Environmental Decontamination (NZ) Limited

Transforming Mussel Shell Waste into Valuable Products - Phase 2

Final Report for Public Dissemination

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Environmental Decontamination (NZ) Limited

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Contents

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General Abbreviations

$CaCO_3$	Calcium Carbonate
CAPEX	Capital Expenditure
CO_2e	Carbon Dioxide Equivalent
EDL	Environmental Decontamination (NZ) Limited
GCC	Ground Calcium Carbonate
GHG	Greenhouse Gas
ISO	International Organisation for Standardisation
MCD	Mechanochemical Destruction
MPI	Ministry for Primary Industries
NIML	North Island Mussel Limited
OPEX	Operating Expenditure
PPE	Personal Protective Equipment
PSD	Particle Size Distribution
R&D	Research and Development
SFFF	Sustainable Food & Fibre Futures
SSA	Specific Surface Area
WMF	Waste Minimisation Fund
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescence

1. Executive Summary

The Mussel Shell Valorisation Programme, led by a team of scientists and engineers at Environmental Decontamination (NZ) Limited (EDL®), has successfully demonstrated a commercially viable pathway for converting New Zealand green-lipped mussel shell waste into high-value industrial products.

Following on from initial Phase 1 R&D, this Phase 2 programme focused on progressing the technology from pilot validation to commercial readiness. This included development of an integrated processing system, validation of product performance across multiple industries, engagement with supply chain partners, and completion of engineering and commercial planning activities.

The programme confirmed that mussel shells can be processed into specification-grade ground calcium carbonate (GCC), suitable for use in construction materials, coatings, plastics, and environmental applications. Pilot-scale operations demonstrated consistent processing performance, while industry testing verified that the material meets key functional requirements for targeted applications.

Strong engagement with the aquaculture sector has confirmed the availability of sufficient feedstock to support commercial deployment. Industry partners have also expressed clear interest in adopting a sustainable, locally sourced alternative to quarried mineral products.

In addition to economic potential, the programme delivers clear environmental benefits by diverting waste from landfill, recovering valuable resources, and reducing reliance on mined materials.

With technical feasibility established and commercial groundwork completed, the project is now positioned for deployment of New Zealand's first mussel shell valorisation facility.

Figure 1. Although commonly treated as waste, mussel shells contain high-value calcium carbonate, representing a significant untapped resource as well as an environmental burden.

2. The Opportunity

New Zealand produces significant volumes of mussel shell waste each year as a by-product of aquaculture processing. Despite being composed primarily of high-purity calcium carbonate, this material is typically disposed of to landfill, rural land, or used in low-value applications.

This represents both an environmental burden and a missed economic opportunity.

Calcium carbonate is one of the most widely used industrial minerals globally, with applications across construction, plastics, coatings, and environmental systems. At present, supply is almost entirely derived from quarried sources.

The transformation of mussel shell waste into GCC presents a unique opportunity to:

- Divert substantial volumes of waste from landfill.
- Create a circular, domestic supply of industrial minerals.
- Reduce reliance on extraction and importation of raw materials.
- Support sustainability goals across multiple industries.

This programme has focused on unlocking that opportunity through a scalable, commercially viable solution.

Table 1. Mussel shell valorisation opportunity at a glance.

Dimension	Key Insight
Resource Availability	Up to 70,000 tonnes of shell waste produced annually in NZ. 5,000-7,500 tonnes per year identified for initial deployment.
Material Properties	High-purity calcium carbonate ($CaCO_3$) suitable for industrial mineral markets.
Current Outcome	Predominantly landfilled, deposited onto rural land, or used in low-value applications.
Replacement Potential	Provides an alternative to imported and quarried mineral products.
Target Markets	Plastics, paints and coatings, concrete, construction materials.
Phase 1 Achievement	Demonstrated micronisation, surface area enhancement, and product feasibility.
Phase 2 Objectives	Validate process, confirm product performance, and secure commercial pathways.
Benefits	- Circular economy and waste reduction. - Sustainable material substitution. - Supply chain resilience. - Regional economic development. - Industry diversification and risk reduction.

2.1 Programme Overview

The Mussel Shell Valorisation Programme has been delivered in two phases.

Phase 1 established proof-of-concept, demonstrating that mussel shells could be processed into fine calcium carbonate materials with properties suitable for industrial use.

Phase 2 (this work) has focused on advancing this capability toward commercial implementation. The objective was to reduce technical, operational, and market risks associated with deploying a full-scale facility.

This has been achieved through:

- Pilot-scale system development and operation.
- Process optimisation and integration.
- Product validation with industry partners.
- Supply chain engagement.
- Engineering and commercial planning.

The programme has been led by Environmental Decontamination (NZ) Limited (EDL®), leveraging its expertise in mechanochemical processing, fine grinding, and industrial scale-up.

3. Summary of Work Completed

Pilot Platform Development

A pilot-scale processing platform was established at EDL's Technology Centre, enabling controlled evaluation of all major process steps. This included drying, pre-processing, grinding, particle classification, and material handling. The modular nature of the system allowed individual components to be tested independently and as part of an integrated process.

Process Development

Extensive trials were conducted to optimise processing conditions and understand material behaviour. These activities established reliable operating windows and confirmed that the process can consistently produce materials suitable for downstream applications. Multiple processing pathways were evaluated to ensure flexibility in future plant design.

Product Development

Representative materials were produced and supplied to industry partners for testing. Feedback from these partners directly informed process refinement and product specification.

Market Engagement

Engagement with manufacturers across construction, coatings, and plastics sectors has confirmed strong interest in the material and provided clarity on performance requirements and commercial expectations.

Commercial Preparation

Engineering design, cost modelling, and deployment planning have been completed to support transition to commercial implementation.

4. Technology Overview

The process developed during the programme converts mussel shell waste into fine mineral powders through a series of controlled mechanical and material handling steps.

Key stages include:

- Feedstock preparation, conditioning, and drying.
- Size reduction through milling.
- Particle size classification.
- Product handling and packaging.

Multiple processing configurations were evaluated to ensure scalability and adaptability. These include both modular and continuous processing approaches.

The programme confirmed that:

- The process can operate reliably at pilot scale.
- Product characteristics can be controlled to meet market specifications.
- The system can be scaled to industrial throughput levels.

The technology has been designed with a focus on operational efficiency, environmental control, and integration into existing industrial environments.

Figure 2 illustrates the generalised process flow examined during pilot operations, from shell receipt through to finished GCC product. The equipment platforms described in the following subsections supported one or more stages of this pathway.

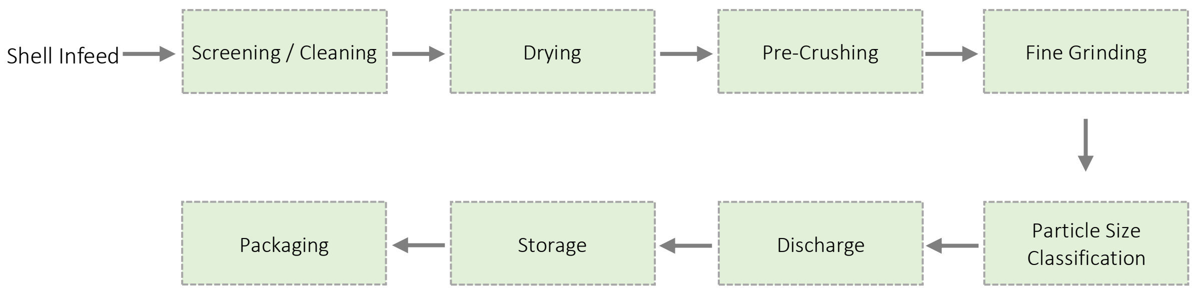


Figure 2. Process pathway evaluated during pilot operations, illustrating how individual equipment platforms contribute to the conversion of shell feedstock into specification-grade GCC.

Collectively, piloting has strengthened confidence in the technical and operational feasibility of commercial implementation and provide a robust foundation for future facility development.

4.1 Pre-Processing Systems

Pre-processing was evaluated to ensure consistent and efficient downstream milling performance. This included drying and pre-crushing of shell material.

Drying was identified as a critical step to reduce moisture variability and improve material flow. Lower moisture content resulted in more stable operation, reduced agglomeration, and improved particle size control during milling.

Pre-crushing was used to reduce feed size and create a more uniform material for fine grinding. This step improved overall process efficiency and reduced energy demand in downstream milling stages.

These findings confirmed that controlled pre-conditioning is essential for achieving consistent, high-throughput operation at scale.

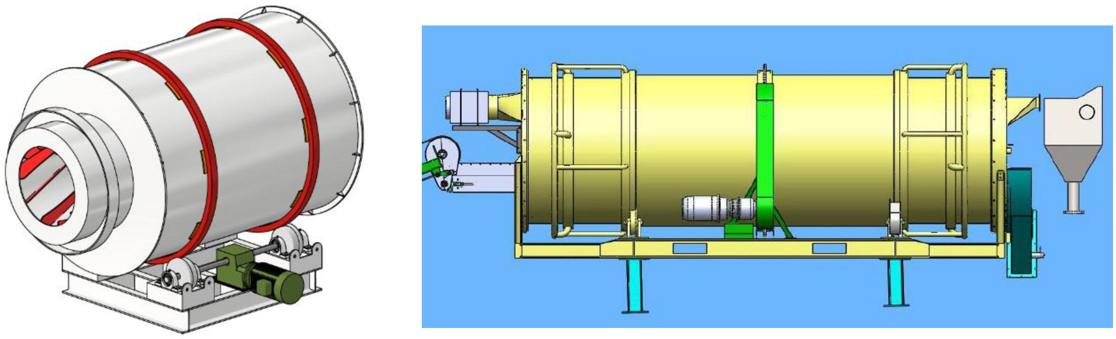


Figure 3. Three-Way dryer evaluated in Phase 2 (left). Dryer with heat recovery dryer concept drawings (right).

4.2 MCD Milling System

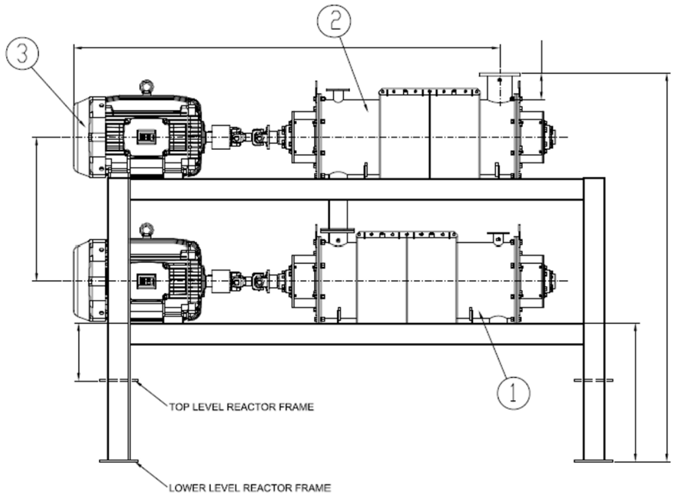
EDL's proprietary milling reactors, known as mechanochemical destruction (MCD®) systems, wwereas evaluated as a modular approach to fine grinding.

Pilot trials demonstrated that the system is capable of progressively reducing particle size through staged processing. The modular configuration allows multiple units to be operated in series or parallel, providing flexibility in both capacity and product specification.

The system showed strong performance in:

- Handling variable feedstock conditions.
- Producing fine, high-surface-area powders.
- Supporting scalable deployment through replication of units.

While highly effective for bulk size reduction and material activation, results indicated that downstream classification is required to achieve tightly controlled particle size distributions for certain applications.



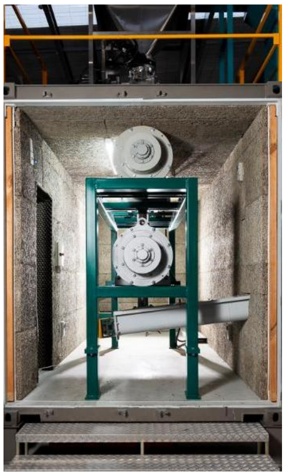


Figure 4. Schematic of MCD reactor system showing a dual reactor setup (left). Installed two-reactor MCD system (right).

4.3 Particle Classification Systems

Particle classification was identified as a key step in producing specification-grade GCC.

At pilot scale, mechanical separation systems were used to generate defined particle size fractions for product testing. These systems demonstrated the ability to reliably separate material into application-specific size ranges.

In parallel, air classification was evaluated as a scalable solution for continuous operation. This approach allows precise control of particle size through adjustment of airflow and rotor speed.

The combined findings confirmed that:

- Product specifications can be tailored to different markets.
- Classification systems can be integrated into continuous processing.
- Consistent product quality can be achieved at scale.

4.4 Dust Management and Containment

Dust generation is an inherent aspect of fine mineral processing and was actively managed throughout the programme.

Pilot-scale dust suppression and containment systems were implemented to:

- Capture airborne particulates at source.
- Maintain safe operating conditions.
- Ensure compliance with environmental and workplace standards.

Figure 6. Pilot scale dust suppression system evaluated in this programme.

Results confirmed that dust levels can be effectively controlled within regulated limits using standard industrial systems.

In addition, containment solutions were developed to manage noise, temperature, and operator exposure. These systems demonstrated that the process can be deployed safely within enclosed industrial environments.

4.5 System Integration and Operability

A key outcome of Phase 2 was demonstrating that individual processing steps can be integrated into a coherent and operable system.

Pilot operations provided practical insight into:

- Material flow between stages.
- Equipment interaction and sequencing.
- Process stability under continuous operation.
- Maintenance and operational considerations.

These learnings have informed the design of a full-scale facility, ensuring that the process is not only technically viable, but also operationally robust.

4.6 Key Technology Outcomes

Across all systems evaluated, the programme confirmed that:

- Mussel shell waste can be consistently processed into fine mineral products.

- Multiple processing pathways are technically viable.
- Product characteristics can be controlled to meet market specifications.
- The system can be scaled to industrial throughput levels.
- Standard industrial equipment and controls can be applied.

The technology has been designed with a focus on scalability, reliability, and integration into existing industrial environments, providing a strong foundation for commercial deployment.

5. Product & Market Validation

A core focus of Phase 2 has been ensuring that technical development is closely aligned with real-world market requirements. Rather than developing material in isolation, the programme has prioritised direct engagement with industry partners to validate performance, understand specification requirements, and confirm practical pathways for adoption.

Construction Materials

Testing has confirmed that GCC derived from mussel shells performs effectively as a fine filler in cementitious systems. Laboratory and partner-led evaluations have demonstrated that the material can be incorporated into concrete and mortar formulations without negatively impacting workability or consistency. In many cases, the presence of fine particles contributes positively to particle packing and mix behaviour, supporting its role as an inert filler within cement-based systems.

This positions mussel shell-derived GCC as a viable supplementary material for a range of construction applications, particularly in formulations where fine mineral fillers are already widely used to optimise performance and reduce reliance on cement.

Coatings and Paints

Engagement with manufacturers in the coatings and construction materials sector has demonstrated strong compatibility between the produced GCC and existing product requirements.

Assessment of particle size distribution and composition indicates alignment with a range of formulations used in paints, coatings, grouts, and related materials. Importantly, feedback from industry has confirmed that the material can integrate into existing production systems without requiring significant modification.

The ability to supply a locally sourced, sustainable alternative to conventional mineral fillers also presents a compelling value proposition for manufacturers seeking to reduce the environmental footprint of their products.

Marine Applications

Exploratory work has also demonstrated the potential for mussel shell-derived materials to be used in marine and environmental applications, including artificial reef structures.

Initial trials have shown that materials incorporating processed shell can provide a stable substrate for marine life, supporting ecological restoration in coastal environments. This represents a complementary pathway for valorisation, linking waste recovery with environmental outcomes.

While still at an early stage, this application highlights the broader versatility of the material beyond traditional industrial markets.

Market Alignment

Across all sectors evaluated, feedback consistently indicates that the material is both technically viable and commercially relevant.

Engagement with industry has moved beyond initial interest toward more practical considerations, including specification alignment, supply consistency, and integration into existing manufacturing processes. This progression reflects increasing confidence in the material as a credible alternative to conventionally sourced calcium carbonate.

The key remaining requirement for widespread adoption is the establishment of consistent, large-scale supply. With this in place, the programme has demonstrated a clear pathway from product validation to commercial uptake across multiple industries.

6. Conclusion

The Mussel Shell Valorisation Programme has successfully progressed from concept to a position of full commercial readiness, demonstrating a practical and scalable solution to one of New Zealand's most underutilised waste streams.

Secured Foundations for Deployment

A critical outcome of the programme has been the establishment of a reliable and scalable supply chain. Engagement with mussel processors across New Zealand has confirmed that sufficient volumes of shell waste are available to support both initial deployment and future expansion. Multiple supply regions have been identified, annual volumes are well understood, and strong industry support has been secured.

Importantly, the presence of legacy shell stockpiles provides an immediate opportunity to accelerate early-stage operations, enabling rapid demonstration of impact from the outset.

A Compelling Environmental Case

Beyond technical and commercial success, the programme delivers a clear and meaningful environmental outcome.

The proposed process enables large-scale diversion of mussel shell waste from landfill, addressing a long-standing disposal challenge while preserving valuable landfill capacity. At the same time, it transforms this waste into a high-value industrial mineral, establishing a circular pathway that retains material value within the economy.

By providing an alternative to quarried calcium carbonate, the initiative also reduces reliance on extractive industries. When considered at a system level, this substitution, combined with reduced transport requirements, presents a strong opportunity for favourable lifecycle emissions outcomes.

Collectively, these benefits position the programme as a practical example of circular economy principles in action, with relevance beyond the aquaculture sector.

Commercial Viability Established

The programme has demonstrated that mussel shell valorisation is not only technically feasible, but commercially credible.

Engineering design, process configuration, and operational planning have been completed based on pilot-scale validation. Cost modelling confirms that the proposed facility can operate within a sustainable commercial framework under realistic market conditions.

Crucially, all key elements required for deployment are now in place:

- Feedstock supply has been secured.
- Product performance has been validated across multiple applications.
- Market demand has been confirmed through direct industry engagement.

This alignment between supply, process capability, and market need significantly reduces deployment risk and supports a confident transition to implementation.

Transitioning from Development to Implementation

With the core foundations established, the programme is now positioned to move into commercial deployment.

The next phase will focus on establishing the first full-scale facility, which will validate continuous operation under real-world conditions, supply material to industry partners at commercial volumes, and demonstrate the full environmental and economic benefits of the process.

This initial deployment will serve as a platform for replication across other regions, enabling a distributed model for mussel shell valorisation throughout New Zealand.

Key next steps include:

- Finalising site and deployment arrangements.
- Completing detailed engineering design.
- Progressing funding and investment pathways.
- Initiating construction and commissioning.

A New Model for Resource Recovery

The Mussel Shell Valorisation Programme demonstrates that waste mussel shells can be transformed into high-value industrial materials through a scalable and commercially viable process.

More broadly, it establishes a new model for how biological waste streams can be reimagined as strategic resources. By integrating resource recovery into the aquaculture value chain, the programme creates a pathway that delivers environmental, economic, and industry-wide benefits.

With all key elements now in place, the project is ready to transition from development to deployment, unlocking value from waste and setting a benchmark for circular resource innovation in New Zealand.