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CHALLENGES AND PROGRESS IN IMPROVING SAFETY AND MANAGING RADIOACTIVE WASTES AT CHORNOBYL NPP AND IN THE CHORNOBYL EXCLUSION ZONE

The commissioning of the New Safe Confinement at the Chornobyl Nuclear Plant Unit 4 site will mark the achievement of one important milestone within the process “conversion of the Chornobyl Unit 4 into safe ecologic conditions”. New radioactive waste management facilities have been developed at Chornobyl Nuclear Plant and at Vektor Complex to ensure the safe management of radioactive wastes in the Chornobyl Exclusion Zone. The continued investigations and safety assessments of different legacy waste sites which were created as part of the accident response measures confirm the efficiency of the measures of the past are and consolidate the basis for the strategy for the safe management of legacy wastes. All these together demonstrates that the national and international efforts vested to manage the consequences of the Chornobyl accident have achieved substantial and visible progress in safety and long term safety will be achieved by their consistent continuation.

Keywords: radioactive waste management, radiation safety, Chernobyl Exclusion Zone.

Introduction

After long years of preparation and construction, in the year 2016 the New Safe Confinement (NSC) has been pitched on its design position. It is expected that all remaining works to make NSC operational including commissioning and obtaining operating licence will be completed by the end of year 2017. With the NSC becoming operational the national program of “conversion the ChNPP Unit 4 into safe ecologic conditions” will enter into a new phase.

Beside the efforts related to conversion of the ChNPP Unit 4 into “safe ecologic conditions”, many other projects has been completed (or are in progress) aimed either at decommissioning of the remaining units of ChNPP, or safe management of radioactive wastes originating at ChNPP and in the Chornobyl Exclusion Zone (ChEZ).

The present article provides an overview and short summary of the some important achievements and remaining challenges in the above listed areas. .

The situation at Chornobyl Unit 4 in 1996 and Way Forward Decisions

As part of the accident liquidation measures in 1986 the “Object Ukrytiye (called also Sarcophagus)” has been erected in less than 6 months under exceptionally difficult radiological conditions as temporary solution with limited design life. After its erection one of the controversial and long discussed subjects was the further approach necessary to establish longer term safe conditions. Among the main challenges encountered in 1996 (10 years after the accident) were:

1. The unreliable and unstable conditions of the Chornobyl Unit 4-Shelter structure.

The construction was built under extreme radiation conditions: prefabricated steel elements were simply stacked on extremely pre-stressed building ruins which could only be partially reinforced with the used cast concrete. As a result, the structural reliability of supporting elements could not be proved. Furthermore, the steel elements piled on these supporting elements with doubtful stability were not connected appropriately between each other (most elements are merely stacked and most of the joints were not welded, bolded or fixed in any way together), with the result that the overall stiffness, stability and consistency of the roof structure was unsatisfactory.

Moreover, the construction was built without the support of deep foundations on a destroyed building, such that settlements led to a tilting of the “Sarcophagus” structure. The tilting was a clear hint of ongoing weakening of the structure stability.

Corrosion and weathering deteriorated the existing structure further, which was never meant to be a sufficient long-term solution (e.g. on December 22, 1988, Soviet scientists announced that the sarcophagus would only last 20–30 years before requiring restorative maintenance work).

The “Sarcophagus” was not airtight, nor water tight, and although a complex dust suppression system was operated, the release of radioactive dust through openings to the environment and ingress of waters was not fully preventable.

The ventilation stack on the joint service building between Unit 4 and Unit 3 was severely damaged and unstable. A potential collapse of this ventilation stack with falling on the “Sarcophagus” could lead to severe damage or even collapse of the “Sarcophagus” itself.

2. Radioactive inventory of the Unit-4-Shelter.

The inventory contained enormous amounts of radioactivity (estimated to about 20 MCi – Megacurie) with a high proportion of gamma emitters and transuranic radioisotopes (TRU, estimates indicate that the sarcophagus may locked in some 200 tons of radioactive core, some 30 tons of highly contaminated dust, some 16 tons of uranium and plutonium and substantial amounts of radioactive reactor core graphite)

As quoted above the inventory contained substantial amounts of fissile materials under unacceptable conditions (damaged fuel elements, various types of fuel containing materials, such as lava-like materials, undefined admixtures of concrete and fissile materials, and dispersed fissile materials). Furthermore, localisation of a substantial part of the original fuel could not be performed as of limited physical access and of very high radiation levels and the conditions of remaining fuel and fuel containing materials cannot be sufficiently controlled.

The few existing and operational monitoring and control equipment registered fluctuating neutron flux events, meaning that local critically could not be excluded.

The lower premises contains water from the immediate response activities, precipitation water (snow and rain) that could penetrate through openings in the roof and aqueous liquids from the wet dust suppression system that is sprayed, meaning that all of this led to the presence of the major amounts of water in a direct contact and interaction with the radioactive and fissile inventory altering and changing the conditions of the latter.

The Unit 4 physically connected through the also damaged joint service building (Building B) with adjacent Unit 3 with a similar 1000 MW RBMK reactor was still operational. This raised additional safety concerns for situation and possible works at Unit 4.

3. Industrial safety/ working conditions

Access ways and corridors to the different reactor compartments and inventories in them were radiologically and physically unsafe and inadequate or even not existing: safety of works inside the “Sarcophagus” required improvements.

The immediate neighbourhood of the “Sarcophagus” was highly contaminated: radiation protection was a problem for works not only inside but also outside of sarcophagus.

Fig. 1 illustrates with selected pictures the situation in 1996.

Based on a joint initiative of Ukraine, G7 countries and the European Union an international team analysed in 1996 the situation and action option within the so-called “ChNPP Unit 4, Short and Long Term Measures” study. This study concluded that for the overall protection of public, workers and the environment a course of action the following a decision tree would be appropriate and is recommended (as shown in the Fig. 2).

Based on this recommended course of action decision was taken to implement a “Shelter Implementation Plan (SIP)” covering phase 1 and the first two parts of phase 2 to reduce gradually the risks and to improve safety in a step by step approach. Beside the stabilization measures the SIP included the erection of a “New Safe Confinement” which allows deconstruction of the unstable parts of existing “Ukrytiye” to eliminate essentially the immanent collapse risk of the aged unreliable structures as well as retrieval of accessible inventory including “Fuel Containing Materials (FCM)”.

The following Fig. 3 illustrates the gradual improvement of the situation through the different phases.

Achievements by 2017 and Vision for Next Steps at Unit 4

The implementation of SIP started in 1998; the major stabilization works were completed in 2008; the contract for NSC erection was signed in 2007 and its completion is expected in 2018. In summary, the main technical achievements of the SIP are (or will be soon), the following:

the unreliable structures were stabilized;

an integrated monitoring system was put in place to ensure much better control of structures, inventory and impacts to the environment (ingress and egress);

a new reliable confinement structure has been erected to allow essential elimination of collapse risk related to old "Sarcophagus" structures by dismantling upper unstable parts.

The following figure illustrates with selected pictures the situation in 1996 (Fig. 4).

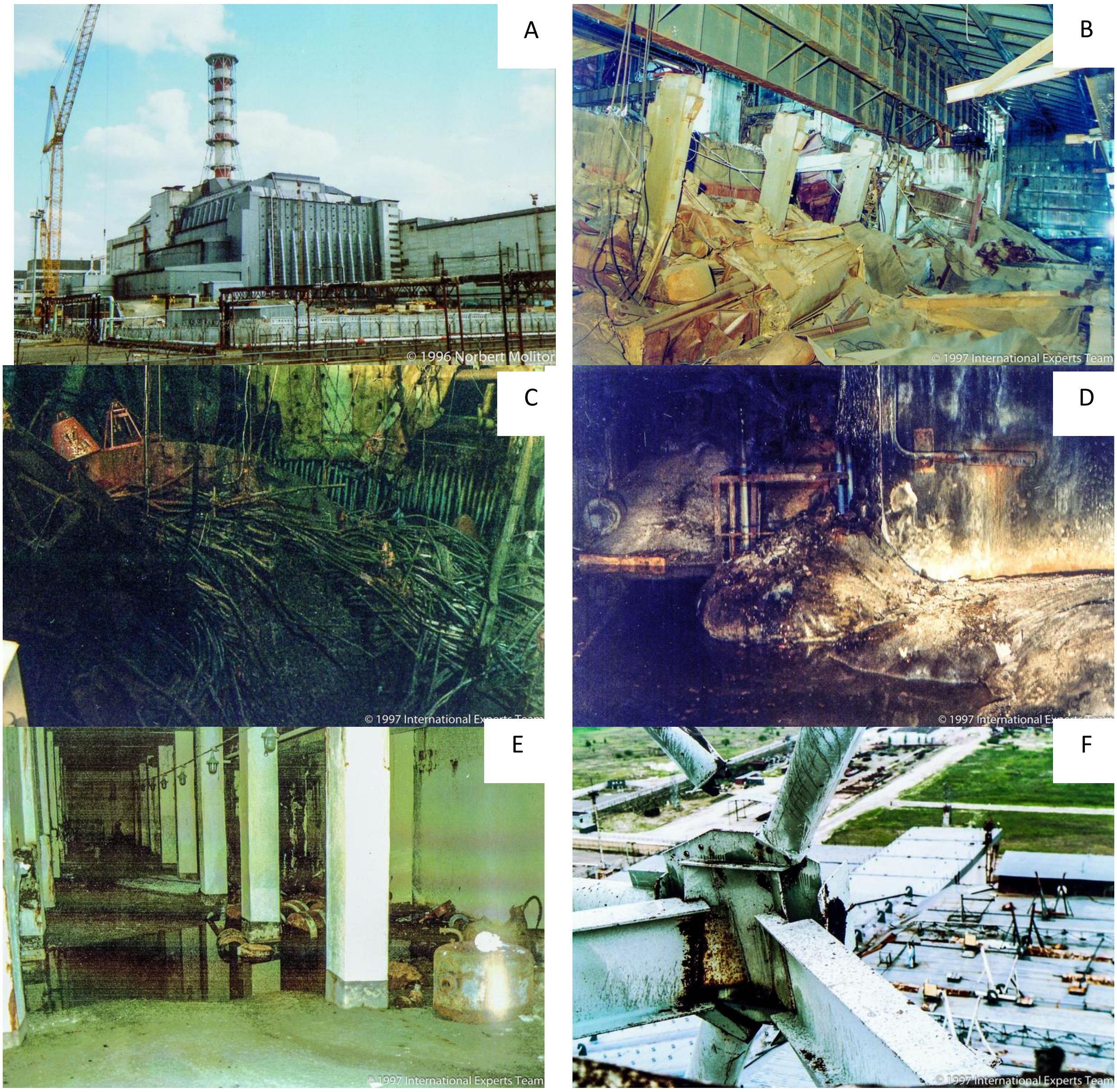


Fig. 1. A - existing Shelter (Sarcophagus); B - inside Sarcophagus; C - destroyed reactor vessel; D - Lava like fuel "elephant foot"; E - water in the premises; F - destroyed node of ventilation stack.
(Picture source: ChNPP, Trischler & Partner, 1996.)

Since decision of recommended course of action, substantial studies and technologies have been developed and know-how was acquired during decommissioning of highly contaminated facilities in Ukraine and other countries. In addition, the Institute for Safety Problems of Nuclear Power Plants (National Academy of Sciences of Ukraine) has performed various studies on FCM, and on its retrieval and removal.

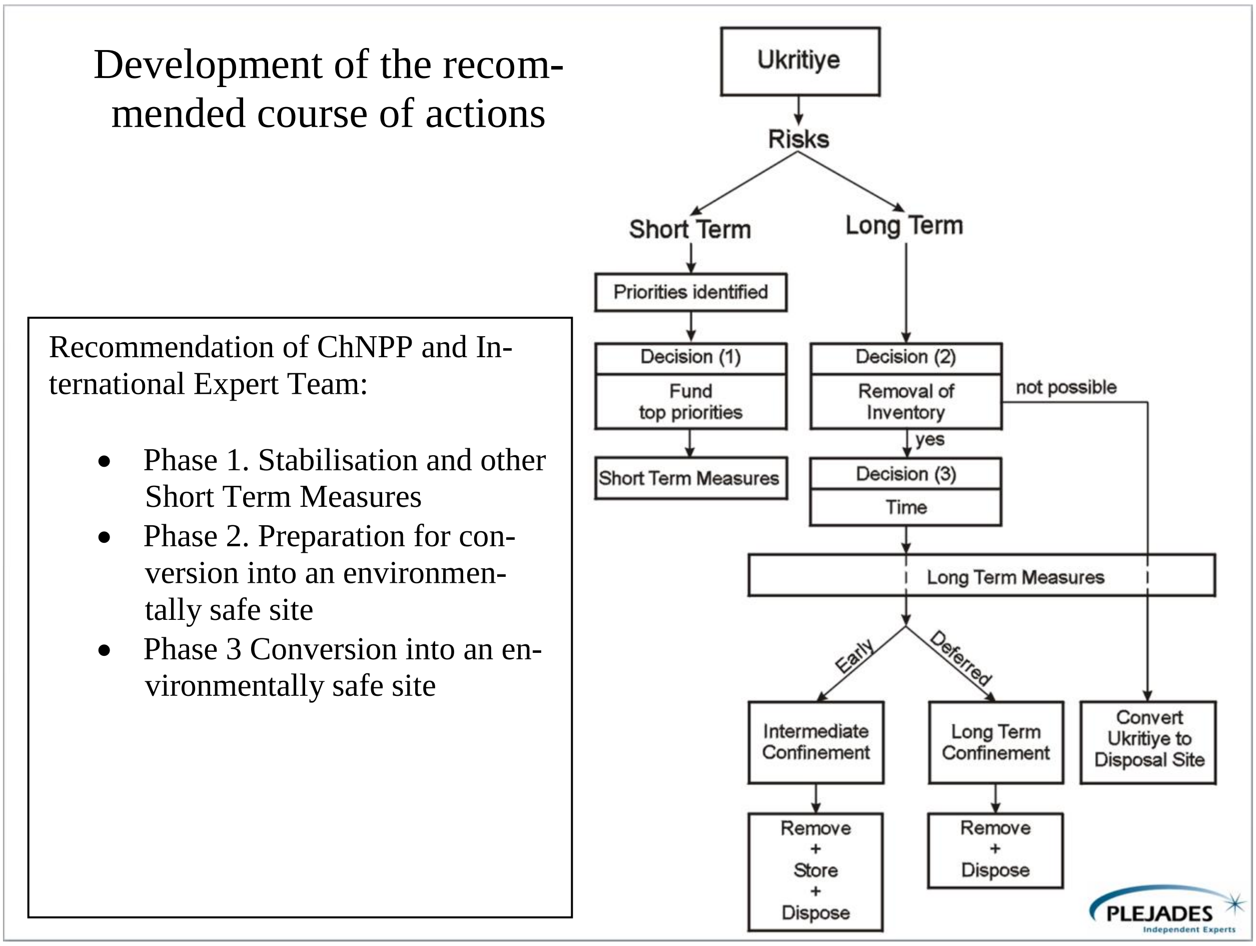


Fig. 2. Comprehensive principle diagram.

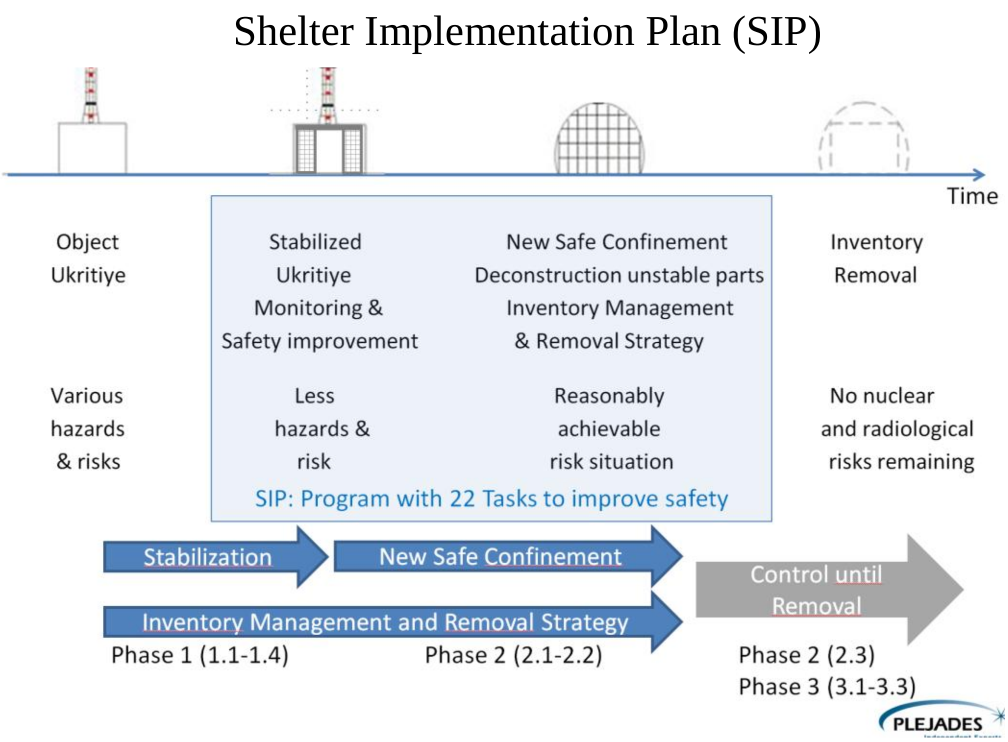


Fig. 3. Gradual improvement of the situation through the different phases.

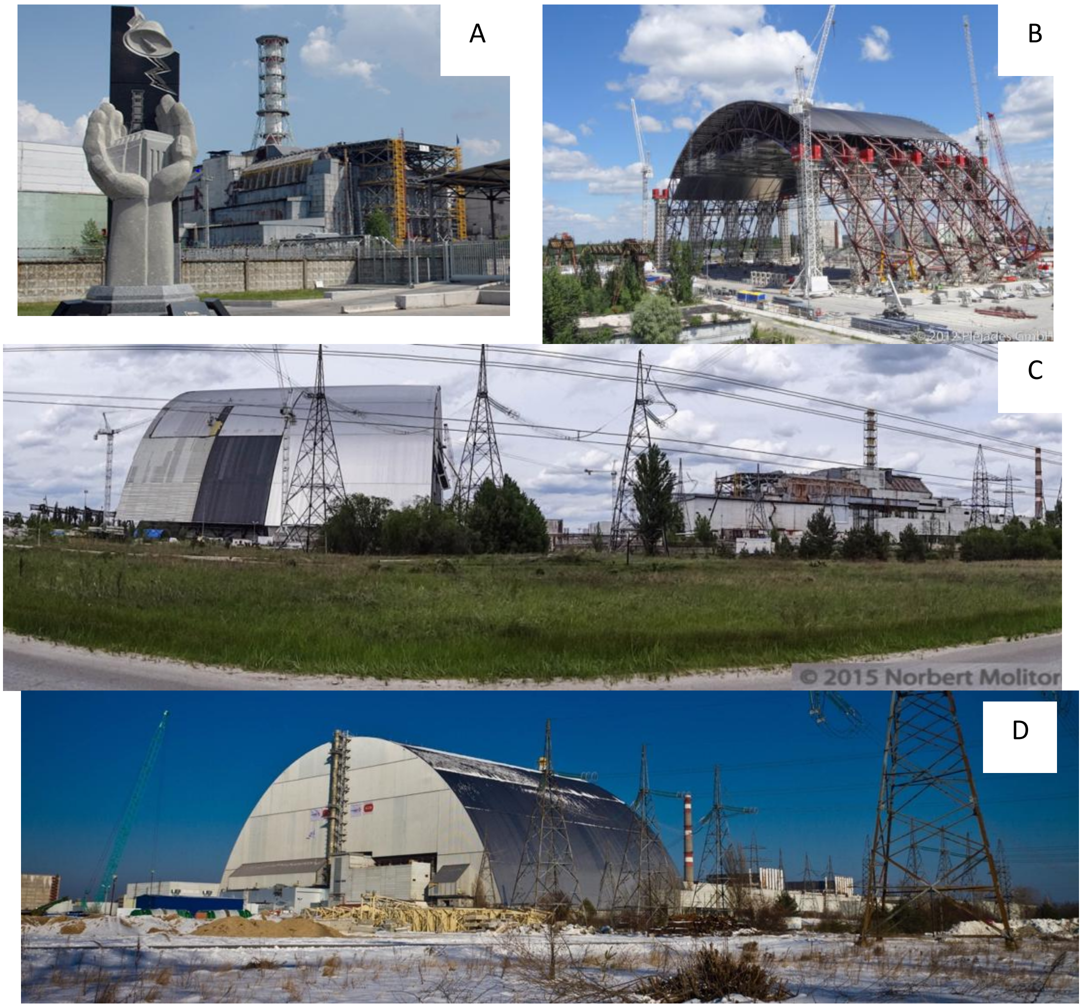


Fig. 4. A - Stabilized Shelter (2008); B - First segment under construction (2012); C - Assembly of the 2 segments prior to pitching (2015); D - Current view of NSC (2017) (Picture source: Plejades).

The occurrence of another large-scale nuclear accident in 2011 in Japan, also contributed to fostering approaches and development of technologies for managing highly contaminated sites including the necessity for management of damaged fuel and debris removal.

To achieve successful retrieval of inventory at ChNPP Unit 4 including FCM, 5 main key processes have to be resolved, as illustrated and simplified below (Fig. 5).

The key elements (simplified processes) shown in the Fig. 5 are:

1. Grip/grab the pieces of inventory from the particular location (from lower to higher activity) and load it into a handling container. This can be done with remote conventional heavy duty dismantling equipment available. Such work equipment can be brought to its operational place by remotely operated cranes planned/installed in the NSC. Useful experience with the use of remote equipment for bulk removal including high level wastes have been collected at Chornobyl site during removal works of the pioneer walls. Once loaded into handled container the inventory can be moved vertically and horizontally by remotely operated cranes out of the Unit 4 towards the next process steps which should be still localised within the new safe confinement. Larger pieces (e.g. steel components) should be gripped and moved as intact large pieces.

2. The next element would be a sorting, which may be possibly combined with preliminary segregation by fragmentation or cutting processes. Preliminary sorting is to adjust and optimise subsequent waste processing steps according to separated different waste streams by the point of its origin (location), type of material and by the activity to essentially fuel containing materials, graphite pieces, metallic parts and rubble.

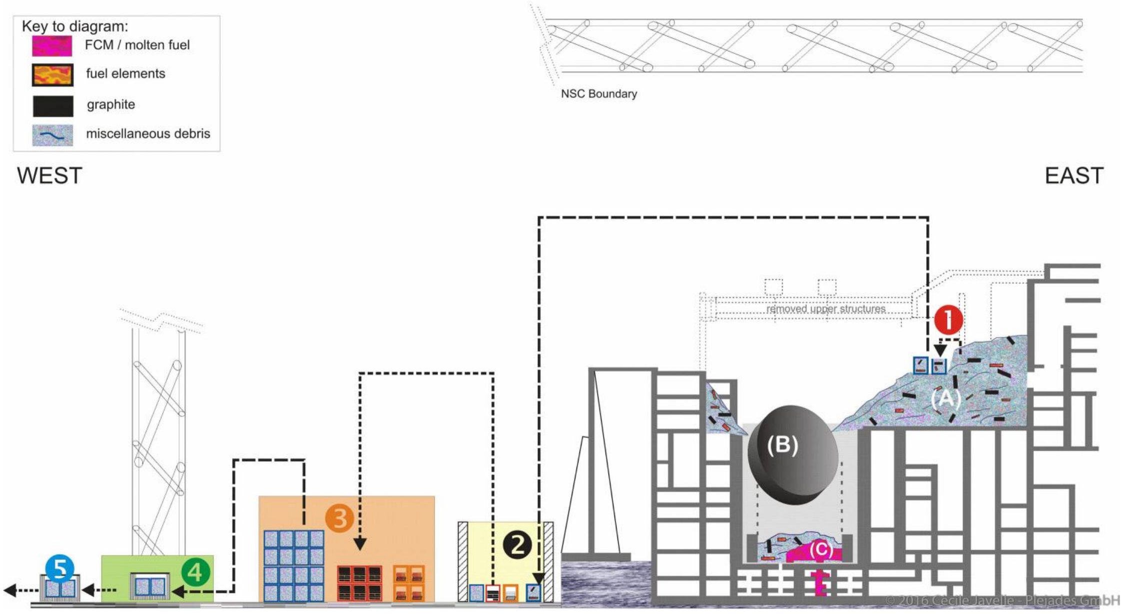


Fig. 5. Main key processes.

After sorting, these different waste streams should be loaded into the preliminary containers labelled for particular type/activity. If the sorting step (2) has to be skipped for some of the inventory taken, the preliminary containers would contain unsorted wastes leaving further sorting to a later process step, which in principle could be an alternative concept.

3. These preliminary waste containers can be stored within the NSC. In terms of improvement of safety that would be a major step forward compared to the current situation with the inventory as unconfined bulk in undefined conditions and locations. It should be noted that this can only be a short-term solution, especially for containers with fissile materials (FCM): e.g. the NSC itself has only a limited lifetime (~100 years). The waste inside the preliminary containers will neither be conditioned nor packaged for long term storage or disposal which is next required step. In addition the preliminary containers will be probably contaminated due to the temporary storage location which will require adequate approach for their further management.

4. The process can be developed further beyond temporary storage inside the NSC. One plausible option is to transfer the preliminary containers through a lock-out facility into adequate over-pack containers. Through the lock-out facility (which will use technologies similar to out-bag principles for hot cells) it can be ensured that the over-pack containers will remain clean (uncontaminated), thus facilitating further handling.

5. The over-pack containers can be then transported to the location for the next processing step, depending on the content: e.g. to Industrial Complex for Solid Radwaste Management (ICSRM) or to new facilities such as for processing of FCM or graphite, or to a long term storage (which could for example be built on the construction site area remaining after completion of NSC).

The configuration of the different elements needs to be adapted to the situation and materials encountered. For instance, the conditions and composition of the bulk in the upper areas marked (A) in the diagram above (dropped materials during immediate accident fighting as well as FCM and moderator graphite from liquidation efforts when cleaning the Unit 3 and turbine hall roof) may require different technical solutions than for inventory which can be only accessed by removing heavy equipment or solid building structures (e.g. reactor bioshield “Elena” (B), building walls and other building structures) when moving downward during removal. The ultimate challenge will be the recovery of lava type fuel components (C) in the lower part of former unit 4 compartments, involving probably different or adapted technologies.

The processing of FCM to be conditioned and/or packaged in the final disposal ready form is one of the most important challenges for a long term safety, where a consistent approach and specific solutions must be found. Although the final form/package for that waste stream will be dependent on geological and engineering barriers of the geological disposal site (Waste Acceptance Criteria) it is more than prudent to start technology development work for conditioning (including packaging) of such waste as early as possible and ultimatly in parallel with removal and segregation of the inventory of the Shelter. The pilot tests for detail characterization, chemical processes for extraction and separation of different elements and investigation of appropriate stable matrices and processes to develop industrial scale facilities should be a logical way forward. Experiences collected in research and testing of real FCM samples over the last 30 years by the scientific organisations located and working in Chornobyl context are a valuable asset for this task and should be used further. This would require configuration and implementation of an appropriate test and development facility able to handle high radiation fields. Since the problem of conditioning fuel debris is not unique only to Chornobyl and corresponding researches are initiated also outside Ukraine, an international cooperation effort should be considered and further discussed for resolution of the challenges related to FCM and fuel debris processing and conditioning at Chornobyl and elsewhere.

The key inventory retrieval processes, all based on access from the top will have to be supported by auxiliary processes such as maintenance and monitoring. Those will require safe access corridors for workers. These can be developed from the existing ones, making good use of the know-how accumulated when access corridors where implemented for stabilization projects during SIP. However, for the next stages, it may be advisable to build new (closed) clean corridors (which can be easily decontaminated) with airlocks for personnel transferring from the corridor into the NSC and re-entering. The personnel airlocks may be fitted with locks for small material and equipment allowing out-/in-bagging of materials and equipment. Roughly following access corridors could be envisaged:

ground level access corridor(s) from the western boundary of NSC;

upper level access corridor(s) from the eastern boundary of NSC (= from Unit 3);

lower level premises access corridor from the South through an access corridor located along the south axis (maybe by using the existing building structures).

Configuration of the retrieval process steps described above will be a challenge and should follow Key Performance Indicators (KPI) to be set in line with desired safety objectives (in terms of nuclear safety, industrial safety, and/or radiation protection), such as:

dose uptake (in terms of ALARA-principles);

waste volumes generated (in terms of waste reduction);

path forward for FCM conditioning/packaging for long term storage or disposal;

releases and environmental impacts (in terms of impact reduction);

effectiveness (in terms of overall safety levels achieved);

efficiency (in terms of efforts and times vested to achieve effectiveness).

Configuration and implementation of the inventory recovery measures, supported by the KPI, might lead to the conclusion that at least part of the inventory may be recovered in the nearer term future (e.g. the easily accessible inventory in the upper part) and that the remaining part of the inventory may be kept a longer time in safe conditions in-situ as already anticipated in in the above mentioned “Short and Long Term Measures Study”.

Shall that be the case, the NSC would be instrumental for further improvement of the conditions of the residual inventory prior to removal (e.g. shrink size, optimize geometry, install long term monitoring and control means) and for eventual implementation of a further optimized confinement which would last longer, and that would be easier and cheaper to be maintained and operated than the NSC.

In summary, it can be concluded that a lot of progress has been achieved since the accident to convert Unit 4 into safe conditions, which will reach a long awaited milestone step with the expected soon completion of the NSC. It is an important step forward to develop the long term strategy for the inventory with different options on timing and approaches for its removal.

Waste Management Achievements and Challenges in the ChEZ

To support accident liquidation in 1986/1987 different waste management measures and facilities were implemented within the ChEZ including:

creation of nine “Radioactive Waste Temporary Storage Places (RWTSP)” in which contaminated vegetation, topsoil and construction debris were buried on site in trenches and clamps to reduce radiation fields in the neighbourhood of ChNPP;

creation of three “Radioactive Waste Disposal Sites (RWDS)” to receive radioactive wastes from accident liquidation which were not kept in the “Object Ukritiye”: “RWDS Podlesny”, “RWDS ChNPP 3rd Stage” which were closed after liquidation measures and “RWDS Buryakovka” which is a trench type disposal still operational to receive low level bulk wastes.

Since the 1990 important radioactive waste facilities were initiated at ChNPP site and nearby Vektor Complex site which are relevant both to support the decommissioning of ChNPP Units 1 to 3 as well as the conversion of Unit 4 into safe ecologic conditions, including:

industrial Complex for Solid Radwaste Management (ICSRM) at ChNPP;

liquid Radwaste Treatment Plant (LRTP) at ChNPP;

dry Interim Storage for Spent RBMK Fuel (ISF 2) at ChNPP;

engineered Near Surface Disposal Facility (ENSDF) at Vektor Complex;

near surface solid radwaste disposal facility for container type waste (SRW 1) at Vektor Complex;

near surface solid radwaste disposal facility for bulk waste (SRW 2) at Vektor Complex;

central Storage for Spent Sealed Radioactive Sources (SSSRS) at Vektor Complex;

Radwaste Processing Facility at Vektor Complex.

Fig. 6 shows approximate delineation of the nine RWTSP and RWDS as well as Vektor Complex in the vicinity of ChNPP.

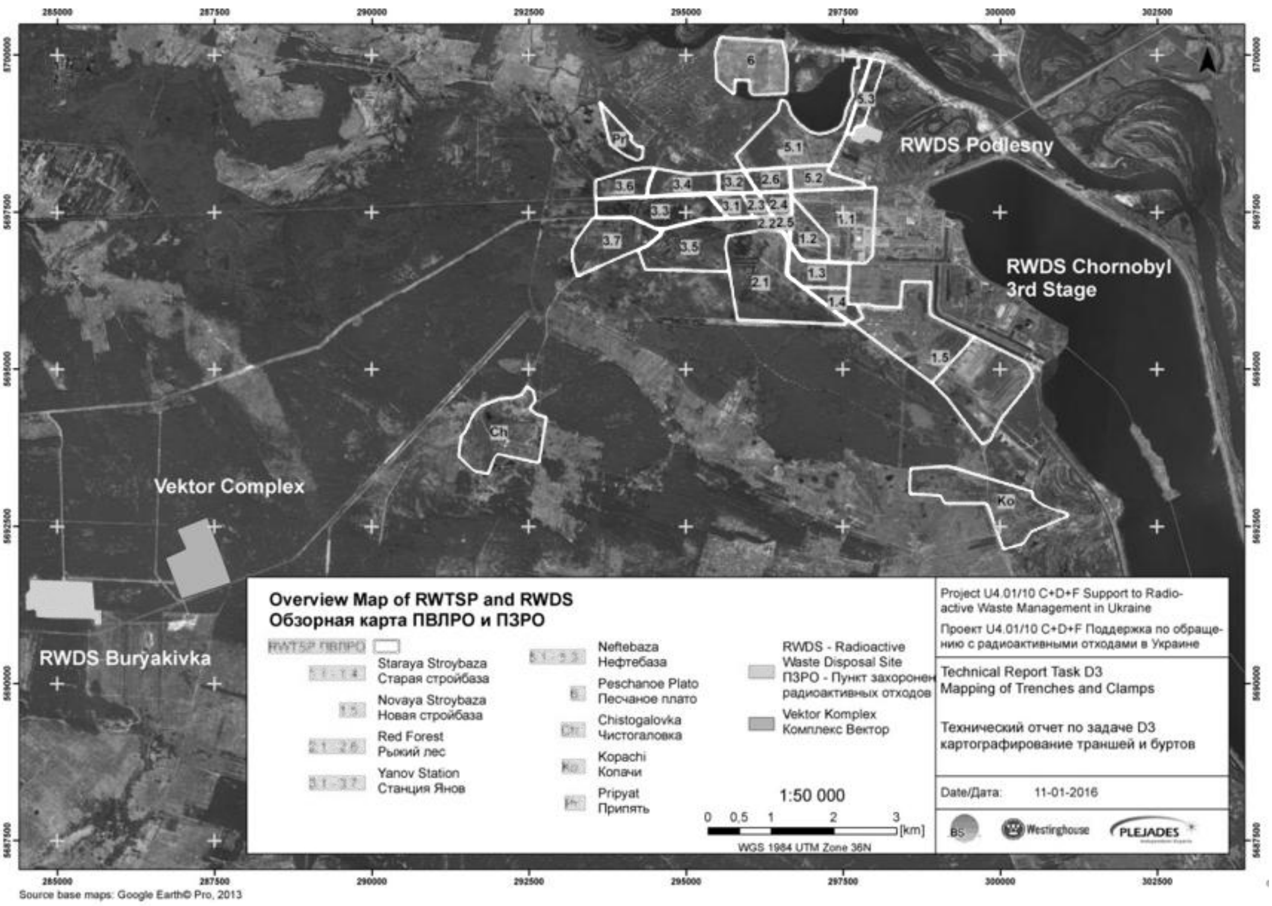


Fig. 6. Delineation of the RWTSP, RWDS and Vektor Complex.

As part of further Vektor Complex development, other additional facilities are under discussion or planning, such as (Fig. 7):

near surface solid radwaste disposal facility (e.g. additional SRW-1, SRW-2, so called SRW-3, SRW-4, SRW-5 type facilities);

storage facility(ies) for vitrified HLW and long lived waste;

spent nuclear fuel long term storage facility (SNF).

With its anticipated development the Vektor Complex will be able to receive most of the wastes from ChNPP Unit 1 - 3 decommissioning, Conversion of ChNPP Unit 4 into safe ecologic conditions and radioactive wastes from operation of power plants and other radioactive wastes which are suitable for near surface disposal over the next 100 - 200 years of operation time. The HLW from different origins as well as the large amounts of long lived radioactive wastes being consequence from the Chornobyl accident will require a deep geological repository which is not part of the Vector complex.

Safety Assessment for Legacy Wastes Sites in the ChEZ

One major challenge for radioactive waste management in the ChEZ is the safe management of radioactive waste located in the RWTSP and RWDS. Since many years the "Central Radioactive Waste Management Enterprise (CRWME)" implements investigations to update the information on the legacy waste inventory which is necessary to perform safety assessments and develop action strategies and plans. In a recent project with funding from the EC-INSC programme an updated inventory has been established by CRWME and international experts (represented by the author team of the present article) for the ensemble of RWTSPs for the reference year 2015 as summarized in the following Table.

All RWTSP	Waste volume, m^3	Total activity, Bq
Clamps and trenches	1 195 000	$3.1 \cdot 10^{14}$
Topsoil, subsoil	278 000	$4.5 \cdot 10^{13}$
Total	**1 473 000**	$\mathbf{3.5 \cdot 10^{14}}$

Fig. 7. A - New Dry Interim Storage for RBMK fuel (2016); B - sorting Robot at ICSRM (2008); C - control monitor snapshot showing solidified waste drum curing hall of LRTP (2015); D - ENDSF at Vektor Complex (2008); E - Near Surface Disposals Type 1 and 2 at Vektor Complex (2016); F - Operator at DSR Storage and Processing Facility at Vektor Complex (2016); Picture source: Plejades (A, B, C, D), NUKEM (E), SAEZ (F).

Based on estimated above inventory safety assessment calculations have been performed with the models developed for different reference persons. The goal of the safety assessment was to estimate the potential radiological impacts, serving as a basis for planning measures for further improvement of the rad-waste storage safety and (if needed) remediation actions at the RWTSP and RWDS. The results of the individual safety assessments for the RWTSP, RWDS and Vektor Complex facilities have been combined into a comprehensive safety assessment to estimate the potential radiological impacts of the whole Vektor Complex and its interaction with the RWTSP and RWDS. Such a comprehensive safety assessment has been performed for the first time for the ChEZ.

Exposure pathways leading to direct irradiation, inhalation and ingestion of radioactive substances in the direct vicinity of the RWTSP, RWDS and Vektor Complex facilities were considered taking into account present and future restrictions of the contaminated territory. Furthermore, the potential exposure for the population outside the ChEZ due to migration of radionuclides via air and groundwater pathway has been assessed. The systematic modelling analysis of the relevant exposure pathways and of dose calculations lead to an overall estimation of the dose impact on workers within the ChEZ and settlers outside the ChEZ today, as well as potential re-settlers inside the ChEZ in the far future. The following diagram shows the dose calculation results due to burials and to contaminated topsoil for an inadvertent settler today and in 200 years.

The following Fig. 8 shows the calculated exposure dose for inadvertent settlers at the RWTSP from burials and top soil contamination.

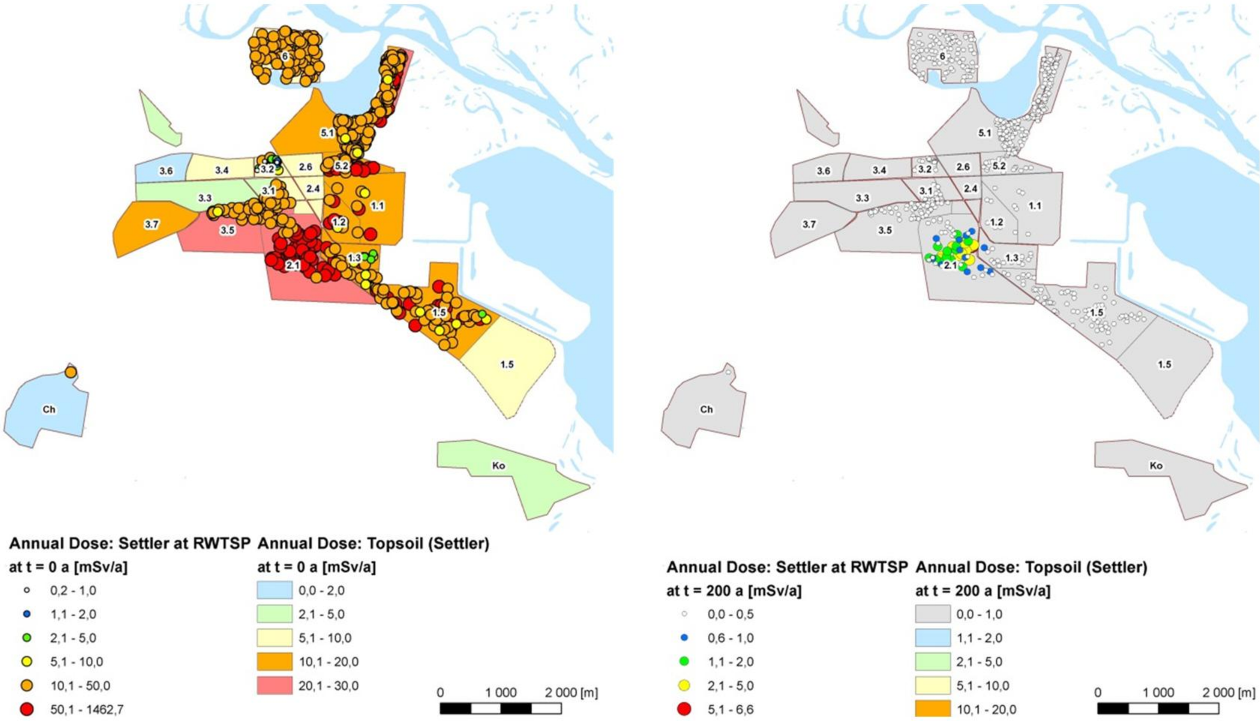


Fig. 8. Calculated exposure dose for inadvertent settlers at the RWTSP from burials and top soil contamination. Left: dose today; right: dose in 200 years.

For an assumed worker "reference person" with a dwell time of 1000 h/year the evolution over time of the overall exposure dose has a similar pattern but with a lower dose level, as shown in the following diagram.

The following Fig. 9 shows the calculated radiological impact for unprotected workers at RWTSP from burials and top soil contamination (dwell time 1000 h/year).

The diagrams confirm that the institutional control in the form of the ChEZ established after Chornobyl accident and maintained for more than 30 years was and is an appropriate and efficient measure to protect general public. Conservative calculations suggest that mainly due to decay of the relatively short lived radionuclides of ^{137}Cs and ^{90}Sr the doses will decrease significantly over the next 200 years, so that dose level above 1 mSv/a (for the considered settler scenario) will be still existing only for a few burials in the main contaminated sectors of RWTSP Red Forest and RWTSP Stara Stroibasa.

The calculated residual radiological impact from RWTSP after 500 years through groundwater pathway under conservative assumptions is generally very low (less than 1 μSv/a) even very low downstream in the most impacted area (less than 0,5 mSv/a).

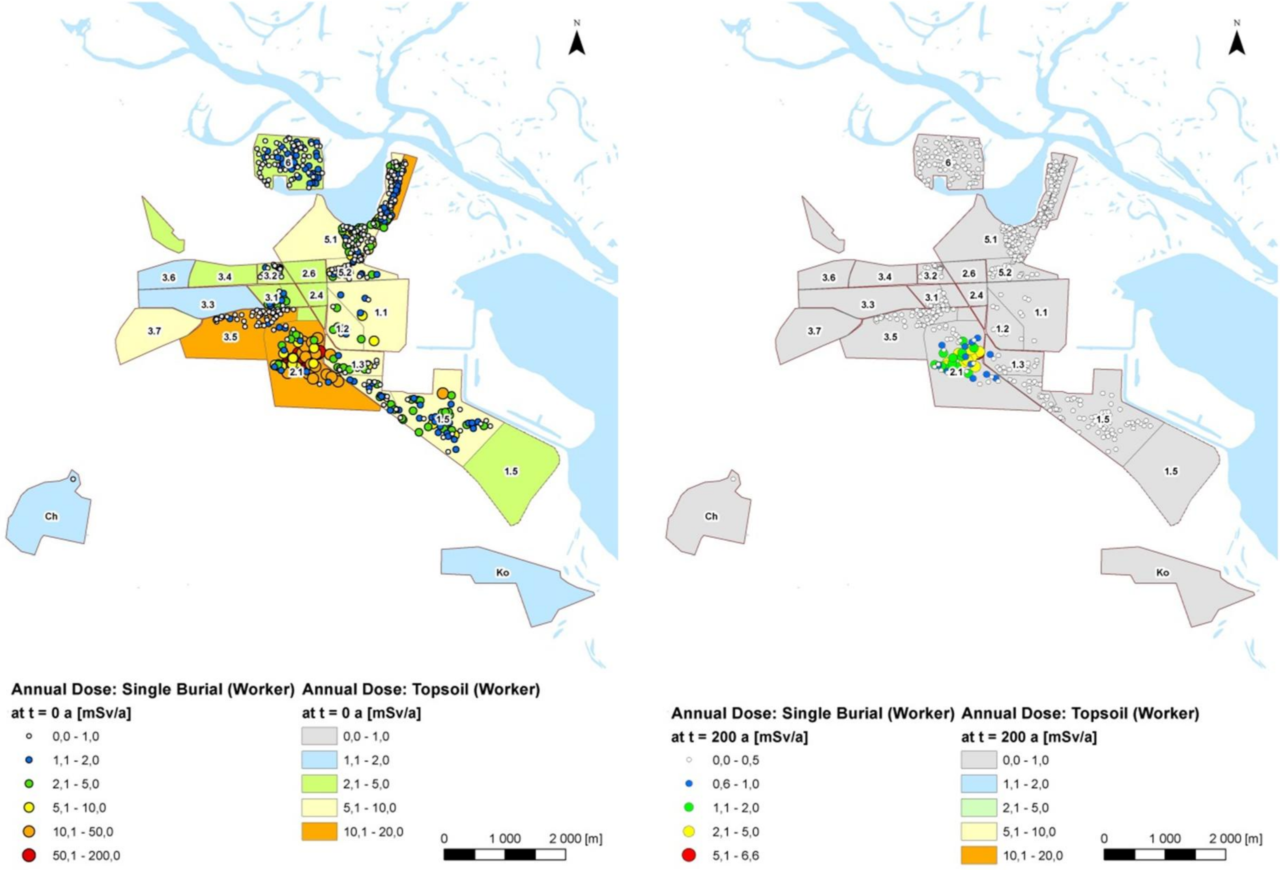


Fig. 9. Calculated radiological impact for unprotected workers at RWTSP from burials and top soil contamination (dwell time 1000 h/year). Left: dose today; right: dose in 200 years.

The following Fig. 10 shows the calculated dose from use of groundwater impacted by the RWTSP, RWDS and Vektor Complex in 500 years, Top: use of groundwater for irrigation and watering, Bottom: use of groundwater as drinking water.

Following conclusions can be drawn from these recent safety assessment studies:

1. The RWTSP are confirmed as risk objects which require risk mitigation measures to protect general public, workers and environment.

2. For the waste burials identified at the RWTSP a robust institutional control within the current boundaries of the current “10 km Zone” over a period of about 500 years is sufficient to ensure protection of population, workers and environment from relevant impacts of RWTSP. After assumed institutional control period of 500 years the residual risks are sufficiently small, so that most restriction may be lifted: e.g. non-nuclear industrial use of sites by unprotected workers would not represent unacceptable risks.

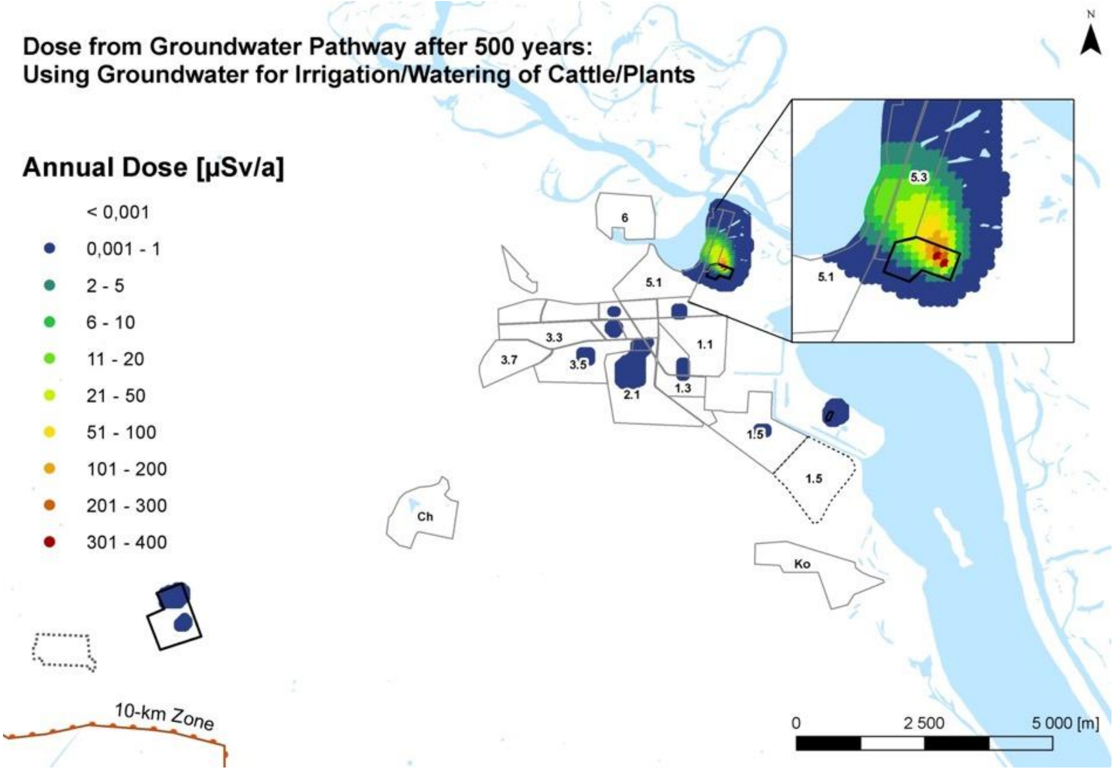
3. The removal of some selected burials (and top soil contamination hot spots) would be justified to improve workers and visitors safety and overall dose savings.

4. Some burials may still represent a residual risk for intensive site use after assumed institutional control period of 500 years. These residual risks may be eliminated by removal or controlled by restrictions. As long as there is no high frequency movement of staff or visitors on locations of these burials, there is no need of early removal, such that by deferring removal, benefit (i.e., lesser dose to remediation workers as well as lesser amount of waste) can be taken from continuing decay of activity inventory.

5. In summary, from perspective of safety for workers and population there is no need to remove all burials and all top soil contamination hot spots in all RWTSP (it would be sufficient to limit removal to some relevant burials).

6. There is a need and added value to continue investigation to reduce the uncertainties associated with the not yet fully characterized burials.

7. On the other side, the safety assessment clearly indicates importance of issues related to the contaminated territory in the ChEZ, which needs to be put in the focus of the activities of CRWME or another respective organisation. Here hot spots may represent locally elevated risk levels. Systematic investigation is recommended to undertake specific safety assessment and ranking of hot spots.



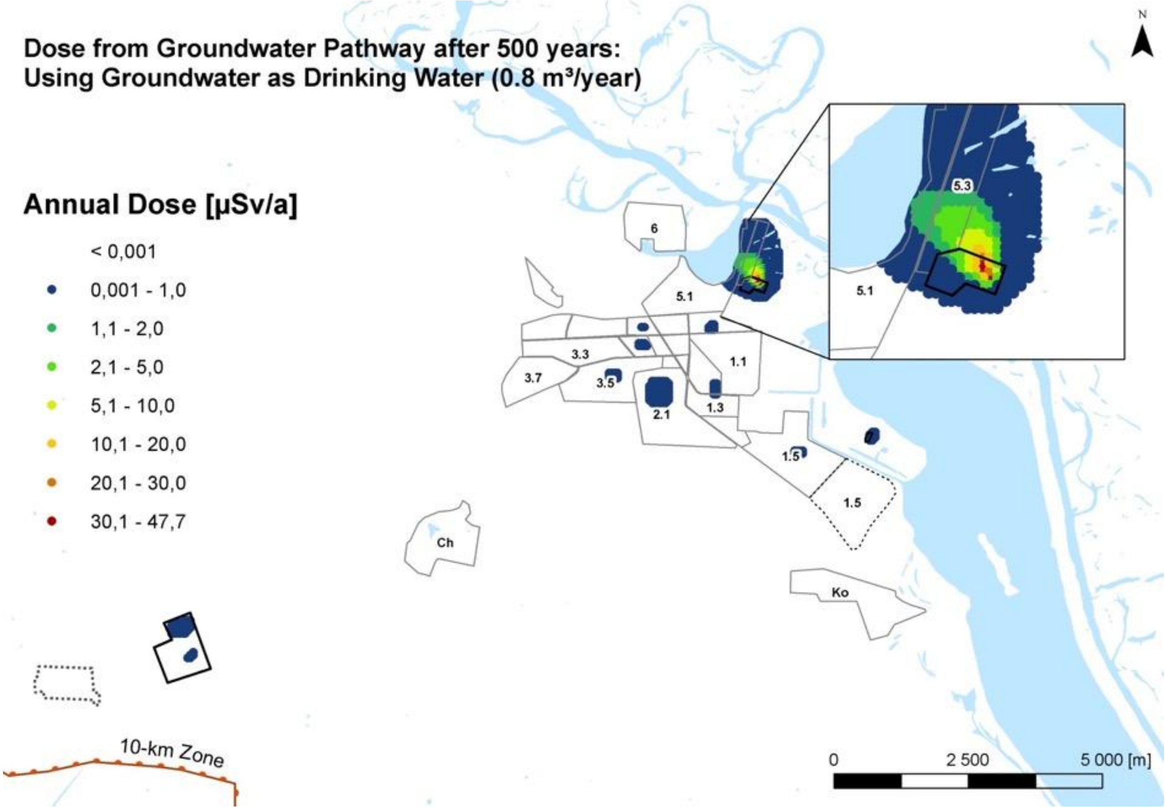


Fig. 10. Calculated dose from use of groundwater impacted by the RWTSP, RWDS and Vektor Complex in 500 years; top: use of groundwater for irrigation and watering; bottom: use of groundwater as drinking water.

8. The comprehensive safety assessment for the existing and future waste facilities at the Vektor Complex show that after post-operational institutional there is only limited residual risks associated to eventually disposed long lived radionuclides mixed with short lived low and intermediate level waste for the intrusion case (direct intrusion or use of groundwater in the immediate downstream). The resulting residual impacts are considerably lower than those from the legacy waste sites of RWTSP and RWDS. This means that anticipated transfer of radioactive wastes from ChNPP to Vektor Complex during decommissioning and remediation works would result in an improved condition, will not require more restrictions than those for the RWTSP and RWDS (institutional control within the boundaries of the current “10 km Zone”.

9. Based on the safety assessment for “RWDS Podlesny”, which contains also some amounts of HLW-TRU, FCM and long-lived waste, enhanced institutional control with access control, facility ageing management and site monitoring as part of active risk management are recommended. For the long term safety retrieval of the HLW-TRU inventory of RWDS Podlesny is a preferred option. For “RWDS Chornobyl 3rd Stage” the safety assessment confirms that institutional control are main action options to ensure short and long term safety. Eventually identified HLW (if any) may be optionally transferred to a more appropriate facility.

10. The availability of a bulk radioactive LLW waste disposal facility as is operational “RWDS Burykovka” is an important for any remedial action in the contaminated areas. With regard to its remaining limited capacity either its upgrade and extension or its replacement by a new facility will be important.

11. Further improvements can be achieved by conception and implementation of specific disposal facilities for VLLW, which will be possible under the new waste classification system currently under preparation, and facilities for management of bulk LLW with organic content (e.g. contaminated vegetation).

12. The next important element in the long term management of the accident consequences is to develop a deep geologic repository appropriate to dispose the FCM-type and other long lived radioactive wastes which will necessary for the resolution of Chornobyl challenges. Its availability would also allow further optimisation of Vektor Complex configuration and operation.

Conclusions and Look Forward

The management of Chornobyl challenges has achieved substantial and visible progress in the 3 relevant fields:

creation of stabilized and safe conditions at Chornobyl NPP Unit 4 site as prerequisite for the conversion of the Unit 4 site into safe ecologic conditions;

development and implementation of a decommissioning plan for Chornobyl NPP Units 1 to 3;

creation of waste management infrastructure for the two activities listed with the bullets above.

The main next challenges are:

development of the approaches to recover and manage safely the FCM type and long lived inventory from ChNPP Unit 4 (as well as the small amounts of similar inventory disposed at “RWDS Podlesny”;

optimization of safe configuration of waste management schemes and disposal facilities based on the new waste classification system for radioactive wastes which is currently prepared;

development of a deep repository suitable to dispose FCM type and long lived wastes from ChNPP. If such a facility would be created, the long lived inventory storages planned in near surface facilities at Vektor Complex may be optimized such that also the eventual residual long term risk after post-operational institutional control would be considerably reduced.

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Abbreviations used

ALARA	As low as reasonably achievable
CRWME	Central Radioactive Waste Management Enterprise
ChEZ	Chornobyl Exclusion Zone
ChNPP	Chornobyl Nuclear Power Plant

FCM	Fuel Containing Materials
HLW	High level radioactive waste
ICSRM	Industrial Complex for Solid Radwaste Management
KPI	Key Performance Indicators
LLW	Low level radioactive waste
LRTP	Liquid Radwaste Treatment Plant
NSC	New Safe Confinement
RWDS	Radioactive Waste Disposal Site
RWTSP	Radioactive Waste Temporary Storage Place
SAEZ	State Administration for the Management of the Exclusion Zone
SIP	Shelter Implementation Plan
SRW	Facility for Solid Radioactive Waste
SSSRS	Centralized Storage for Spent Sealed Radioactive Sources
TRU	Trans Uranium Elements

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ВИКЛИКИ І ПРОГРЕС У ЗАБЕЗПЕЧЕННІ БЕЗПЕКИ ТА ПОВОДЖЕННЯ З РАДІОАКТИВНИМИ ВІДХОДАМИ НА ЧАЕС І В ЧОРНОБИЛЬСЬКІЙ ЗОНІ ВІДЧУЖЕННЯ

Уведення в експлуатацію нового безпечного конфайнмента на майданчику № 4 ЧАЕС ознаменує досягнення однієї важливої віхи у процесі перетворення чорнобильського енергоблока № 4 на екологічну безпечну систему. Нові об'єкти з поводження з радіоактивними відходами були розроблені на ЧАЕС і в комплексі "Вектор" для забезпечення безпечного поводження з радіоактивними відходами в чорнобильській зоні відчуження. Тривалі дослідження та оцінки безпеки різних майданчиків відходів, що були створені в рамках робіт із мінімізації наслідків катастрофи, підтверджують ефективність заходів, проведених у минулому та формують основу стратегії безпечного поводження з відходами, що залишились у спадщину. Усе це разом показує, що національні та міжнародні зусилля, спрямовані на контроль впливу наслідків Чорнобильської аварії, досягли суттєвого й помітного прогресу в галузі безпеки, і довгострокова безпека буде досягнута завдяки їхньому послідовному продовженню.

Ключові слова: поводження з радіоактивними відходами, радіаційна безпека, зона відчуження ЧАЕС.

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ВЫЗОВЫ И ПРОГРЕСС В ОБЕСПЕЧЕНИИ БЕЗОПАСНОСТИ И ОБРАЩЕНИЕ С РАДИОАКТИВНЫМИ ОТХОДАМИ НА ЧАЭС И В ЧЕРНОБЫЛЬСКОЙ ЗОНЕ ОТЧУЖДЕНИЯ

Введение в эксплуатацию нового безопасного конфайнмента на площадке № 4 ЧАЭС ознаменует достижение важной вехи в процессе преобразования чернобыльского энергоблока № 4 в экологически безопасную систему. Новые объекты по обращению с радиоактивными отходами были построены на ЧАЭС и в комплексе "Вектор" для обеспечения безопасного обращения с радиоактивными отходами в чернобыльской зоне отчуждения. Длительные исследования и оценки безопасности различных наследственных площадок отходов, которые были созданы в рамках мероприятий по реагированию на катастрофу, подтверждают эффективность мер прошлого и закрепляют основу стратегии безопасного обращения с наследственными отходами. Все это вместе показывает, что национальные и международные усилия, направленные на контроль над воздействиями последствий Чернобыльской аварии, достигли существенного и заметного прогресса в области безопасности, и долгосрочная безопасность будет достигнута благодаря их последовательному продлению.

Ключевые слова: обращение с радиоактивными отходами, радиационная безопасность, зона отчуждения ЧАЭС.

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