SAFESPUR members'
Report E9404

Applying Innovation to Decommissioning and Remediation on Nuclear Sites

A report of a workshop held by the SAFESPUR Forum on 18 November 2009 at NSG Environmental Ltd, Scientia House, Western Avenue, Matrix Park, Chorley, Lancashire PR7 7NB

SUMMARY

Speakers	Darrell Morris	NDA
	Mike James	Sellafield Ltd
	Richard Clayton	WSP Remediation Ltd
	Divyesh Trivedi	National Nuclear Laboratory
	Sammy Jones	Impact Services, Inc
	Joe Quarini	Bristol University
Chairman	Peter Booth	National Nuclear Laboratory

THE ISSUES

The UK's nuclear industry is benefiting from applied technologies for the treatment and management of legacy waste, storage and disposal as well as interlinked decommissioning activities and site remediation. The challenges that lie ahead are significant and may need to be resolved through the application of innovative solutions that can be drawn from a number of industries and technology disciplines. It is important to consider building synergistic relationships with other sectors thus allowing the dissemination of technologies and sharing of best practice.

This event provided an overview of the Nuclear Decommissioning Authority's research and development activities on waste and decommissioning. Examples of the application of innovative and/or transferable technology to the nuclear industry in support of decommissioning, waste management and remediation were forwarded by the speakers. This event concluded with a site tour of the new testing facilities at NSG Environmental, including the nuclear waste management development facilities.

LEARNING POINTS

1. Innovation with regard to decommissioning and remediation on nuclear sites
2. Role of the Nuclear Decommissioning Authority (NDA)
3. Technology Readiness Levels (TRLs) for the nuclear industry
4. Sustainability framework and sustainable remediation design processes
5. Modeling tools and remediation technology demonstrators
6. Suitable use of innovative methods (from other industries) for the nuclear industry

R&D across the NDA for waste and decommissioning

Darrell Morris (NDA)

- *completed a PhD at Basel University, Switzerland on inorganic coordination chemistry funded by Unilever (1992-1995)*
- *chartered chemist with over 10 years experience in the chemical and nuclear industry (Johnson Matthey (developing automotive catalysts - Tier II supplier to the automotive industry), National Nuclear Laboratory)*
- *currently responsible for coordinating the NDA's directly funded Research & Development programmes*
- *portfolio includes university based research and industry based contract research*

The Nuclear Decommissioning Authority (NDA) was established via the Energy Act 2004 by the Government to safely clean up the UK civil public sector nuclear legacy with due regard to environmental, security and socio-economic issues. It also ensures that current commercial operations are run safely and efficiently on behalf of the UK taxpayer; with the dictum of "*Dealing with the Past, Protecting the Future*". The NDA's responsibilities incorporate operational responsibilities, waste management, commercial and clean-up; tied together with its competition, socio-economics, skills, R&D, stakeholders and capability enablers. The primary function of the NDA is to decommission and clean-up 19 sites in the UK, which include reactors, fuel reprocessing plants, fuel fabrication plants, redundant enrichment plants and nuclear laboratory complexes; developing national solutions for dealing with Low Level Waste, as well as implementing the geological disposal facility for higher activity wastes.

The NDA's R&D role is to promote, and where necessary, fund generic research relevant to nuclear decommissioning and clear-up. The current R&D strategy is to link and encourage Site Licensed Companies (SLCs) to carry out R&D in conjunction with the supply chain, with an NDA led strategic R&D programme being carried out by the supply chain. The NDA provides overall leadership in order to deliver its mission. Indirect NDA R&D involves SLCs and the supply chain accounts for approximately £90 million (FY08-09), while direct involvement with the supply chain amounts to £11 million.

Direct NDA-funded research key objectives are to inform strategy/policy; innovation (generic needs/risks/opportunities); maintain/develop key technical skills; and promote links to SLCs. There are 3 categories of direct NDA research funding – Technology Demonstration Project (TDP), concepts and Direct Research Portfolio (DRP). The DRP includes university interactions (Lot 1), waste processions (Lot 2), material characterisation (Lot 3), and actinide and strategic materials (Lot 4), which is offered to framework contractors and competed via the Official Journal of the European Union (OJEU). This scheme provides direct funding to universities, technical support and access to experimental facilities via university interactions, while waste processing funding consists of framework contractors interaction and full cycle processes (retrieval processing /waste form /packaging /storage /disposal). Material characterisation funding focuses on framework contaminated land and waste characterisation, and actinide and strategic materials research focuses on plutonium, uranium and spent fuel. The NDA also funds multiple concepts research projects with potential deployment in the medium to long term, with a value of up to £50,000 and lasting less than 1 year. Concept projects are open to the supply chain, and evaluated technically by the Nuclear Waste Research Forum (NWRF). The demonstration of N-Visage™ for thick shielding geometries by REACT Engineering Limited and computer modelling of organic forms by Fortis Mechanical Design Ltd are sample projects funded within the NDA's concepts research. The laser cutting and scabbling project is an example of TDP research, which could be funded up to £1 million. This project presented decommissioning area on an appropriate timescale and knowledge transfer, and demonstrated benefits from the recent development in fibre lasers, remote laser unit and laser on end of fibre optic cable and cutting with no resistive force.

Applying appropriate and innovative technology is critical to the NDA's mission of accelerating and delivering clean-up programmes. The launch of the R&D area on the Internet enables the dissemination of information and the sharing of innovative thinking across estate and supply chain, as well as the commitment to openness and transparency.

Innovation on Sellafield site in decommissioning and waste management

Mike James (Sellafield Ltd)

- *20 years experience in the field of analytical chemistry*
- *working in the field of technology innovation and technology transfer, included commissioning assessment of new and novel technologies to address the site's challenges*
- *led a major Best Practicable Environmental Option (BPEO) on the treatment of low level wastes and more recently a major assessment of thermal treatment processes for the immobilisation of intermediate level wastes*

Innovation is often debated as it brings different meaning to different people. Within Sellafield, innovation is "*introducing a change that brings benefit to the organisation*". Business improvement focuses on procedures such as project delivery and process; engineering process; safety case process; and plant modification process. Technological innovation focuses on topics such as project implementation; site, facility and plant operations; characterisation and assessment; addressing gaps; mitigation of technical risk; and assessing opportunities. The Technical Directorate aims to "*deliver quality technology and maintain technical capability to underpin delivery of the Sellafield LTP*" through the development of skills and capabilities, collaboration between the National Laboratory, universities and the supply chain in order to be at the forefront of technology.

Technology innovation starts with the lifetime planning of delivery sites, technology identification and the provision of current and future requirements. The identification for the future is systematically approached to develop technology elements through Technology Road Maps and Technology Readiness Assessments. The deployment of R&D at Sellafield includes changing the acid concentration in reprocessing plants; assessing the tolerance of higher impurities for alternative chemical supplies; understanding biological behaviour of algal blooms in storage ponds and corrosion effects of plant equipment; corrosion chemistry of plant and equipment (*eg* evaporators for highly active radioactive liquors); sludge properties – chemical, physical (rheology) studies. Seed corn investments within Sellafield include investment in new and novel technologies, as well as commissioning trials, demonstration and assessments. Current and future challenges look into legacy facilities, waste processing, environmental issues, characterisation and demolition, decommissioning and beta-gamma decommissioning.

Areas of new and available technologies interested by Sellafield include characterisation; remote size reduction and dismantling; modelling; chemistry/process knowledge; waste treatment processes; process improvements; novel techniques; waste categorisation, processing and packaging; condition monitoring; and decontamination. Sellafield has also set up an innovation portal to allow suppliers (or the general public) to provide proposals on new and novel applications that can be assessed by business improvement and technology specialists, focussing work on addressing gaps and opportunities. Challenges to innovation encapsulate commercial processes, internal process reengineering, change and "*not invented within the UK*" perception.

In conclusion, technology development has been essential to the establishment of Sellafield's bespoke plants and processes. The Technology Road Mapping and Technology Readiness Assessments (TBURD) will play an increasing part in focussing future requirements, and further development will be essential to address the challenges on site. More importantly, implementing new technologies and processes are vital for the future.

What are the options for sustainable remediation technology selection?

Richard Clayton (WSP Remediation Ltd)

- *Director of WSP Remediation and has 15 years experience in the characterisation and remediation of contaminated sites.*
- *followed the sustainable remediation debate for the last 2 years and implemented sustainable remediation management practices within WSP Remediation Limited.*

- *currently part of the NICOLE Sustainable Remediation Working Group chairing the Economics Sub Group and currently preparing a position paper on sustainable remediation.*

Sustainable remediation technology has received a lot of attention from various organisations, potentially due to the effects of global warming, corporate agenda, or to gain competitive advantage. It is argued that there is no such thing as a sustainable remediation technology; that sustainable remediation is a way of thinking – a change in behaviour. Truly sustainable remediation is (potentially) incompatible with environmental compliance. Remediation is viewed as a positive step, which could lead to the reduction and/or removal of risks and legislation.

The development of environment remediation has been extensive internationally. In the USA, the U.S. Environmental Protection Agency (USEPA) Remediation Guide was released in 2008 and the Sustainable Remediation Forum (SURF) USA White Paper in 2009. Locally, the SURF UK (framework for assessing the sustainability of soil and groundwater remediation) draft for consultation was recently announced, with the definition of "*the practise of demonstrating, in terms of environmental, economic and social indicators, that an acceptable balance exists between the effects of undertaking the remediation activities and the benefits the same activities will deliver*". SURF UK revolves around 6 principles:

- Principle 1: Protection of human health and the wider environment
- Principle 2: Safe working practices
- Principle 3: Consistent, clear & reproducible evidence-based decision-making
- Principle 4: Record keeping and transparent reporting
- Principle 5: Good governance and stakeholder involvement
- Principle 6: Sound science

Future work could be expected as a result of the Sustainable Remediation Position Paper produced by the Network for Industrially Contaminated Land in Europe (NICOLE), which should be in place by 2010. A policy of sustainable remediation is crucial to establish the link and balance between the aspects of environment, social and economics of a country or continent.

In designing a sustainable remediation project, the environment, social and financial factors were identified as the least understood factors. The least understood guidance factors were stakeholder identification, agreed objectives, boundaries definition, and quantify/estimate impacts. Where delivering green remediation technologies, SURF USA recommends the minimisation or elimination of energy or natural resource consumption; harness or mimic a natural process; reduce or eliminate releases to the environment, especially air; reuse or recycle inactive land or discarded materials; and permanently destroy contaminants. Thermal treatments could be used to accelerate treatment timescales. However, it requires much energy or natural resource consumption and it does not mimic a natural process, among others.

Sustainable remediation rapidly evolved through the years, demonstrated by the various proposed frameworks. Green remediation technologies exist, but most work is required in developing a sustainable remediation design process and the relationship between risk

assessment and sustainability needs to be further explored. Education will be a decisive factor for the successful uptake of sustainable remediation.

Remediation technology demonstrators

Divyesh Trivedi (National Nuclear Laboratory)

- *23 years working for BNFL in research, leading to the formation of the NNL on breakup of BNFL*
- *undertaken site investigations, monitoring, experimental studies, modelling (both code development and running codes) and project management*
- *involved in programmes both for the NDA directly and NDA Sites which have investigated the plausibility of remediation options*

Dr Trivedi's presentation focussed more on the technical solution and demonstrated the breadth of the National Nuclear Laboratory's (NNL) studies on remediation technologies. Over the past 10 years, a wide range of experimental studies was carried out, which includes electrokinetics, FIRS technology, soil washing and others. The scope of modelling studies incorporated the ReCLAIM tool, SimER, TRAFFIC and GoldSim models.

NNL'S electrokinetic experiment simulates the effects of electro osmotic advection and ionic migration as applied by electrokinetic remediation techniques. Experiment activities included the experimental set-up building on previous bench scale experiments, working together with Sellafield and Dounreay, in the area of contaminated soils. This is demonstrated through the development of the FIRS technology generating in-situ Fe(OH)3 layers at different time scales, and from samples from selective leaching of contaminated soils from several sites.

Modelling studies are mapped to DEFRA/EA CLR 11. The scope of modelling within the NNL include the development of the ReCLAIM tool for simple scoping/screening type assessments, as well as developing SimER, TRAFFIC and GoldSim models to evaluate the effectiveness of remediation methods – was presented and demonstrated. ReCLAIM is an electronic spreadsheet tool that can undertake simple generic and site-specific assessments of radioactively contaminated land. It is designed principally for Nuclear Licensed Sites but can be applied more widely. The tool can calculate doses for predefined exposure pathways and scenarios; calculate soil/water screening levels for individual radionuclides for a specified dose target and for defined scenarios and pathways; take into consideration radionuclide additivity and background radioactivity, and be very flexible: users can modify pathway parameter values, develop custom pathways and scenarios or combine pathways to define site specific scenarios. SimER (Simulation of Environmental Risks) is a powerful performance assessment code to be used to support decision-making on site end states and management strategies for sites at a level consistent with requirements for regulatory submissions. Applications of SimER include contaminated land and waste disposal. SimER's capabilities include 3D groundwater flow (saturated and unsaturated conditions) and contaminant transport (radioactive and non-radioactive); representation of topographical details and geological structures; explicit climate and landscape change representation; 3D modelling of engineering and remediation options for contaminated land sites; and more. TRAFFIC (TRansport And Fluid Flow Including Chemistry) is a detailed supporting level code able to simulate fully coupled, flow, transport and chemical processes. The capabilities of TRAFFIC incorporate the production of a 3D finite element code; detailed groundwater flow and contaminant transport; variably saturated flow, variable density flow; heat transport, and more. The applications of TRAFFIC include groundwater flow and contaminant transport in nuclear contaminated land; modelling processes of natural attenuation including microbial effects; modelling of remediation technologies (chemical reactive barriers, electrokinetics); and underpinning modelling to support plant and waste safety cases.

NNL uses modelling to understand experimental studies and to provide simulation for different events. Over the years, NNL has developed very advanced tools for simulating remediation. The demonstrated tools could also be found on the NNL website.

GeoMelt vitrification: Life cycle benefits for the treatment of toxic and radioactive wastes

Sammy Jones (Impact Services, Inc)

- *Chief Operating Officer of Impact Services*
- *30 years operational experience in military, DOE and nuclear industries*

IMPACT Services is a radioactive waste management company with four locations and two licensed processing facilities in the USA, and acquired GeoMelt from AMEC in March 2009. In the UK, IMPACT has teamed up with AMEC to continue proof of process demonstrations at AMEC's Birchwood Facility.

The two primary treatment configurations are the In-Container Vitrification™ (ICV) and Subsurface Planar Vitrification™ (SPV). GeoMelt technologies are a collection of vitrification processes that are used to safely treat and stabilise a wide variety of materials including organics, heavy metals, and radioactive contaminants generated by both commercial and government clients. GeoMelt is able to transform hazardous chemical and radioactive wastes into an ultra-stable vitreous and crystalline material similar to volcanic obsidian that is typically 10 times stronger than concrete. Unaffected by wet/dry or freeze/thaw cycling, the product is unsurpassed in leach resistance and it is expected to maintain its physical and chemical integrity over many tens of thousands of years. Corrosion tests have demonstrated that the GeoMelt product is more durable than granite or marble. Materials treatable by GeoMelt include metals such as Pb, Cd, Cr, Ni, Ba, Zn, Hg, Cu, Al, Fe, Nd, Rb, Be, and As; organic materials such as PCBs, Dioxins/Furans, TCE/PCE, Carbon Tetrachloride, Benzene/Toluene, Acetone, Formaldehyde, Methylene Chloride, Ethylene Glycol, Methyl Ethyl Ketone, Pentachlorophenol, HCB, DDT, DDD, DDE and Lindane; debris such as wood, tires, asphalt, plastic, concrete, steel plates, drums, rocks, bricks/clay pipe, glass bottles, ash, asbestos, tanks and filters; radionuclides, for example, Pu, U, Cs, Sr, Co, Ru, Am, Ra, Rd and Tc.

The operation of GeoMelt requires minimal energy usage – it is a common misconception that it requires much power. The energy requirement is about half of what other thermal processes require due to greater efficiency and less heat loss, where Joule heating (resistive heating) is operational within the body of the melt. Heat "losses" occur at the melt boundaries and serve to pre-heat adjacent waste materials. In the ICV configuration, sides and bottom are insulated so most heat loss occurs at the top surface where waste material feed pile resides. Energy for melting ranges from 0.6 to 1.5 kWh/kg of material melted. Energy requirements for off-gas treatment and other services will be about equal for all treatment technologies. Examples of GeoMelt's application and processes on various sites were demonstrated.

The main benefits of GeoMelt are its robustness and flexibility, as it can accommodate highly variable materials and its capability to process and waste package are project specific. It also requires minimal pre-treatment, cutting down on size reduction and sorting of wastes. The shielding technology is demonstrated in the ICV package design provides inherent shielding and the provision of in-situ treatment if there is a high risk and cost of exhumation. There is a great reduction of waste volume, typically 25 - 50 per cent for soil, more for other wastes. GeoMelt has demonstrated capability over the years and has a proven track record in other applications.

The GeoMelt Demonstration Unit is scheduled for delivery and installation at AMEC's Birchwood Facility by March 2010, followed by commissioning and training of UK staff.

Applying 'Ice Pigging' to the Nuclear Industry

Joe Quarini (Bristol University)

- *Nuclear Engineering BSc (QM, London 1970-1973)*
- *Worked for UKAEA at Harwell (1976-1992)*

- *Ice pigging is his major research activity (Four postgraduates all dedicated to ice pigging)*

Pigging is the process of passing an object through a duct in order to clear or to clean it. This is brilliantly developed within the hydrocarbon recovery industry, where the pipes are straight and simple. However, the pigging process cannot be used in the event of a drastic reduction of diameter, sudden changes of direction, pipe 'tees' and heat plate exchanges. Cleaver 'pigs' will need to be created.

The solution was 'ice pigging'. Various parties were interested since this was specific to their needs – demonstrations were required to address these needs, problems and challenges of the industry. Over the past six years, the water industry (specifically Bristol Water) has committed and benefited the most. Application to the nuclear industry started with the partnership with the Nuclear Decommissioning Agency (NDA) in 2006/2007.

Video demonstrations of 'ice pigging' were shown. The initial demonstrations showed its effectiveness in the removal of loose fouling in horizontal and vertical piping; demonstration of various pipe diameter inlet. A case study video from Bristol Water was shown. Among the achievements included 58 actual trials and 53 on 'live' mains, AC pipes diameters 8" to 18", longest successful distance 3.3km (12"), plastic 2.7km in 6" diameter and iron pipes 60m to1600m, (6'' to 10'') – mostly within Bristol Water territory, Cornwall and Wessex Water. There was also a successful test and demonstration in Barcelona, Spain. On-going experiments are pushing the limits towards 24" to 30" diameter pipes. Video demonstrations on moving bricks and grout removal were shown. The application of 'ice pigging' in the nuclear industry were held in collaboration with the NDA, Sellafield sites, Magnox North and British Energy.

Crushed, pumpable ice appears to make innovative and paradigm shifting pigs. Ice pigging provides engineers with a new tool, enabling more innovation and greater benefits to do things that were not previously possible. This technique can move significant objects by carrying capacity – depending on ice fraction and depending on local aging (if ice slurry is allowed to 'mould' itself around object, then local grip increases), which is typically 100 and as much as 1000 times 'better' than water. To date, it is proven that it is possible for the pigs to form in open pipes, possible to get effluents out of open ducts and the 'simple' plumbing is applicable. Future research will evolve around the mechanical requirement of robustness of duct and the optimisation and development of 'standards'.

Chairman's summary (circulated post event)

Thanks were given to all the speakers and delegates who attended the above workshop on the 18th November. A special thank you went to NSG Environmental for hosting the workshop and for conducting the facility tours in the afternoon.

The primary focus of the workshop was on the application of innovation towards solving the many decommissioning, waste management and remediation challenges faced by the industry today and tomorrow. Linking into the theme of innovation we were able to explore a number of the mechanisms available to initiate and gain funding for research.

Darrell Morris's presentation on research at the NDA successfully set the scene for the subsequent programme. Presentations were then given by;

- Sellafield Ltd on their approach to applying innovation;
- WSP on sustainable remediation technology selection;
- NNL on the benefit of remediation technology demonstrators;
- Impact Services on the application of Geomelt; and,
- Bristol University on the success and transferability of ice pigging to the nuclear industry.

The key summary points for me that came out of the workshop were as follows;

- Darrell Morris reminded us that with all our work we are "Dealing with the past and protecting the future";

- The NDA's role is not just about funding but importantly "promoting";
- Mike James re-emphasised the use of Technology Readiness Levels for our industry and highlighted the wide variety of decommissioning and environmental challenges at the Sellafield site;
- Richard Clayton discussed the sustainability framework and the importance of developing a sustainable remediation design process.
- Divyesh Trivedi demonstrated how modelling tools and remediation technology demonstrators can not only save money but assist in the decision making process;
- Sammy Jones discussed the Geomelt technology and highlighted the many contaminants it could treat and stabilise;
- Joe Quarini provided a visual presentation of how innovation originally applied to another industry had potential applications to the nuclear industry;

The workshop reminded me again that we must look outside of our own industry for potential solutions and that we need to be able to make sustainable decisions with the data we have at our disposal. The key challenge therefore is justifying the decisions we make when perhaps the data is not as exhaustive as we would like. Research needs to be aimed at filling these gaps and reducing these uncertainties.