Conceptual Design for a Short-Lived Low- and Intermediate-Level Waste Repository at the Al Tuwaitha Nuclear Center, Baghdad, Iraq-17189

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ABSTRACT

The European Commission under their Instrument for Nuclear Safety Cooperation (INSC) has initiated a project supporting Iraq's efforts for the safe disposal of short lived low- and intermediate-level radioactive waste (SL-LILW) arising from the decommissioning of Iraqi nuclear installations. The INSC project includes both the development of an initial conceptual level basic design and preliminary safety assessment (PSAR) report and the subsequent detailed engineering design and supporting intermediate safety assessment report (ISAR). The project is being executed by a Consortium led by NUKEM Technologies Engineering Services GmbH and joined by DBE TECHNOLOGY GmbH of Germany; JAVYS a.s. of Slovakia and MCM Environmental Services Ltd of the United Kingdom. The current paper focuses on the development of the conceptual level basic design.

In previous decades Iraq had a significant nuclear program which encompassed ten nuclear sites spread out across the country. The largest site was located at the Al-Tuwaitha site near Baghdad where 18 nuclear facilities were located. The facilities suffered significant damage from bombing and subsequent looting during the first Gulf War in 1991. Currently, the Ministry of Science and Technology (MoST) is the radioactive waste management operator in Iraq and also the license holder for the ten Iraqi nuclear sites, all of them heavily damaged.

Because of the ongoing security concerns in Iraq MoST has selected the Al Tuwaitha Nuclear Center as the preferred and best suited location for development of an SL-LILW repository. As an initial step in development of the conceptual design various repository design options for the site were examined and assessed. The assessment considered similar facilities that have been implemented internationally. At the conclusion of the assessment and in conjunction with the Iraqi Beneficiaries from MoST, a near-surface vault design was selected for the facility.

The design of the facility relies on experience gained from existing low-level waste repositories at Centre de L'Aube in France and the El Cabril solid radioactive waste disposal facility in Spain as well as on more recent experience gained in the design of the Bulgaria National Disposal Facility (NDF) under construction near the Kozloduy Nuclear Power Plant. Similar to these reference designs, the concept for the Al Tuwaitha Disposal Facility (ATDF) will rely on a series of reinforced concrete vaults into which containerized waste will be placed. Each vault will consist of two chambers designed specifically to hold the waste. Central drainage points in each waste chamber will lead to an infiltration water collection system designed to detect any failures in the waste containment. Each disposal

vault will be sealed after filling by installation of a reinforced concrete closure slab. Once all of the waste has been disposed of the site will be decommissioned and a multilayer protective cover will be installed over the sealed disposal vaults. The multilayer cover will act to further isolate the waste from the environment by limiting the access of water to the waste.

Due in part to the presence of shallow groundwater at the site and to avoid potential damage to the facility by flooding from the nearby Tigris River the concept for the Al Tuwaitha Disposal Facility requires construction of the disposal vaults on a raised platform several meters above ground level. Construction of this platform will be integrated into the conceptual safety design and materials will be selected which further enhance the isolation function of the disposal system by hindering or delaying the release of radionuclides to the environment. The infiltration water collection system, which will be constructed in a specifically designed accessible gallery embedded and fully integrated into the platform, will provide access to inspection points located beneath each disposal chamber.

The ATDF when completed will be a further demonstration of the adaptability of the disposal vault concept for use in isolating SL-LILW from the environment.

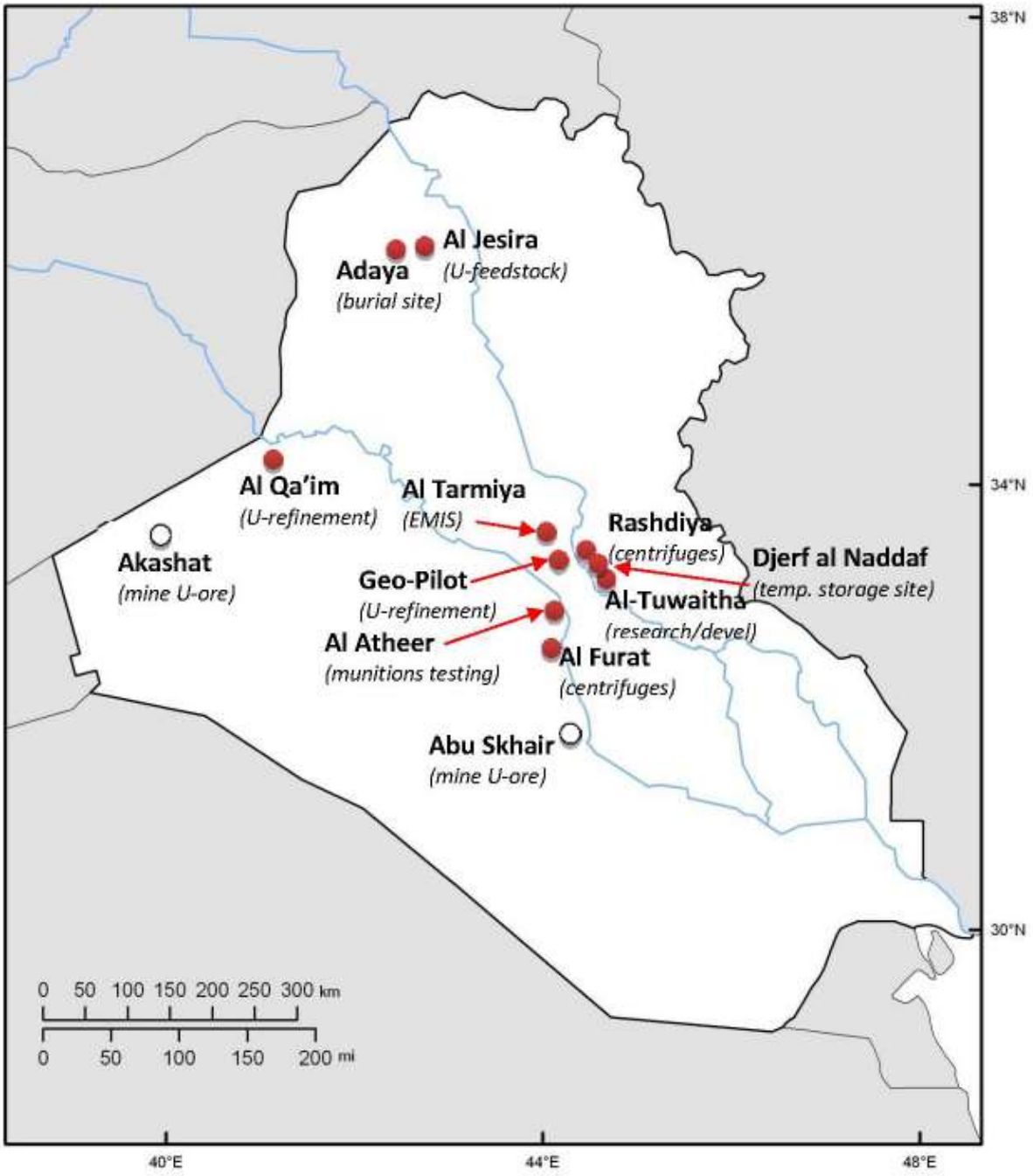
INTRODUCTION

Prior to the Second Gulf War, Iraq had a significant nuclear program that included activities conducted at ten different nuclear sites across the country, specifically at Al Tuwaitha, Adaya, Al Jesira, Al Q'aim, Al Tarmiya, Ash Sharqat, Rashidaya, Al Atheer, Al Furat and the Geo-Pilot plant (Figure 1). The main nuclear site with the heaviest concentration of activities was and remains the Al-Tuwaitha Nuclear Center, located about 20 kilometres south of Baghdad. The Al Tuwaitha site was responsible for the majority of research and development activities. The site originally housed two small active research reactors, the 500 kW Tammuz-2 (also known as Osiraq-2) and 5 MW IRT-5000 reactors, radiochemical laboratories, isotopes production facilities and hot cells, radioactive waste treatment and storage facilities, uranium metal production facility, fuel fabrication and nuclear administrative facilities. Many of the nuclear facilities lost their containment either as a direct result of warfare or subsequent looting and radioactive materials were spread into the environment as evidenced by contaminated soils that still exists at Al-Tuwaitha.

Iraq, supported by international financial and technical aid, has been working for the past decade on decommissioning its nuclear facilities and sites and ensuring their transfer to a radiological safe mode of operation. The main focus of activities is to protect the Iraqi public and site personnel against radiation exposures that could result from existing radioactive materials in the environment that are not adequately secured or appropriately contained. Furthermore, the current conditions of the nuclear facilities in Iraq constitute an ongoing security threat particularly in consideration of the loss of effective institutional control at some of the sites. Although all fuel and enriched uranium materials have been shipped out of the country and the majority of orphaned sealed sources have been recovered by the Ministry of Science and Technology (MoST), radioactive waste still remains a significant issue particularly at the heavily war damaged Al Tuwaitha Nuclear Center. Urgent actions are therefore needed to further improve the over-

all situation in Iraq and at Al Tuwaitha, including establishing a local disposal facility to effectively isolate the large quantities of low level waste (LLW) remaining in Iraq, including some waste classified as short-lived intermediate level waste (SL-ILW). (Note only waste suitable for near surface disposal is considered, which can include both LLW and SL-ILW). Of the ten existing sites waste suitable for near surface disposal is located at Al Tuwaitha and at the Geo-Pilot site.

To address this urgent need the European Commission, under the framework of its Instrument for Nuclear Safety Cooperation (INSC), awarded Project IQ4.01/11 "Feasibility Study, Basic Design and Engineering Design of an Engineered Radioactive Waste Disposal Facility" to the Consortium led by NUKEM Technologies GmbH of Germany and joined by DBE TECHNOLOGY GmbH of Germany, JAVYS a.s. of the Slovak Republic and MCM Environmental Services Ltd of the United Kingdom. The Consortium is working together with the Iraqi government as the main Project Beneficiary and MoST as the defined Project End-User.



SOURCE: IAEA 2013

FIGURE 1: Nuclear sites in Iraq (red points)

BACKGROUND

Nuclear energy research in Iraq began with the establishment of the Al Tuwaitha Nuclear Center in 1967. The site originally housed the 2-MW IRT-2000 research reactor, a radioisotope production facility as well as a waste storage station. The IRT-2000 was later upgraded to a 5-MW reactor, the IRT-5000. Other facilities were added to the site over the following years.

The Al Tuwaitha site has been the target of numerous air strikes and military ground actions. In 1980 at the outset of the Iran-Iraq War, the Iranian Air Force

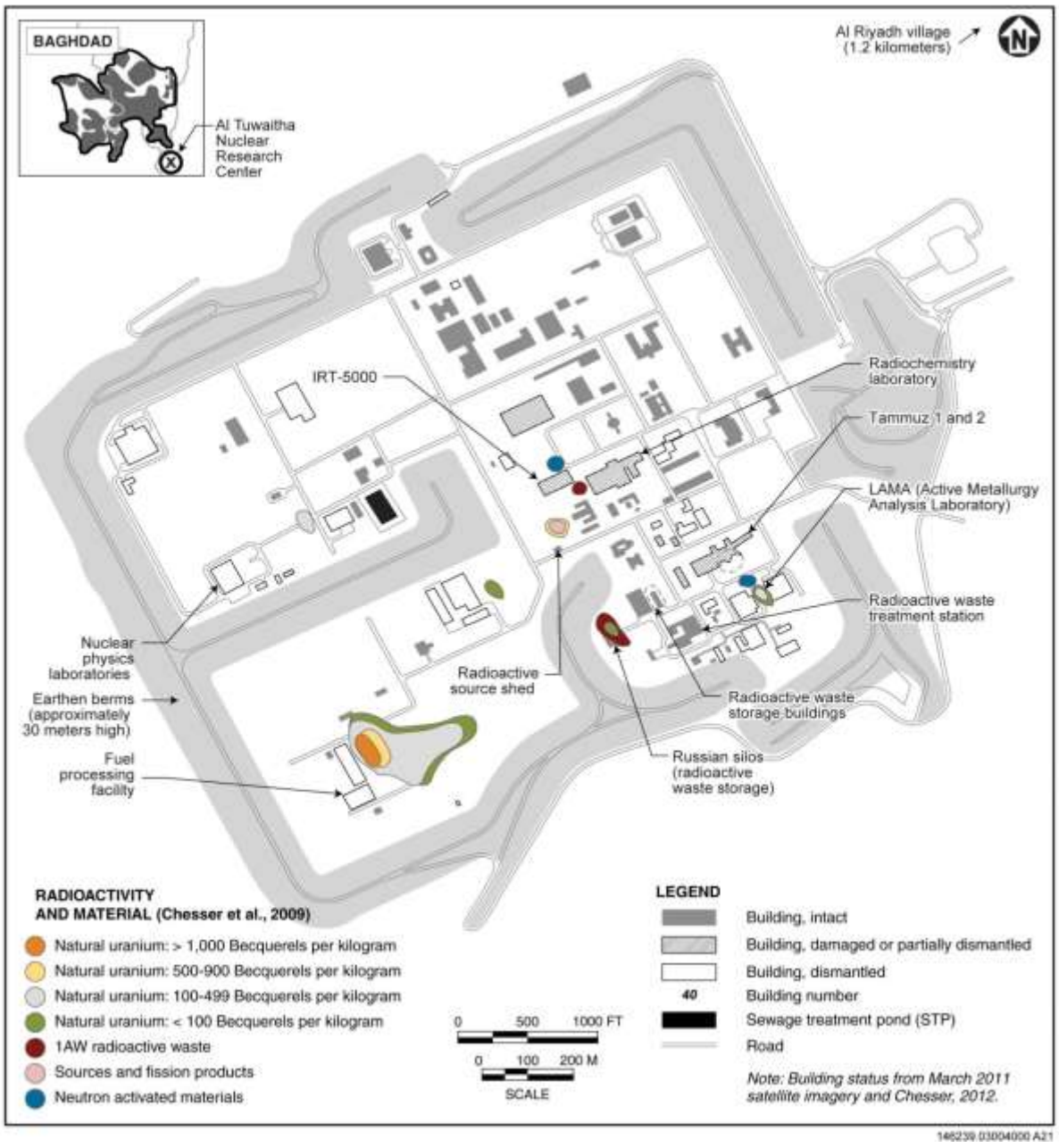
bombed the site, although with little resulting damage. The following year Al Tuwaitha came under attack from the Israeli Air Force with at least eight bombs striking the containment dome of the 40-MW Tammuz-1 reactor (also known as the Osirak-1 reactor). The reactor had not yet been fuelled at the time and as a result no known nuclear contamination was reported. The facility was never refurbished and was subsequently dismantled. Following the Israeli attack the Al Tuwaitha site was fortified by the construction of 30 m high earthwork berms surrounding the entire site and increased military defences.

In 1991 Al Tuwaitha again came under attack by American led allied forces involved in the First Gulf War. Allied bombing inflicted a great amount of damage to the Al Tuwaitha site destroying the Tammuz-2 research reactor (also known as the Osirak-2 reactor), which had been shut down before the outbreak of military actions. In addition a spent fuel production facility containing two hot cells was destroyed resulting in some contamination of the area. Most of the administrative facilities were also destroyed.

In 2003 during the Second Gulf War additional facilities at Al Tuwaitha were destroyed. During the course of the war between the loss of Iraqi military control at the site and establishment of control by Coalition Forces the site was extensively looted by civilians. The looting resulted in the inadvertent dispersal of radioactive materials at and around the research center and in nearby homes and villages. Higher activity objects (e.g. sealed radioactive sources) have been largely recovered from within the population. During the occupation of the site by Coalition Forces a large number of previously existing records were inadvertently destroyed and as a result limited detailed information is available on the exact nature and extent of all potential existing radiological wastes.

CURRENT SITUATION

The facilities at Al Tuwaitha (shown in Figure 2) were not taken out of operation in a planned and controlled manner, but rather as a result of their destruction from direct military actions and the subsequent dispersal of radioactive materials within the facility and surrounding areas by looting. The ongoing site recovery activities must therefore be considered as an intervention measure consistent with similar measures implemented at sites where nuclear accidents have occurred. Ideally planned solutions consistent with a well-structured decommissioning project are not possible. While progress has been made in decommissioning some of the facilities, containerizing some of the more accessible wastes and in establishing a new Interim Storage Building (Figure 3) considerable work remains at Al Tuwaitha. Note that the building is awaiting a license for operation and currently does not contain waste.



SOURCE: Copland and Cochran 2013

FIGURE 2: Layout of Radiological Facilities at Al Tuwaitha

Figure 3: New Interim Storage Building

The current status of the main Al Tuwaitha facilities is summarized below:

- The 500-kW Tammuz-2 research reactor (Figure 4) was originally supplied by France. It was a pool type reactor that was heavily damaged in the 1991 Gulf War. It is scheduled for full decommissioning. Decommissioning activities are expected to result in approximately 70 tons of solid wastes and 7 m³ of liquid waste. Structures deemed as unsafe were removed in 2013.
- The 5-MW IRT-5000 (Figure 5) research reactor was originally supplied by Russia. It was a pool type reactor that was destroyed in the 1991 Gulf War. Decommissioning activities started in 2013. Decommissioning activities are expected to result in approximately 90 tons of solid waste and 25 m³ of liquid waste.
- The Radiochemistry Laboratory was used for reprocessing irradiated fuel to extract radionuclides and plutonium for research purposes. The facility includes two laboratories, hot-cells, glove boxes, ventilation trap filters, and storage tanks for liquid waste. It was destroyed in the 1991 Gulf War. Decommissioning activities are expected to generate 55 tons of solid waste and approximately 10 m³ of low level liquid waste. Some areas inside the facility are heavily contaminated.
- The Active Metallurgy Testing Laboratory (referred to as LAMA) was used for destructive and non-destructive testing of irradiated experimental fuel. It was destroyed in the 1991 Gulf War. Decommissioning activities were completed in 2010. Some sources and hot spots were found during decommissioning. The final survey report was submitted to the Iraqi regulator, the Radiation Protection Center (RPC).

- The Italian Isotope Production Facility was originally built for the production of isotopes for use in medical applications. It consists of two hot-cells that were damaged in the 1991 Gulf War. The facility is in the final stages of decommissioning, which will result in approximately 10 tons of solid waste and 10 m³ of liquid waste.
- The Fuel Fabrication and Uranium Purification Facilities were constructed for the manufacture of unenriched natural uranium oxide nuclear fuel for use in laboratory scale research. They were operated from 1981 until being damaged during the 1991 Gulf War. Decommissioning activities (planned to begin in 2014) are expected to produce 10 tons of solid waste contaminated with uranium, including pipes and metallic storage tanks, about 150 kg of U as U oxides containing sludge from a nearby and 10 m³ of liquid waste.
- The Radioactive Waste Treatment Station (Figure 4) was associated with the French supplied Tammuz-2 complex and was designed to deal with low and intermediate level waste (LILW). The facility was destroyed in the 1991 Gulf War. The associated solid radioactive waste storage unit was refurbished. Decommissioning activities for the remaining facilities is expected to generate about 25 m³ of liquid LILW containing alpha, beta, and gamma emitters and about 30 tons of solid waste stored at the site. A mobile treatment unit has been built and tested by MoST.
- Several existing radioactive waste storage facilities are located at Al Tuwaitha including a solid waste silo for waste from the French complex, a storage facility for solid waste and sludge at the Radioactive Waste Treatment Facility, and Russian waste silos with radioactive waste from upgrading of the IRT-5000 research reactor (Figure 5). Radioactive sources are stored in Bunker 8 after completion of security improvements. A new Interim Storage Building for radioactive waste has been completed.

FIGURE 4: Recent view of Selected Facilities at Al Tuwaitha Nuclear Center

FIGURE 5: IRT-5000 Reactor Building after its destruction in 1991

In addition to the Al Tuwaitha sites the waste associated with the Geo-Pilot Plant decommissioning will require disposal as LLW. The Geo-Pilot Plant was a former yellow cake production facility outside of Al Tuwaitha near Baghdad that produced approximately 10 kg of material resulting in the generation of 15 tons of solid waste and 2 m³ of liquid waste.

DATA GAPS AND UNCERTAINTIES

Considerable data gaps exist both with respect to the exact radionuclide inventory and waste characterization details as well as with respect to the total volume of radioactive waste. In addition site characterization data is currently inadequate for both detailed design and safety assessment purposes and additional information will need to be acquired as the project progresses.

The existing data gaps related to the waste inventory are driven in large part by the destruction caused during the various military actions, the loss of a significant portion of the archived documentation during the site's occupation by Coalition Forces, as well as the subsequent looting of the site prior to the Iraqi government's re-establishment of control at the sites. Due to the lack of adequate records and the extensive destruction that occurred at the site it is not possible to fully recreate a reliable radionuclide inventory for the radioactive waste arisings in Iraq. Special consideration will therefore need to be given to developing adequately conservative assumptions to ensure sufficient consideration of the potential radionuclide inventory when conducting the required safety assessments for the planned disposal facility. To this end experience from similar facilities will be utilized to assess an upper limit for the possible inventory for use in safety models.

For purposes of developing the conceptual design, a preliminary analysis of the potential waste volumes requiring disposal as LLW has been completed. As indicated the resulting assessment contains considerable levels of uncertainty. The completed analysis provides a preliminary range of LLW volumes originating from nuclear site decommissioning and radioactive waste treatment operations across Iraq considered suitable for near surface disposal. As stated above the majority of these wastes are located at Al Tuwaitha with a relatively small volume originating from the Geo-Pilot site.

Further uncertainties exist with respect to subsurface conditions at the site and additional site characterization work will be needed to fully support radionuclide transport modelling, particularly with respect to understanding ground water flow conditions the distribution of sediment types, i.e., sands, silts and clays, in the subsurface. This information will also allow the future optimization of the foundation designs, which currently assumes conservative ground stabilization methods would be implemented to ensure adequate support for the facility. Work activities focused on gathering the required site characterization data are currently being planned as part of the current project.

ASSESSMENT OF EXISTING LLW VOLUMES FOR DISPOSAL

Much of the existing LLW is currently stored in either 220 L drums or in shielded 450 L drums. All LLW that has already been containerized is first stored in 220 L drums pending future disposition. Much of this waste has yet to be properly characterized. The preliminary assessment of existing waste volumes estimated that a maximum of 10,350 of the 220 L drums will be required to contain the existing and expected volumes of LLW to be generated by full decommissioning of the nuclear facilities in Iraq.

With respect to waste that has been identified as higher activity LLW, a significant volume of waste has been conditioned into 450 L drum. This waste is first placed into 220 L drums, which are in turn cemented into 450 L drums with one 220 L drum per each 450 L drum. The cement is used to provide adequate shielding for interim storage and handling purposes. To date 1291 drums have been conditioned into the 450 L drums in this manner. Typical storage practices, as currently practiced, are shown in Figures 6 and 7. (Note that the drums shown in Figure 6 do not contain waste. The Facility is awaiting final licensing approval to begin operations.)

FIGURE 6: New Interim Storage Building for LLW

FIGURE 7: Conditioned 450 L LLW drum storage on an external pad in Basra awaiting transfer to Al Tuwaitha

In addition to the 220 L and 450 L drums an additional 59 large 6 m³ drums have been prepared for the storage of conditioned radioactive Cs137 contaminated soil. These large drums have an external diameter of 2 m and are 2 m in height. The drums are constructed with a 10 cm thick exterior steel encasement that is lined with 20 cm thick cement shielding layer.

At Al Tuwaitha, a total waste volume between 2,700 m³ and 4,900 m³ has been estimated for disposal. This volume includes the waste contained in 220 L drums (including future waste arisings), conditioned waste contained in the 450 L drums and the waste contained in the 6 m³ drums. In addition approximately 1,500 to 2,000 m³ of waste is anticipated from other locations within Iraq. Therefore the total volume of LLW requiring disposal is estimated as being between 4,200 and 6,900 m³.

For disposal at the ATDF it has been assumed that the majority of existing waste with the exception of the 6 m³ drums will be contained in either the 450 L drums or in 220 L drums. To facilitate waste handling and disposal of the 220 L and 450 L drums, as well as a limited quantity of bulk wastes, the basic design concept assumes that the waste will be delivered to the ATDF contained in one of two standardized waste package (WP) variants. Both variants will have identical exterior dimensions of 2 m × 2 m × 2 m to facilitate emplacement in the disposal chambers. The two variants will include a shielded version for disposal of up to 18 of the 220 L drums and an initially unshielded version for disposal on the of up to 4 of the 450 L drums.

As previously stated it is important to note that after the drums have been placed inside each WP the remaining void space will be filled with a cement grout which will provide additional shielding. As a result upon delivery to the ATDF all WPs are considered to be shielded.

SITE AND DISPOSAL CONCEPT SELECTION

Due to the ongoing unstable security situation in Iraq it was not possible for the Iraqi government to implement a "blank map" site selection process following generally recognized best international practices and recommendations. Instead the facility was sited within the security perimeter of the well-fortified Al Tuwaitha Nuclear Center, which is owned and operated by MoST, and secured by the Iraqi Military. As a result of this site selection by the Iraqis, it is incumbent upon the Consortium to determine a design option that meets both the security needs for siting the facility at Al Tuwaitha as well as ensuring the long-term safe containment of the waste well into the future. To this end internationally recognized and successfully implemented design solutions were evaluated for their applicability to the Iraqi situation.

After conducting a thorough review of existing design solutions (including among others trench disposal systems, mined disposal, silo designs, and various other options), the near-surface concrete vault style repository option was selected in close cooperation with the Iraqi Beneficiary and End-User. It was concluded that this type of repository would be the most appropriate option for addressing both the security requirements as well as the long term safety concerns facing Iraq. This option provides a high-level of containment, thereby enhancing physical security and at the same time ensuring adequate radiation shielding for potentially

exposed Al Tuwaitha personnel. The modular nature of the disposal solution allows for a relatively rapid rate of waste emplacement and isolation of the waste as each disposal vault once filled is subsequently sealed. The system can easily be extended to accommodate more waste if determined necessary.

A significant level of international experience in the construction and operation of the vault type disposal option is readily available. The selected option for Iraq will follow the approaches as adopted in the following countries:

- The LLW repository at Centre de L'Aube, France
- The El Cabril solid radioactive waste disposal facility in the province of Córdoba, Spain
- The Dukovany Nuclear Power Plant (NPP) outside of Třebíč in the Czech Republic; the National Radioactive Waste Repository near Mochovce in Slovakia
- The planned Bulgarian National Disposal Facility near the Kozloduy Nuclear Power Plant

LLW DISPOSAL CONCEPT TAILORED TO THE AL TUWAITHA SITE

The ATDF conceptual design follows best international practices for the design of a near surface disposal facility scaled to the scope of the Iraqi waste disposal need. The ATDF will be completed as a multiple-barrier engineered facility specifically for the disposal of LLW.

Of particular concern in the development of the design solution for the ATDF is the location of the site within the Tigress River's flood plain. To address this concern specific engineering design considerations are needed. Specifically, it will be necessary to raise the emplacement area to an elevation deemed adequate to ensure that the base of the disposal vaults remain above high water levels even during low probability flooding events. Raising the base elevation of the disposal system will ensure that waste once emplaced will not come into contact with potential flood waters.

The design concept assumes that all waste will have been appropriately conditioned and packaged in adequately sized, cubic-shaped, standardized waste packages (WPs). At the disposal area the WPs will be emplaced inside specifically designed reinforced concrete vaults that will function to provide both radiation-shielding during the operational period and long-term radionuclide containment after closure. After each disposal vault has been filled it will be sealed with a reinforced concrete closure slab that will be poured-in-place. After all of the waste has been disposed of and the disposal vaults sealed a final engineered multi-layer cover will be installed over the site. The multi-layer cover shall function to conduct infiltrating water away from the disposed waste; preclude or greatly reduce external intrusions by humans, animals or plants; and provide protection against long-term erosion agents such as rainfall and wind. The design of the multi-layer cover will also need to account for potential erosion from flooding along its flanks.

Radiological safety at the ATDF will rely on passive systems to the extent possible. Safety will be ensured at all times by the simultaneous application of a system of physical barriers for radionuclide containment and radiation shielding,

which, during the operational period, are complimented by appropriate administrative measures and operational procedures.

MULTIPLE BARRIER SYSTEM

The ATDF will rely on a multiple barrier system to ensure the safe isolation of the radioactive waste from the environment for a long as the radionuclides in the waste remains a hazard. The barriers are intended to act in series, so that the failure or functional degradation of one or more barriers over time is compensated by the containment capability of the remaining barriers.

Consistent with the IAEA's definition, a "barrier" as applied to the disposal concept for the ATDF is any physical (engineered or natural) obstruction, which prevents the movement of radionuclides or provides shielding against radiation. Therefore barriers are defined as any material, structure, or feature that for a defined period of time prevents or substantially reduces the propagation of radioactive substances, i.e., the rate of movement of radionuclides, from the waste to the environment.

The multi-barrier system will consider a combination of barriers designed to protect workers, the public and the environment. The waste form and waste package working together will provide adequate shielding during operations. The disposal vaults, constructed from reinforced concrete, filled with waste contained in WPs, and subsequently sealed with a reinforced concrete cover will function to ensure the virtual complete retention of radionuclide from potential releases throughout the period of institutional control and beyond.

The Multilayer Cover that will be constructed over the disposal vaults at closure of the ATDF will consist of a series of engineered layers specifically designed to prevent water from reaching the disposal vaults and the therein contained waste. The layers will alternate between drainage and sealing layers. The safety function of the multilayer cover is to:

- Prevent or greatly limit the access of water to the disposal vaults
- Prevent or greatly limit the potential intrusions of humans, animals or plants into the disposal vaults
- Provide protection against long-term erosion agents such as rainfall and wind

The engineered platform, constructed as a multilayer foundation to support the disposal system, will raise the base level of the disposal vaults above potential high water levels associated with flooding of the nearby Tigris River thereby addressing a high consequence off-normal scenario. The raised platform will also function to increase the travel time of radionuclides to the accessible environment, i.e., the biosphere, in the case of failure of a preceding barrier.

Finally, the naturally occurring geologic and hydrogeologic conditions at the site will work to delay the travel time of radionuclides to the biosphere. The performance of the natural barrier, although difficult to assess due to the natural variation in geologic and thus hydrologic conditions, can play a significant roll and will therefore be conservatively considered in the safety assessments planned for the ATDF.

WASTE OPERATIONS AT THE AL TUWAITHA DISPOSAL FACILITY

The operational phase of the ATDF will include provisions for the receipt, inspection, management and disposal of conditioned radioactive waste. To this end the ATDF will be divided into two zones: the Disposal Zone and the Operations Zone. The Disposal Zone will consist of the reinforced concrete vaults; the raised disposal platform, including the inspection tunnel and infiltration control system; the mobile roof equipped with a 30 tonne rated overhead crane; the Radiation Protection Area Fence; and required supporting infrastructure. The Operations Zone will be constructed concurrently with the Disposal Zone. The Operations Zone will consist of the Buffer Storage Management Building (BMSB) and the Enterprise Support and Management Building (ESMB), the ATDF Boundary Fence, the Main Access Control Point, and all related supporting infrastructure. The BMSB is intended to provide flexibility in planning WP disposal operations and will be able to accommodate up to 64 WPs. It is assumed that all WPs will be delivered ready for disposal consistent with waste acceptance criteria (WAC). Only confirmation testing of surface activity in support of operational safety is intended for the ATDF.

From a radiation protection perspective, the ATDF will be further subdivided into two areas: the Radiation Protection Area and the Monitored Area. All activities related to radioactive waste handling, inspection, and storage, including sample collection and testing, will be housed within the Radiation Protection Area. A permanent staff presence is not foreseen within the Radiation Protection Area and access will be granted on an as-needed basis only. All operational support and monitoring activities will be conducted in the Monitored Area. ATDF staff and management offices will be located within the Monitored Area. Radioactive materials will not be located or handled within the Monitored Area. Strict adherence to the separation of activities is required and access to and from each area will be monitored. Personnel entering or exiting the Radiation Protection Area will be checked for radiation using a hands and feet portal monitor.

DISPOSAL SYSTEM

The reinforced concrete disposal vaults will be located in the disposal zone. The vaults will be constructed on a raised platform to ensure that the base of each vault remains above potential future high water levels from possible intermittent floods. The WPs and a limited volume of bulk waste will be disposed of in the reinforced concrete disposal vaults. The disposal vaults have been designed to account for the following main factors:

- Provision of adequate radiation shielding during waste emplacement as well as during vault sealing operations
- Maximum height of the vaults in consideration of the final multilayer cover
- Optimized filling and sealing rate
- Optimized weight distribution in consideration of foundation conditions and long-term settling
- Sizing of the mobile roof

Each disposal vault will be divided into two chambers separated by a common wall. Each chamber will be sized to hold 3 rows of 6 WPs in 3 layers for a total of 54 WPs per chamber or 108 per disposal vault. In total, ten vaults are foreseen as adequate to account for the estimated waste volumes determined suitable for disposal at the ATDF. The disposal vaults will be arranged in a single row. Additional vaults or an additional row of vaults can be added should a future need arise. An inspection gallery will be constructed beneath the row of disposal vaults to provide access to the disposal vault drainage system, referred to as the infiltration control system. This system is provided to monitor any water that may have infiltrated into the disposal system and potentially come into contact with radioactive waste.

WP will be emplaced in the vaults using an overhead crane installed inside a mobile roof. The mobile roof is intended to provide adequate protection from inclement weather conditions during waste emplacement operations. In the event of strong winds or sand storms the mobile roof is equipped with an emergency metal cover panel to temporarily seal the operational disposal vault in order to preclude a build-up of sand and grit within a chamber.

Each disposal vault will consist of a lower reinforced concrete slab for support; four reinforced concrete side walls and one interior dividing wall, also constructed from reinforced concrete, which separates the vault into 2 equally sized chambers. The floor slab of each chamber of each disposal vault will be slopped towards a central drainage point. The drainage point is connected to the underlying infiltration control system. In order to compensate for the slopped floor a thin pervious layer of levelling concrete will be added to provide a level surface for emplacement of the WPs. The base slab and levelling layer will have a combined thickness of 0.7 m.

The vaults will be capped with 12 precast reinforced-concrete removable cover-panels. The cover panels will be placed on top of the walls to close the chamber openings. The cover panels will act to protect the chambers prior to waste emplacement. After each vault is filled the cover panels will be used to provide radiation shielding for the installation of the closure slab. Once full with WPs and the cover panels have been emplaced the mobile roof can be relocated to the next operational disposal vault. Conventional construction equipment can be used to install the closure slab.

The raised platform upon which the vaults will be constructed will be installed over an improved subsurface foundation. Due to the natural conditions at the site, expected to be representative of a typical fluvial sedimentary environment, a conservative foundation improvement strategy is being planned (Figure 5). To this end high performance micropiles will be used to stabilize the naturally occurring subsurface sediments which will be covered by a 0.5 m thick reinforced concrete slab intended to anchor the micropiles in place. Next a 4 m thick engineered soil-cement cushion will be placed over the anchor slab to raise the platform to an elevation of at least 1.5 m above ground surface. The ICS Inspection Gallery will be constructed as an integrated component within the cushion. The cushion will in turn be topped by a 2 m thick slab of reinforced concrete, forming the main foundation slab for the disposal faults. Thus in consideration of the base slab of the disposal chamber, the base level of the lowest WPs will be at least 4 m above the local ground surface to ensure that the disposed waste remains

dry even during high water floods. (Note the final elevation will be determined after additional site characterization work has been completed.)

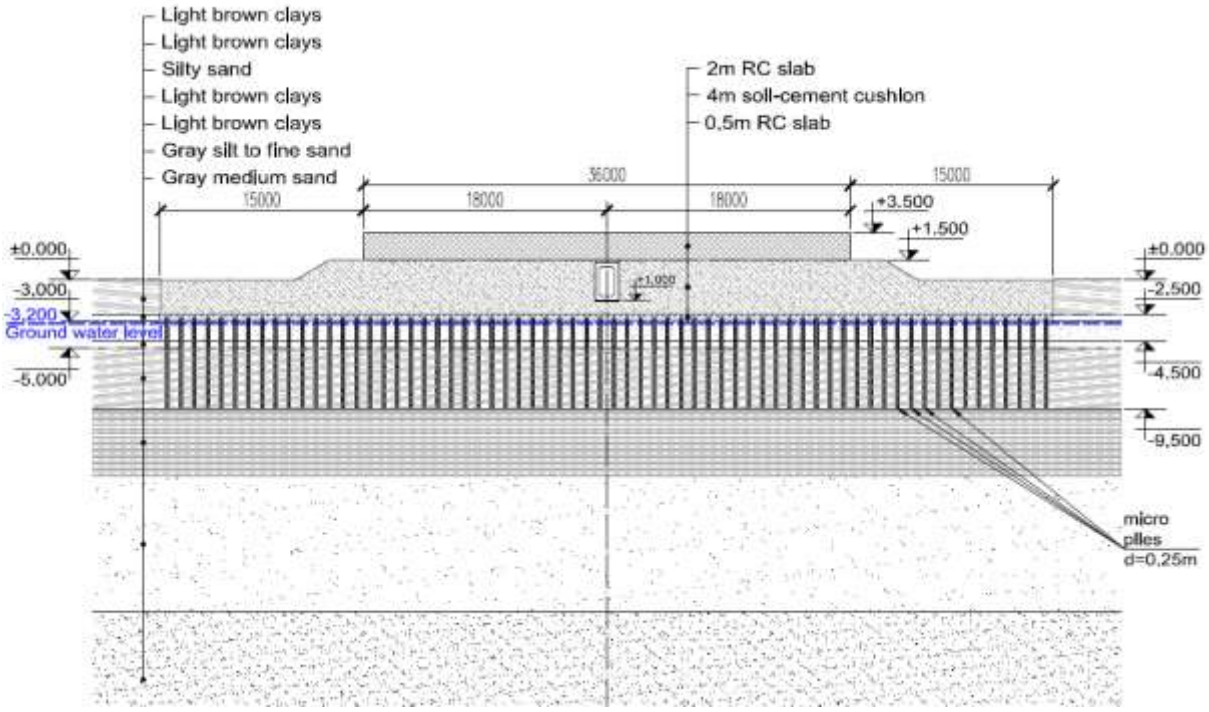


FIGURE 5: Foundation improvement for the ATDF Disposal Zone

CONCLUSIONS

The overall objective of the project is the safe disposal of LLW, including some SL-ILW, arising from the decommissioning of Iraqi's nuclear installations. Due to the partial destruction of a number of these installations and their current state of disuse, as well as the continuing security concerns in the region, the project is seen by the Iraqi Beneficiary and End-User as having a high priority. The final goal of the project is to ensure that the Beneficiary and End-User have a licensable design for a waste repository that meets Iraqi national safety requirements in a manner consistent with accepted best international requirements and standards. With an appropriately licensed design the Iraqi Beneficiary and End-User can under a future project tender the design for construction.

The general site selection for the disposal facility was determined by the Iraqi government, which selected the Al Tuwaitha Nuclear Center as the best option, particularly in light of ongoing security concerns. The specific site location within the Al Tuwaitha site is currently being evaluated and will be based on additional site characterization information to be collected as the project progresses. Nevertheless at the basic design stage the conceptual development provides sufficient flexibility relevant to final siting details to adequately describe the facility to a level appropriate for the subsequent engineering design. The conceptual level basic design together with the current understanding of site geologic and hydrogeologic conditions will form the basis for the safety assessment to be documented in the PSAR.

As a final stage of design development to be completed under the current INSC project, the design will be further developed to a level suitable for issuing a construction license. The engineering design to be completed at this stage will adequately define and specify the material and construction needs for the facility. Coupled with the results of the ISAR also to be completed under the INSC project the Beneficiary and End-User will be able to tender construction of the ATDF under a further project.

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