

**DEVELOPMENT OF A FUEL-CONTAINING MATERIAL REMOVAL AND WASTE  
MANAGEMENT STRATEGY FOR THE CHERNOBYL UNIT 4 SHELTER**

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**ABSTRACT**

A study was performed to develop a strategy for the removal of fuel-containing material (FCM) from the Chernobyl Unit 4 Shelter and for the related waste management. This study was performed during Phase 1 of the Shelter Implementation Plan (SIP) and was funded by the Chernobyl Shelter Fund. The main objective for Phase 2 of the SIP is to stabilize the Shelter and to construct a New Confinement (NC) by the year 2007. In addition, the SIP includes studies on the strategy and on the conceptual design implications of the removal of FCM from the Shelter. This is considered essential for the ultimate goal, the transformation of the Shelter into an environmentally safe system.

Based on the findings of the conceptual design studies for the NC including the FCM database and the removal technology study, the application of multi-criteria analysis and ALARA led to the following recommended strategy:

- FCM, in general, should be left undisturbed and continuously monitored and controlled for the period of time required to provide the necessary infrastructure for its removal and disposal.
- Waste management during the shelter stabilization, NC construction, and the dismantling of unstable structures must include working areas inside the Shelter as well as on the Industrial Site.
- To mitigate the risk of delayed FCM removal with FCM monitoring, an aggressive demonstration of FCM removal technology should be conducted to assure that the technology would be available if needed

- Retrieval, packaging, and on-site temporary storage of accessible FCM may be useful to decrease the radiological risk of unconditioned FCM.
- Efforts should be made to develop and construct the Ukrainian Deep Geological Repository (DGR) in accordance with the State Program on the Management of Radioactive Waste.
- Small-scale FCM removal operations may be performed under the protection of the NC after the dismantling of the unstable parts of the present Shelter is completed, if the necessary infrastructure can be made available.
- Assuming present day technologies, FCM removal operations would take approximately 50 years.

## INTRODUCTION

A study was performed to develop a strategy for the removal of fuel-containing material (FCM) from the Chernobyl Unit 4 Shelter and for the related waste management. This study was performed during Phase 1 of the Shelter Implementation Plan (SIP) and was funded by the Chernobyl Shelter Fund. The main objective for Phase 2 of the SIP is to stabilize the Shelter and to construct a Safe Confinement (SC) by the year 2007. In addition, the SIP includes studies on the strategy and on the conceptual design implications of the removal of FCM from the Shelter Object (SO). This is considered essential for the ultimate goal, the transformation of the SO into an environmentally safe system.

The objective of the Phase I study was to recommend a strategy and schedule for the removal, sorting, treatment, transportation, and disposal or storage of the FCM and the associated radioactive or hazardous material. Technical feasibility, risk reduction, and cost were the primary considerations in the selection of this recommendation.

In the accordance with the requirements of the SIP the following scope was covered in this study:

- The various alternatives available for waste management and FCM removal
- A cost-benefit analysis of these alternatives
- The recommended FCM removal and WM strategy
  - Processes for FCM retrieval
  - General equipment description
  - Packaging methods for the FCM waste removed
  - Dose-reduction proposals
  - Optimal time to remove FCM
  - Packaging and interim storage alternatives for the removed FCM
  - Packaging and handling of other waste such as nonradioactive, hazardous or toxic, and radioactive low-level and intermediate-level
  - Management of the waste in conjunction with the expected consolidated Chernobyl Nuclear Power Plant (ChNPP) waste handling and processing facility
  - Waste management for the SIP project in general

The main steps of the strategy selection were:

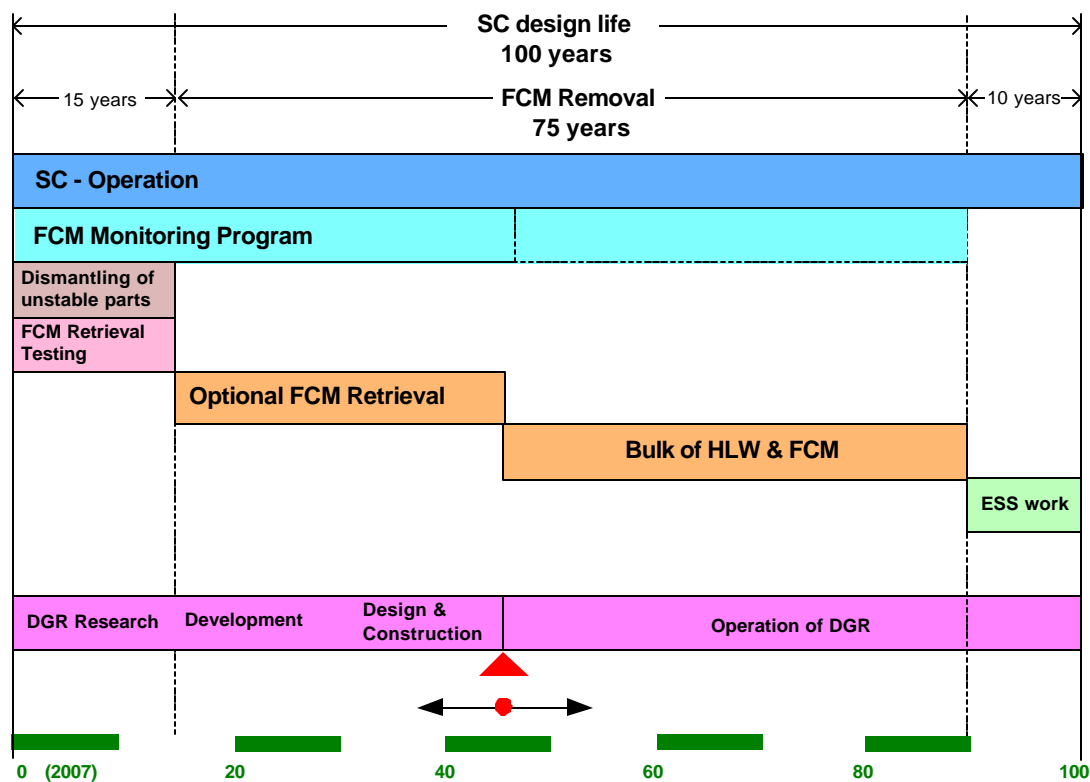
- The compilation and analysis of initial data on the characteristics of the SO and the ChNPP site relevant to this study, including:
  - The present state of the SO
  - The collection and collation of existing FCM data
  - The WM procedures of ChNPP and its future plans
  - The existing regulatory framework

- A review of previously proposed strategies to transform the SO into an environmentally safe state, including:
  - Comparison according to the scheme "Early or Deferred Removal"
  - The extraction of cost, dose, and time-schedule information
- The ranking of strategies by expert evaluation
- Development of a recommended strategy for the removal of FCM and the associated waste management considering the results of other SIP tasks, primarily:
  - Characterization of fuel containing material
  - FCM retrieval technology development
  - Safe confinement strategy

## RESULTS OF THE STUDY

### Baseline Strategy Recommended

The baseline strategy and recommended schedule is shown in Fig. 1.



**Fig. 1. The baseline strategy and recommended conceptual schedule**

Some key points that led to its definition are:

1. The SC has a projected lifetime of 100 years (Task 21). If the FCM removal can be completed within that time period, a second SC will not be necessary and substantial costs can be avoided.
2. Long-term interim storage is expensive and should be avoided. Thus, it is prudent to delay FCM removal until the FCM can be disposed of directly into the DGR. Our schedule provides 30 to 60 years after the commissioning of the SC for the development, design, and construction of this repository. (A contingency plan is discussed below.)

3. Sufficient time must be available for both FCM removal and cleanup. The schedule estimates for FCM retrieval developed in Task 20 were used, and an estimate that an additional 10 years would be sufficient to dismantle the SO structures remaining after the FCM has been removed.
4. Immediately after the commissioning of the SC, 15 years is estimated to be sufficient for the demolition, size reduction, and treatment of unstable SO structures.
5. During the construction phase of the DGR, retrieval of accessible FCM will commence. This requires prior dismantling of unstable SO parts and that FCM retrieval has been successfully demonstrated on a prototype installation and operation on the lower levels of the SO.
6. Optional FCM retrieval, in particular of its dispersed and mobile forms, requires that some amounts of FCM and high-level radioactive waste (HLW) can be stored within the boundaries of the SC. Larger amounts of FCM and associated HLW can and should be retrieved after the commissioning of the DGR.
7. FCM retrieval from the Cascade Wall requires the dismantling of part of the SO.
8. The risk that there might be a sudden need to control and/or remove the FCM will be accommodated. This means that (1) all activities essential to ensure that possible FCM degradation is monitored and met by early retrieval measures, and (2) all FCM removal equipment development and testing continues.

Within these constraints, a more precise schedule for FCM removal is a matter for optimization in the next work phase. FCM removal should be completed as early as possible to eliminate operational costs at the SC.

Table I provides a brief synopsis of these considerations.

Table I. The Strategy Baseline

SIP Output:	Report Task 21.4, a/b Design life of safe confinement Unstable structure dismantling Report Task 20, R 5/6 Duration of FCM removal	100 years Approx. 15 years Approx. 50 years
Assumptions:	FCM removal during life cycle of safe confinement DGR available FCM remains in a controllable state including early removal measures Period of shelter conversion after FCM removal FCM Retrieval Technology Demonstration Experiment	Approx. 50 years During life of the SC Approx. 10 years Year 2001-2004
Additional Features:	No interim storage of FCM and long-lived HLW (technical requirements, capacity, and costs are very high) Temporary storage for FCM and HLW inside safe confinement (technical requirements, capacity, and costs are comparatively small) FCM retrieval after finishing dismantling of unstable structures and its waste treatment Preparation of FCM removal concurrently with the project of DGR for Ukraine FCM removal at start of construction of DGR	

## **CONTINGENCY PLAN**

An effective way to reduce costs and collective dose for the recommended strategy is to avoid long-term interim storage. However, a risk in this strategy is that the DGR might not be available when required.

There are two reasons why the DGR would not be available:

1. Its construction is no longer a part of the national Waste Management Program of Ukraine or,
2. It is still foreseen but delayed.

Case 1 means that FCM cannot be disposed of in a DGR. The appropriate response would then be to adapt the strategy to the national strategy of the management of spent fuel and high-level radioactive waste from Ukrainian NPP of that time.

Case 2 means that local control measures and immobilization will be necessary.

## **RETRIEVAL PROCESSES**

There is no uniform retrieval process for these tasks. While different, they share certain common features:

1. All aim to bring FCM from its present form into a safer, confined state with multiple protective barriers.
2. All perform size reduction to the FCM to fulfill nuclear safety requirements and match the geometry of the transportation containers.
3. Identification of FCM and of Associated Waste (AW) is done by radiation measurements and by visual observations at its original place. FCM and AW are collected and placed into primary containers and then transported to central infrastructure area, where further separation takes place.
4. All activities are done remotely.
5. Prior to any retrieval/removal activity, all areas will be provided with the appropriate infrastructure to provide the necessary energy, auxiliary utilities, and communication.
6. In all areas, a special zoning concept will be established to ensure safe working conditions. The zoning concept will define rooms for permanent occupancy and for restricted occupancy. Control of remote handling equipment will be done from rooms zoned for permanent occupancy. Rooms with restricted occupancy will serve mainly for the maintenance of failed equipment.
7. Besides this safety and radioprotection concept, a safeguards concept for fissile material will be provided. The SC and SO constitute one material balance areas with a key measurement point.
8. Table II shows an example of the approach using remote-controlled techniques for different FCM retrieval processes recommended at various areas in the SO.

The FCM retrieval processes shown in Table II are judged feasible for this application. This assessment is based on the following considerations:

- The application of remote technologies already proven in the dismantlement of nuclear facilities under severe conditions (radiation, contamination, disordered structures)
- The equipment is available on the market and needs only a reasonable adaptation to the shelter conditions. This will be demonstrated in the FCM Retrieval Technology Demonstration Experiment (Task 20)
- Failed equipment is designed so that it can be remotely recovered and brought to a maintenance area
- The safety and zoning concept

Table II. Technological Approaches for Various SO Areas

<b>Retrieval Areas in SO</b>	<b>Tool Carriers for Remote Operations</b>	<b>Direction of Attack</b>	<b>Transport of Primary Containers out of Area Retrieval</b>
0-9 m Level Premises	Full track vehicle	Horizontal from deaerator building	By full-track vehicle
Reactor Hall including South Storage Pool and Reactor Vault	Overhead crane + construction machines	Vertical through opened roof	By rail-mounted vehicle
	Overhead crane + autonomous pedestals	Vertical through opened roof	
Pioneer Wall	Overhead crane + full-track vehicle	Vertical/horizontal	By overhead crane + full-track vehicle
Cascade Wall	Overhead crane + heavy equipment	Vertical	Horizontal

Another approach, using a so-called “wet” technology, may be applied to the Industrial Site to reduce the volume of waste during the construction of Safe Confinement and to clean up the Industrial Site of SO. If this approach proves successful it could be applied accordingly in other retrieval areas, in particular for early stabilization and retrieval measures.

Figure 2 shows how waste arising from the FCM removal and other activities during the SIP project will be managed. Only well-proven waste management technologies and facilities are applied.

After volume reduction, the FCM will be packaged in canisters. The resulting canisters can be stored temporarily in specially prepared storage areas in suitable locations inside the SC. The associated HLW will be volume-reduced and then packaged into standardized 200 l drums. The bulk of associated waste is in the Pioneer Wall and in the Cascade Wall, and is expected to be low-level and intermediate-level waste. It will be disposed in bulk in existing surface disposal facilities.

The treatment of dismantled shelter parts will be accomplished in a dismantling and decontamination work area. FCM and associated waste will be treated in two similar facilities - the FCM packaging facility and the HLW packaging facility. Water collected in SO and SC as well as liquid waste coming from FCM retrieval operations and maintenance will be collected, treated, and released. Concrete, gravel, soil, and metallic structures will be segregated and, in most cases, released to an industrial waste site in the exclusion zone.

Special kinds of waste require special attention and treatment. For these wastes the specialized facilities of the Industrial Complex of Solid Radwaste Management (ICSRM, Lot 2) and the Center for the Treatment and Disposal of Radioactive and Hazardous Waste (CTD) will be used.

The recommended FCMR and WM strategy results in the costs and collective doses shown in Table III. The cost estimate is based on western experience, taking into account local cost level for labor and material where it applies. They do not include operational costs and technical maintenance of the safe confinement, its technical equipment and monitoring systems, or operation cost of FCM removal and waste management. In general, cost savings by synergy of operations may be expected. These costs also do not include transportation and disposal of FCM and HLW in a DGR.

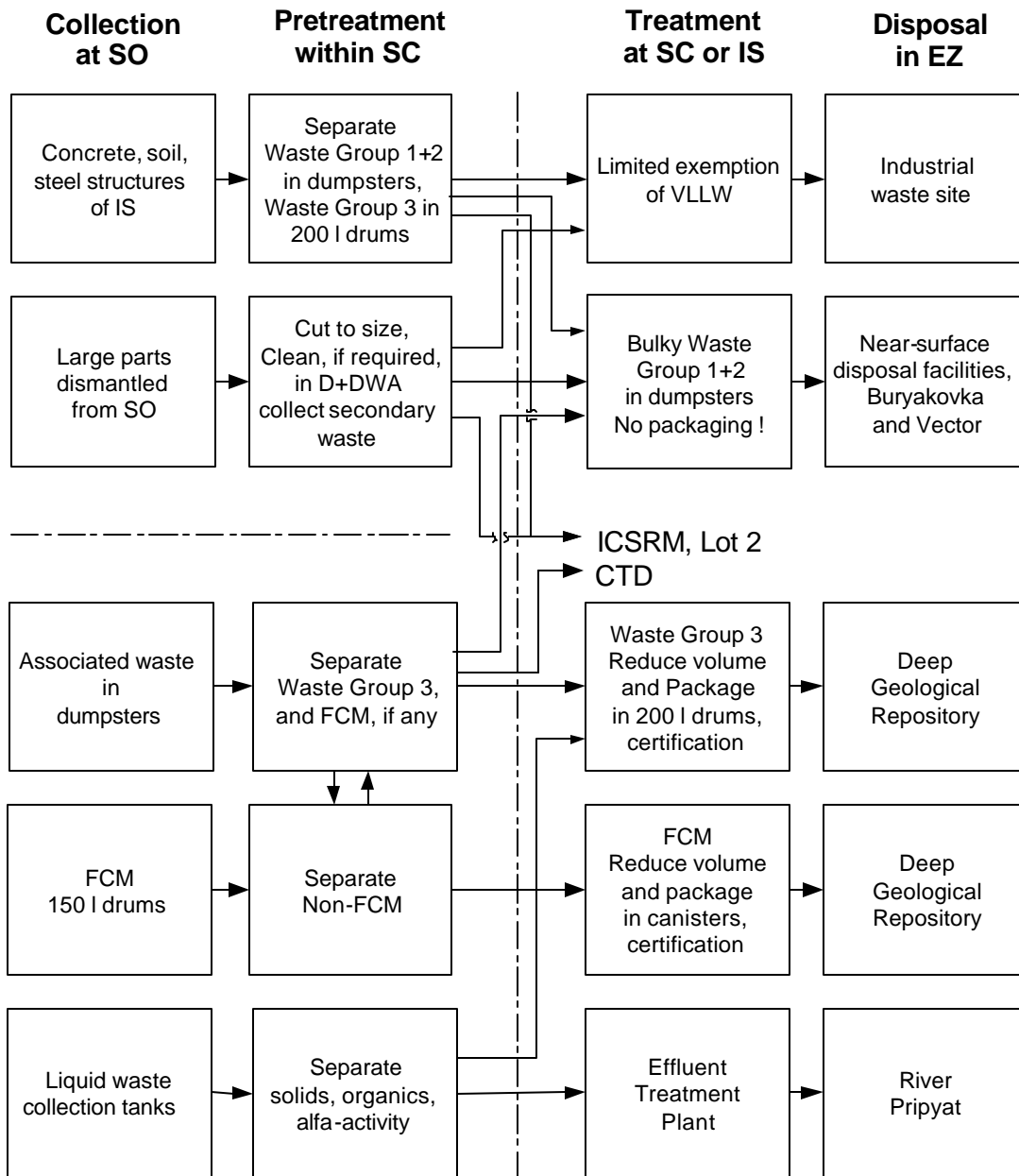


Fig. 2. Waste management flow diagram for SC construction and operation and for FCM removal

Table III. Preliminary Costs Estimation of the Recommended Strategy Elements

<b>Main Strategy Elements</b>	<b>Cost (M EUR)</b>	<b>Collective Dose (Sv)</b>
1 FCM Retrieval		
1.1 Installation of Retrieval Facilities	280	6
Operation of Retrieval Facilities	**	130
Spare and wear part	91	
<b>Subtotal 1</b>	<b>371</b>	<b>136</b>
2 FCM and HLW Packaging		
2.1 Installation of Packaging Facilities	102	*
Operation of Packaging Facilities	**	*
Spare and wear part	*	
Containers	68	
<b>Subtotal 2</b>	<b>170</b>	<b>*</b>
3 Services of other WM facilities		
3.1 Solid and liquid LLW and ILW treatment	50	10
Surface disposal of LLW and ILW	25	10
<b>Subtotal 3</b>	<b>75</b>	<b>20</b>
<b>Total 1 – 3</b>	<b>616**</b>	<b>156*</b>

All figures are rounded, no contingencies included

\* To be estimated during Phase 2

\*\* Operation cost is not included

### RECOMMENDATIONS FOR FUTURE WORK

On the basis of this study, we recommended that the following tasks be undertaken to ensure a firm base for the SIP Phase 2 work, the conceptual study of the recommended strategy.

- Integration of a FCM inspection program into the Prototype Demonstration Experiment to ensure that the FCM characteristics are sufficient for conceptual and detailed design
- An investigation during the SC conceptual design to identify the optimum arrangement for Waste Treatment Facilities inside and/or adjacent to the SC
- Study of the issue of temporary storage of FCM and HLW packages in rooms/areas of SC, SO, or Unit-3 to determine technical requirements, capacities and cost
- Improvement of the database for FCM control, FCM retrieval, and for operational cost of SC
- Development of a basic flow diagram of FCM removal and other waste streams for strategy optimization