

PROJECT PLUTO

Microbes as Threats and Tools for Australian
Nuclear Infrastructure (2026).

**BY POLYMATH PHARMACEUTICALS
AND
WESTERN SYDNEY UNIVERSITY ADVISORY COMMITTEE**

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GenAI Used:	Claude Opus 4.6 (Anthropic), Claude Opus 4.7 (Anthropic) Gemini-3-pro-image-preview (Google), Kagi Assistant (Kagi)
Purpose:	Kagi Assistant was used heavily to explore extremophile and radiation-shielding reference literature and specifically <i>Deinococcus radiodurans</i> within greater historical, industrial and medical contexts. Claude was used to brainstorm policy framing for the briefing, edit prose, and manage VBA and citation formatting (custom Zotero CSL style). Gemini Nano Bannana Pro generated several abstract visuals under supervision with image prompts generated by Claude Opus 4.7.
Prompt example (Kagi):	" <i>Deinococcus radiodurans</i> discovery context food sterilisation gamma irradiation"
Prompt example (Kagi):	"Papers and interesting case studies of polyextremophilic or radiotrophic microbes corroding nuclear waste with relevance for dated and unmaintained nuclear weapons and their continued operation" [Academic lens] [Link]
Prompt example (Kagi):	"the project of going out to Maralinga, Australia, to find melanized organisms, we need a suitable analogue that seems to be cuttlefish squid ink and their specific melanin nanoparticles comparing the regular protective effects of radiotrophic microbe melanin vs selenium melanin nanoparticles and cuttlefish melanin is critical, but we need standardized method for extracting pure nanoparticles from commercial cuttlefish/squid ink." [Academic lens]
Prompt example (Claude):	"Let's focus on the things that will be graded" used to cross-check the draft against the BIOS3004 assessment criteria.
Prompt example (Claude):	"We may need to review the header and footer VBA Macro, to nuke existing ones when run and overwrite completely especially since it's not considered the layout of this new document" [Link]
Prompt example (Gemini):	"Please create a minimalist, direct visual abstract that resembles the essence of the best scientific illustrations often made in adobe illustrator or BioRender, based on this draft government briefing." [Link]
Commentary:	AI-suggested references were skimmed, indexed, read and sorted between Zotero's library folders before inclusion. Kagi returned relevant literature but required manual filtering and specification for quality and relevance, I made many annotations inside Zotero's native PDF viewer and noticed edges around the lenses used by Kagi's Assistant regarding deeper and likely more redacted military concerns. Uploading drafts and all exemplars to Claude's project folder, Claude provided indispensable structural feedback, especially regarding Microsoft Word VBA macros and handling citations. All final text is original work.
Acknowledgement:	The author acknowledges the cognitive debt Kosmyna 2025 clarified.

Executive Summary

"[...] the immediate lesson to the greater scientific community may be a warning — ignore extremophiles at your peril."

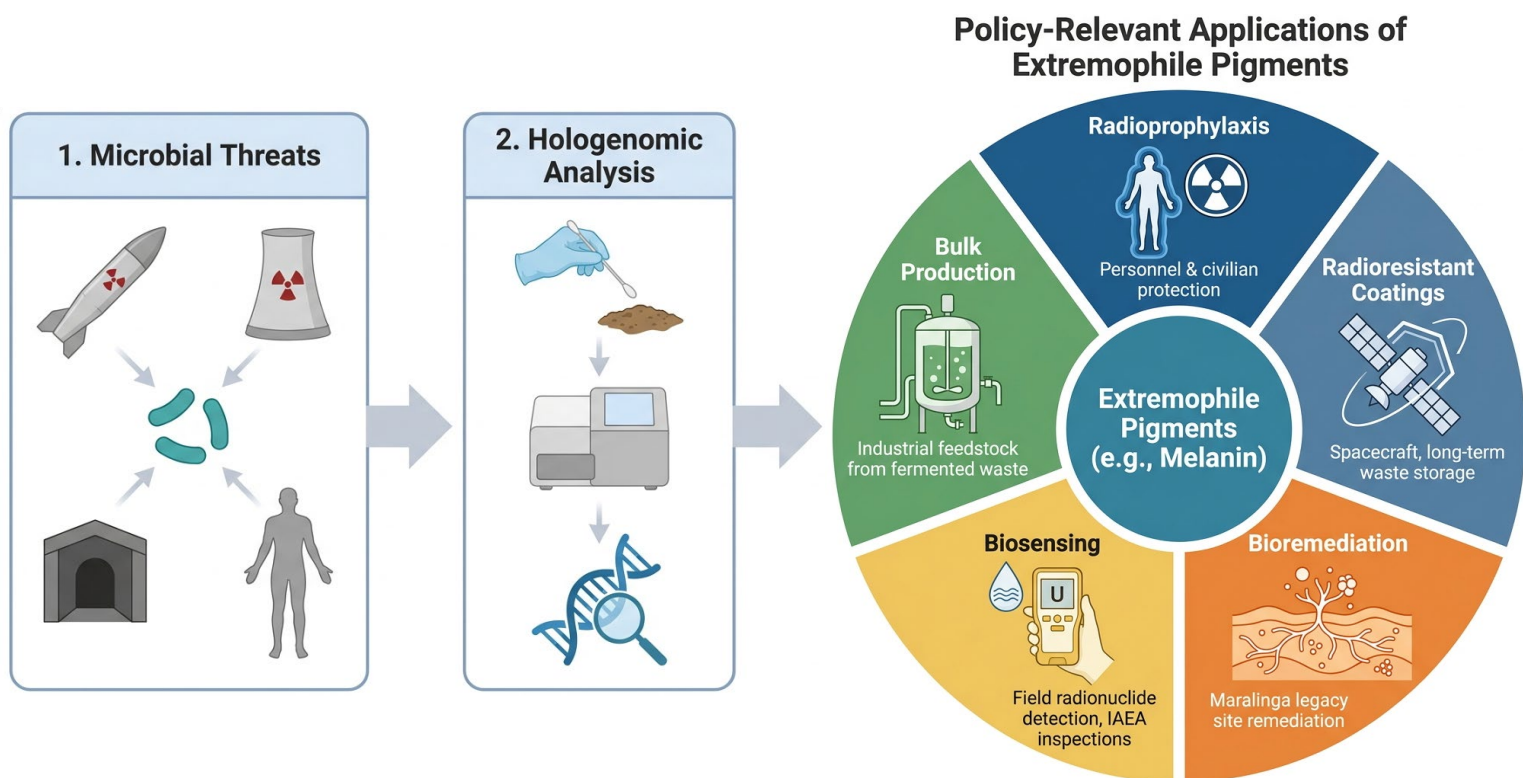
— Michael J. Daly, 2011

Humanity races towards nuclear solutions to meet their growing energy needs and wartime compulsions. Operating reactors, refineries and disasters alike facilitate thriving radiotrophic communities (MacGregor 2024). They pose unique threats to long-term nuclear facilities, crewed deep space missions and critical atomic weapons. They also promise material science and medical utility.

Deinococcus radiodurans was discovered in 1956, yet unlike most atomic states Australia still hasn't systematically sampled its own legacy nuclear sites. Monte Bello, Emu Fields and Maralinga remain contaminated with residual weapons-grade plutonium, and we stand on the world's wealthiest natural uranium deposits. This is an unexamined metagenomic opportunity on sovereign land. Microbial corrosion of reactor infrastructure and spacecraft represents a clear operational cost Australia will inherit when scaling domestic nuclear capabilities.

The proposed coordinated response involves expanding AusTrakka to sample Australian mines, legacy test sites, operating reactors, and experimental AUKUS submarines. By identifying, isolating, and sequencing radioresilient polyextremophiles, characterising their pigments, and sharing data between ANSTO, ARPANSA and national research institutions, Australia can mature three application streams: radioresistant materials to defend strategic nuclear resources, biosensing and bioremediation to reduce and detect nuclear footprints, and pigment-based radiophylactics to protect personnel and civilians.

This work is underscored by 2026's ongoing fuel crisis and the urgent transition towards energy self-sufficiency. The pipeline below amplifies our overlooked biological resource across defense, medicine, environmental monitoring, and bioremediation.



Suspects

Deinococcus radiodurans, discovered during routine canned meat gamma-sterilisation in 1956, proved the most radioresilient organism known with direct impact on food spoilage (Duggan 1963). Since then, radiotrophic biofilms have been found everywhere. In nuclear reactor pools (Petit 2023), competing for dominance in Australian uranium mines (Mumtaz 2013), near Iranian facilities (Arjomandi 2018), Nevada test sites (Durrell 1960), space craft, corroding Chernobyl No. 4 reactor walls (Zhdanova 2000) and used nuclear fuel rod aluminium casings (Santo Domingo 1998). Often these species nest in groundwater heavily contaminated with plutonium, uranium and other toxic metals finding exclusive, unexploited energy niches (Icopini 2009; Jroundi 2023).

Monte Bello, Emu Fields and Maralinga were the joint AUS-UK nuclear test sites from 1952-1957. Several 'minor tests' simulated nuclear accidents with non-fissile detonations, explosively scattering 22.2kg Plutonium, 40kg Uranium and pyrophoric debris across 3000km². Although MARTAC decontaminated Maralinga, vitrifying and burying debris, vitrification was abandoned after an unexplained explosion, melting only 11/40 pits. All debris was buried in shallow 2m trenches without any Pu/U recovered or accounted for. 50 years later 62% of Pu inventory persist in the undisturbed 0-2cm topsoil, readily bioaccumulating from arthropods to large mammals (Johansen 2014). No decline in wildlife uptake recorded in over three decades. Additionally, Emu Fields never underwent any decontamination. UV-B only penetrates 100microns into soil, yet melanized fungi are found near soil surfaces (0-0.2cm) outcompeting deeper, lighter species found below (0.2-0.5cm) across hot deserts (Grishkan 2011). With the world's most abundant superficial U/Th deposits, few other naked environments naturally converge broad ionizing spectrums quite like Australian uranium mines or legacy sites.

Legacy sites' unique, vibrant biomes had ample time to adapt to the AUS-UK's distinct high Pu-239/240 ratio and bomb casing, making this exclusive ecosystem a compelling metagenomic research opportunity for the Australian Government to assess bioremediation and natural adaptation in contaminated deserts (Townsend 2006).

Climate change presents additional concerns. With intensifying windspeeds and rising desertification, frequent dust storms increase the likelihood of existing airborne dematiaceous spores infecting the traditional Maralinga Tjarutja landowners and aerosolising hot particles.

Microbially-Influenced-Corrosion threatens most metal containers, including permanent spent waste storage (Santo Domingo 1998), crewed spacecraft (Novikova 2006) and ocean vessels. Submarine MIC biofilms in saltwater filters, cooling pipes and tubing are well documented and constantly removed, much like the European JSI TRIGA Mk II reactor cooling water (Bratkic 2022; Nicklin 2007). Whilst diesel biofouling is concerning, nuclear fuel biofouling is under-researched in bioactive, saline environments with known corrosion vulnerabilities. Melanin complexes leach metals from Antarctic rocks and toxic environments; fungi then digest them with powerful enzymes (Dadachova 2011). These hazards mandate manufacture, maintenance, or monitoring systems that target and deprive microbes of bioavailable materials. Glass vitrification techniques explored by MARTAC and early Plutonium documentation are one of many nuclide immobilization methods that deny microbial digestion on geologic timescales (Parkinson 2002).

Notably, the monospecies discovered in a 2km deep South African gold mine subsisted off deep earth radioactive decay that split water molecules into consumable hydrogen (Chivian 2008). Adequate perimeter shielding around any permanent waste facility could limit this route by designing the opposite of Figure 1b's experimental setup and block even residual radioactive decay from piercing storage

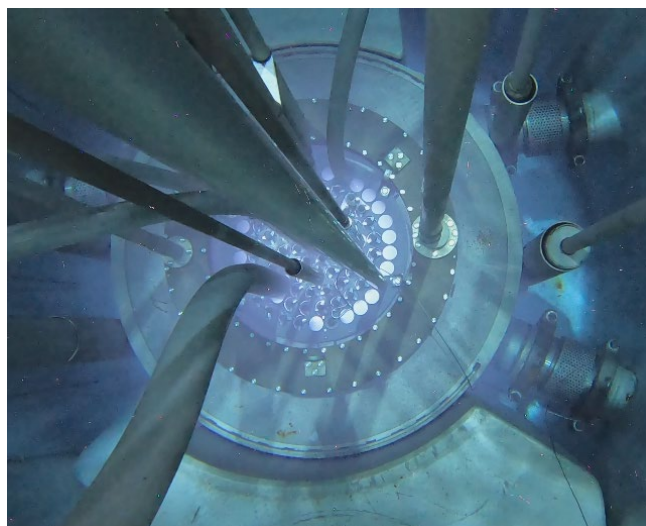


Fig1a. JSI TRIGA Mk II reactor regularly cleaned of corrosive bio-film (Bratkic 2022)

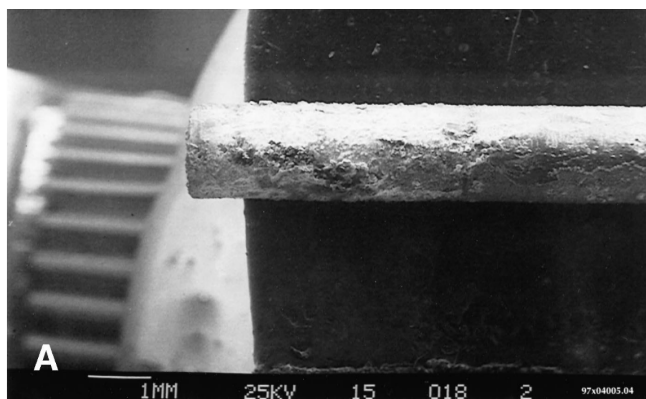
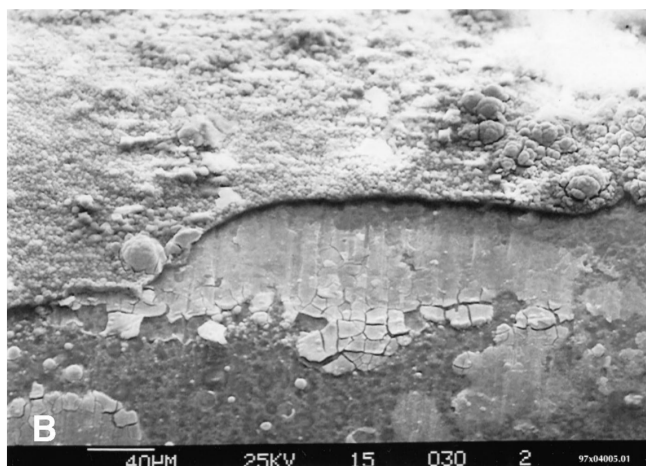


Fig1b. ESM of metal coupon corrosion underneath microbial bio-films in spent fuel basin (Santo Domingo 1998)



Fig1c. Dust storm at Taranaki during decontamination work, >40km/hr windspeeds (MARTAC 2003)

pools.

Credible health risks to radiation adjacent workers should include dematiaceous pathogens like canned scourges (*C. botulinum* and *D. radiodurans*), research extremophiles (*C. sphaerospermum*) and flood-related soil microbes. Their knack for rapid DNA repair, preference for raw meat substrate, desiccated spores, and virulent melanised walls sculpt a perfect opportunistic infection, especially for (but not exclusively) immunocompromised patients, nuclear submariners and radiology specialists (*Aspergillosis*) (Revankar 2010; Morton 2026; Barnes 2018).

Mechanism

Radioresilience emerges from potent antioxidant microbial pigments or oxidant-reducing metal complexes ameliorating IR-generated superoxidant damage. Radiotrophism or confirmed preference for radioactive environments may also be attributed to melanin. When melanin nanoparticles or cell wall crystals are struck with IR, electrons are ejected via Compton scattering and could fuel intracellular processes like photosynthesis (radiosynthesis). Although the implications for radiovoltaics are ripe, and melanin is regularly used in cosmetic products, pigments are currently being investigated as the first and only effective radioprophylactic (Dadachova 2008), significantly reducing cellular IR damage and accelerating repair. National radioprophylactic distribution could minimize civilian injury in any nuclear incident. Protecting yesterday's rodents, today's sunscreen applicants, tomorrow's soldiers and next week's astronauts from lethal irradiation (Kunwar 2012; Cordero 2017a, 2017b, 2017c).

Solutions

The further we research advanced pigments, the more applications we find. Chemical engineering already improved synthetic melanin nanoparticles, adapted Uranium-binding proteins have for mobile sub micromolar radionuclide tests and enhanced wastewater filters, often using the genes or proteins of microbes growing in the same (or similar) mines (Cao 2025; Tibolla 2025; Hillson 2007). Identifying which genes indicate U/Th/Pu metabolism and creating preliminary field biosensors reduces latency between on-site sampling and lab analyses for random IAEA inspections and internal ANSTO monitoring.

Self-replicating melanised fungi achieve comparable radiation shielding to water at 63% the thickness at fractions of its transport weight and cost, potentially augmenting future regolith-based extra-terrestrial in-situ resource utilization (Shunk 2020).

As the National Microbial Genomics Framework (2019-2022) suggests, expanding AusTrakka's low-cost whole genome, metagenomic or hologenomic sequencing—whilst computationally intense—may prove essential to recognizing and tracing polyextremophiles whilst logging the transfer of pathogenic, radioresilient or antimaterial genes or organisms across unwelcome territories (Alberdi 2022). Government agencies must examine these radioactive environments and share their data with independent researchers. This, combined with the investigational leads and approaches above will grant Australia insights into surviving inhospitable environments whilst protecting our strategic nuclear resources, personnel and population (MacGregor 2024; McKay 2001).

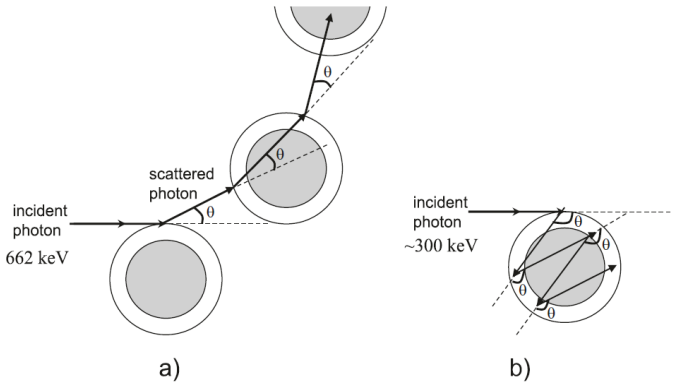


Fig2a. Proposed melanin Compton scattering (Dadachova 2008)

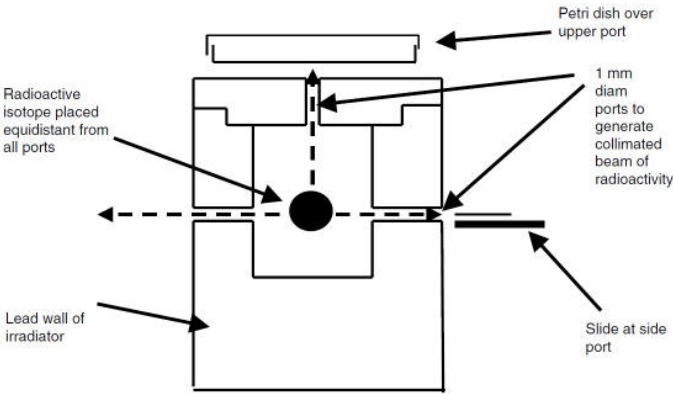


Fig2b. Experimental radiotrophic growth setup (Zhdanova 2004)

Table 1: Comparison of radiation attenuating capacity of *in-situ* resources on Mars with melanized composites. Attenuation coefficients for the compounds were obtained from the NIST XCOM database [42], with buildup-factors generated by the RadPro Calculator [65], based on molecular formulas and/or densities for the respective materials as referenced, unless trivial or noted otherwise.

Material and literature source for molecular formula and density	Mass Attenuation Coefficient 'μ/ρ' [cm²/g] at 150 MeV *	Linear Attenuation Coefficient 'μ' [cm⁻¹] at relative material density	Required thickness [cm] to reduce Martian radiation levels by ~97% ‡
Water	0.0149	0.0149	367
Martian regolith [66]	0.0268	0.0407	128
Martian regolith + melanin (equimolar mixture) [67]	0.0288	0.0518	106
Non-melanized fungus † [53]	0.0141	0.0155	351
Melanized fungus ‡	0.0213	0.0234	232

* cumulative radiation environment on the surface of Mars [54]; † from 234 mSv/a, the average radiation dose on Mars [54], to 6.2 mSv/a the average radiation dose on Earth [7, 8]; ‡ based on an empirical elemental formula for the biomass of baker's yeast [53], adjusted for 60% water content [50]; ‡ based on 92.8% [w/w] non-melanized fungal biomass (as in †) and 7.2% [w/w] melanin content (DHN-melanin).

Fig2c. Comparison of radiation attenuation between traditional shielding approaches and melanin (Shunk 2020)

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