning activities, the proposal allows to distinguish between 6 jobs (with tasks and sub-tasks of different numbers) i.e. foresees a much higher level of detail.

The more important challenge for collecting detailed data for NPPs under decommissioning is whether a detailed data collection can be implemented in the practice and whether the objectives of a detailed analysis of the data can be reached, i.e. whether experience exchange on radiation protection during decommissioning can be effectively fostered by detailed data. First response from some decommissioning projects indicate that a too detailed collection of data would not be reasonable because site-specific aspects would make valid comparisons impossible. A high effort would be necessary to collect detailed data, but no additional benefit could be obtained from the data with respect to experience exchange.

As such, a discussion on a data collection on the occupational exposure for NPPs under decommissioning needs to be continued and alternative approaches should be identified to balance the effort for data collection and benefit from the analysis of these data. The central questions may become “To what extent can a detailed data collection support an experience exchange?” and “What data are needed to appropriately describe the occupational exposure of the personnel in NPPs under decommissioning to gain a more detailed understanding on their working conditions?”.

## 4. Conclusion

Although the ISOE provides valuable tools for the understanding and improvement of radiation protection measures, an adaptation of the ISOE data acquisition structure is necessary for decommissioning projects. Even if the existing ISOE data structure was populated completely, it would not be possible to understand in detail the occupational exposure of the personnel and to identify or understand the improvement of radiation protection measures during decommissioning. The reasons for this deficiency are the complexity and diversity of decommissioning projects which are not reflected by the existing structure.

An improved ISOE data structure must be both detailed enough to reflect the complexity of decommissioning works but easily structured enough to encourage the participants of ISOE to provide data as complete as possible. It must consider the basic limitations given by the nature of decommissioning projects and account for the specific properties of decommissioning works. Only then, deeper insights into the occupational exposure can be gained and hints on “best practice” and on improvement of radiation protection during decommissioning can be derived from the database and a peer-by-peer discussion on radiation protection measures can be initiated.  It is still an open issue and it is a challenge to balance the requirements on a data collection and the goals which realistically can be reached taking into account the practical limitations of the decommissioning projects.