

INDUSTRIAL CASE STUDY

Medical Waste Treatment & Autoclave Systems

Continuous Pre-Vacuum Autoclave Sterilisation with Integral Shredding

Industrial-Scale Batch-Continuous System — 750 kg/Cycle, 6 Cycles/hr

Designed, Engineered & Validated by KERONE Engineering Solutions Limited

|                                                                             |                                                              |                                                            |
|-----------------------------------------------------------------------------|--------------------------------------------------------------|------------------------------------------------------------|
| <b>4.5 TPH</b><br>PLANT CAPACITY<br>Effective (750 kg x 6 cyc/hr)           | <b>134°C</b><br>PROCESS TEMP.<br>Saturated Steam, Pre-Vacuum | <b>20 min</b><br>HOLD TIME<br>At Sterilisation Temperature |
| <b>≥ 5 log</b><br>SPORE INACTIVATION<br>G. steartothermophilus (Req. 4 log) | <b>75%</b><br>VOLUME REDUCTION<br>Integral Shredding         | <b>~1.8 Yrs</b><br>PAYBACK PERIOD<br>At CBWTF Tariff       |

Project Reference Detail

|                     |                                                                                                                             |
|---------------------|-----------------------------------------------------------------------------------------------------------------------------|
| Client Organisation | MediClean Waste Management Pvt. Ltd. — Common Biomedical Waste Treatment Facility operator, Southern India                  |
| KERONE Reference    | KRDC/ICS/BMW-Autoclave/2026-06   Based on KRDC Lab Report 65/KRDC/LAB/22                                                    |
| Technology          | Continuous Pre-Vacuum Steam Autoclave with Integral Twin-Shaft Shredder & Automated Loading                                 |
| Feedstock           | Category-wise segregated biomedical waste — Red & White (sharps) streams per BMWM Rules 2016, average 8% dense plastic load |
| Product Output      | Sterile, shredded, unrecognisable residue — ≥ 5 log <sub>10</sub> spore reduction, landfill / co-processing ready           |
| Plant Location      | Client CBWTF site — inline with existing receiving, weighing and barcode tracking system                                    |
| Compliance Basis    | BMWM Rules 2016 (as amended)   CPCB Guidelines for CBWTFs   ISO 17665 Moist Heat Sterilisation   STAATT Level III           |
| Document Date       | July 2026   Validated on KRDC Lab Data — April 2026                                                                         |

Healthcare Waste Management | Autoclave Sterilisation | Infection Control | Moist Heat Thermal Processing | Environmental Compliance | CBWTF Operations

## Executive Summary

MediClean Waste Management Pvt. Ltd., a Common Biomedical Waste Treatment Facility (CBWTF) operator serving over 260 healthcare establishments across a Southern India metropolitan cluster, faced a growing mismatch between collection volumes and treatment capacity. Their existing gravity-displacement autoclaves ran 70-minute cycles with no shredding, required manual bag handling at both load and unload, and produced treated waste that remained visually recognisable — a direct non-conformance with the "unrecognisable waste" requirement for red-category plastics under the Bio-Medical Waste Management Rules, 2016.

KERONE Engineering Solutions Limited was engaged to design, validate and specify a continuous pre-vacuum autoclave sterilisation system capable of achieving validated moist-heat inactivation while integrating shredding directly into the treatment cycle — at a sustained effective throughput of 4.5 tonnes per hour (750 kg per cycle, 6 cycles per hour).

Following a structured validation programme at KRDC (Kerone Research & Development Centre) using an instrumented pre-vacuum autoclave rig on the client's own segregated waste, with biological indicator challenge testing at multiple hold times (10, 15, 20 and 30 minutes at 134°C), the optimal industrial process envelope was established. The KERONE continuous pre-vacuum autoclave — operating at 134°C saturated steam with a 20-minute validated hold time following four fractionated vacuum pulses — delivers a 5.4 log<sub>10</sub> reduction of *Geobacillus stearothermophilus* spores against the statutory 4 log<sub>10</sub> requirement, with 75% volume reduction through the integral post-cycle shredder.

| CHALLENGE                                                                                                                                                            | KERONE SOLUTION                                                                                                                                                               | OUTCOME ACHIEVED                                                                                                                                           |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Gravity autoclaves at 70-min cycles, no shredding, manual bag handling; treated waste remained recognisable; rising labour cost and no electronic cycle audit trail. | Continuous pre-vacuum autoclave at 134°C, 20-min hold, four-pulse vacuum fractionation, integral twin-shaft shredder and automated bin handling — validated from KRDC trials. | 5.4 log <sub>10</sub> spore inactivation (STAATT Level III+), 75% volume reduction, 2.3x cycle throughput and full electronic batch record for SPCB audit. |

## Key Performance Summary

| KPI                                                 | Existing Route (Baseline)        | After KERONE System (4.5 TPH effective) | Improvement                      |
|-----------------------------------------------------|----------------------------------|-----------------------------------------|----------------------------------|
| Spore Inactivation ( <i>G. stearothermophilus</i> ) | Chemical indicator only          | 5.4 log <sub>10</sub> (validated)       | STAATT Level III+                |
| Cycle Time                                          | 70 min (gravity autoclave)       | 20 min hold + 12 min pulse/vacuum       | 2.3x cycles/hr                   |
| Volume Reduction                                    | Nil (no shredding)               | 75%                                     | Landfill volume cut              |
| Treatment Cost                                      | INR ~9.8/kg                      | INR ~4.2/kg                             | 57% cost reduction               |
| Waste Recognisability                               | Partially intact — non-compliant | Fully unrecognisable                    | BMWM Rules compliant             |
| Air Removal from Load                               | Gravity displacement — uneven    | 4-pulse fractionated vacuum             | Eliminates cold-spot air pockets |
| Annual Treatment Capacity                           | ~2,100 t/yr (constrained)        | ~4,320 t/yr at 80% loading              | +106% capacity                   |

Table 1: Key performance indicators — existing gravity autoclave route vs KERONE continuous pre-vacuum autoclave system

## Industry Context & The Business Challenge

India generates approximately 740 tonnes of biomedical waste per day across more than 2.7 lakh registered healthcare facilities. Autoclaving remains the most widely deployed sterilisation technology among CBWTFs, valued for its lower capital cost relative to microwave systems and its established validation base under ISO 17665 and CPCB guidelines. However, a large share of installed autoclave capacity in India consists of older gravity-displacement units, which rely on steam pressure alone to displace air from the load and are demonstrably less effective at penetrating densely packed plastic waste than pre-vacuum designs.

Gravity autoclaves depend on the load being loosely packed and evenly distributed to allow steam penetration; in practice, compacted red-category plastic bags create air pockets that resist steam penetration and create cold spots where spore inactivation falls short of validated levels. Regulatory audits increasingly require biological indicator evidence rather than a chemical strip alone, and CBWTF operators without a fractionated vacuum system struggle to demonstrate consistent penetration into dense, irregularly shaped loads.

### The Operational Problem — Why the Existing Route Fails

| Parameter                       | Client's Existing Operation        | Statutory / Best-Practice Requirement                           | Gap                                  |
|---------------------------------|------------------------------------|-----------------------------------------------------------------|--------------------------------------|
| Air removal method              | Gravity displacement, single pulse | Fractionated pre-vacuum, multi-pulse                            | FAIL — cold-spot risk in dense loads |
| Microbial inactivation proof    | Chemical indicator strip only      | Biological indicator, $\geq 4 \log_{10}$ G. steartothermophilus | FAIL — no validated proof            |
| Shredding of red-category waste | None — manual mutilation only      | Mandatory — rendered unrecognisable                             | FAIL — non-compliant                 |
| Cycle record retention          | Paper chart recorder               | Electronic cycle data, 5-year retention                         | FAIL — audit exposure                |
| Throughput vs collection growth | ~30 kg/min effective               | $\geq 60$ kg/min projected 2027 demand                          | FAIL — capacity shortfall            |
| Treatment cost per kg           | INR ~9.8/kg                        | INR 4–5/kg benchmark (pre-vacuum autoclave)                     | ~2x cost gap                         |

Table 2: Existing operation vs statutory requirement | Source: KRDC site assessment & BMW Rules 2016 (as amended)

### The Commercial Opportunity — Closing the Capacity and Compliance Gap

The Opportunity: At an effective 4.5 TPH throughput (750 kg per cycle, 6 cycles per hour) operating 16 hours a day for 300 days a year at 80% loading, the annual treated volume is approximately 4,320 tonnes — more than double the existing gravity-autoclave capacity. Reducing per-kg treatment cost from INR 9.8 to INR 4.2 while doubling throughput allows the client to both absorb organic collection growth and bid for additional third-party CBWTF contracts without incremental land or shed footprint.

### About the Client Facility

MediClean Waste Management Pvt. Ltd. operates an authorised CBWTF with a State Pollution Control Board consent covering more than 260 healthcare establishments, including three tertiary-care hospitals. The facility runs barcoded bag-level traceability from collection through disposal and maintains an on-site effluent treatment plant for wash-water discharge. The KRDC validation trial was conducted on the client's actual segregated red- and white-category waste (a 60 kg representative composite sample, dispatched 2 April 2026) to ensure that all process parameters reflect real load density and packing configuration rather than synthetic surrogate waste.

## Process Validation — From KRDC Lab to Industrial Scale

KERONE's engineering approach mandates laboratory-scale validation before any industrial system specification. KRDC conducted a structured experimental programme on the client's actual biomedical waste composite over 7 days (2–8 April 2026), using an instrumented 60-litre pre-vacuum autoclave rig with a four-pulse fractionated vacuum sequence, in-load fibre-optic temperature probes and biological indicator challenge packs, to establish the process envelope that informs the 4.5 TPH industrial plant design.

### KRDC Experimental Programme — Key Findings

Biological indicator strips carrying a certified population of  $1.0 \times 10^6$  *Geobacillus stearothermophilus* spores were placed at the geometric cold spot of each load — identified by prior thermal mapping at the centre of the densest bag — and incubated for 48 hours post-exposure per ISO 17665 rapid-readout protocol. Class 6 chemical integrators were run in parallel as a secondary indicator. Chamber pressure and temperature were logged continuously through the full pulse-vacuum, steam-admission, hold and exhaust sequence.

| Test Condition    | Hold Time (at 134°C) | Vacuum Pulses | Spore Log Reduction         | Assessment                             |
|-------------------|----------------------|---------------|-----------------------------|----------------------------------------|
| Control (no hold) | 0 min                | 0             | 0.0 log <sub>10</sub>       | Baseline — untreated waste             |
| Short hold        | 10 min               | 2             | 2.8 log <sub>10</sub>       | Insufficient — below statutory limit   |
| Intermediate      | 15 min               | 3             | 4.1 log <sub>10</sub>       | Marginal — minimal safety factor       |
| <b>OPTIMAL</b>    | <b>20 min</b>        | <b>4</b>      | <b>5.4 log<sub>10</sub></b> | <b>Optimal — STAATT Level III+</b>     |
| Extended          | 30 min               | 4             | 5.6 log <sub>10</sub>       | No material gain — higher steam demand |

Table 3: KRDC laboratory results — pre-vacuum autoclave trials on client biomedical waste composite | KRDC Test Report 65/KRDC/LAB/22 | Biological indicator challenge per ISO 17665 / STAATT protocol

The findings establish 20 minutes at 134°C following four fractionated vacuum pulses as the design point. Below 15 minutes, cold-spot inactivation at the centre of dense bags falls short of the statutory 4 log<sub>10</sub> threshold; beyond 20 minutes, the incremental log reduction is negligible while steam consumption rises by approximately 32%. Comparative trials using a single gravity-displacement pulse in place of the four-pulse vacuum sequence, at the same 20-minute hold, achieved only 3.6 log<sub>10</sub> reduction at the cold spot — confirming that fractionated vacuum air removal, not hold time alone, is the parameter that determines penetration into densely packed loads.

### Scale-Up Methodology — Lab to 4.5 TPH

KERONE's scale-up process follows a structured engineering framework where laboratory parameters are translated to industrial equipment specifications using validated steam penetration and thermal models. The key translation factors for this project are:

| Parameter                 | KRDC Lab (60L Rig)               | Industrial Plant (750 kg/Cycle Autoclave) | Scale-Up Factor      |
|---------------------------|----------------------------------|-------------------------------------------|----------------------|
| Sterilisation Temperature | 134°C                            | 134°C                                     | 1:1 (direct)         |
| Optimal Hold Time         | 20 min                           | 20 min hold                               | 1:1 (direct)         |
| Vacuum Pulses             | 4 fractionated pulses            | 4 fractionated pulses, PLC-sequenced      | 1:1 (direct)         |
| Chamber Volume            | 60 litres                        | 3,200 litres (750 kg load basis)          | ~53:1                |
| Steam Source              | Electric steam generator, in-lab | Dedicated steam boiler, site-mounted      | Configuration change |

| Parameter        | KRDC Lab (60L Rig)  | Industrial Plant (750 kg/Cycle Autoclave)          | Scale-Up Factor       |
|------------------|---------------------|----------------------------------------------------|-----------------------|
| Loading          | Manual, single tray | Automated bin-lift charging, dual chamber          | Automated             |
| Shredding        | Post-cycle, offline | Integral post-cycle shredder, inline discharge     | Configuration change  |
| Cycle Sequencing | Single batch        | Twin-chamber staggered cycling, 6 cyc/hr effective | Continuous-equivalent |

Table 4: Scale-up translation factors — KRDC laboratory rig to 750 kg/cycle industrial pre-vacuum autoclave system

## Industrial Plant Design — 4.5 TPH Effective Continuous-Cycle System

### Process Flow — Sequence of Operations

| Stage                        | Operation                                                    | Key Condition                        |
|------------------------------|--------------------------------------------------------------|--------------------------------------|
| 1. Waste Intake              | Barcoded bag reception, weighing, category verification      | Colour-coded segregation check       |
| 2. Charging                  | Automatic bin lifter loads sealed chamber trolley            | Enclosed, no manual bag contact      |
| 3. Vacuum Fractionation      | Four alternating vacuum / steam-admission pulses             | Removes trapped air from dense loads |
| 4. Sterilisation Hold        | Saturated steam hold at set temperature                      | 134°C   20 min validated hold        |
| 5. Verification              | In-chamber probes and BI validation confirm cycle parameters | Automatic reject on deviation        |
| 6. Controlled Exhaust        | Staged steam exhaust and drying pulse                        | Prevents flash-boil carryover        |
| 7. Discharge & Shredding     | Trolley discharge into twin-shaft shredder                   | < 25 mm fragments   75% volume cut   |
| 8. Air & Condensate Handling | HEPA-filtered chamber vent + condensate to ETP               | Odour control   contained discharge  |

Fig. 1 (described): KERONE 750 kg/cycle pre-vacuum autoclave — continuous-cycle industrial process sequence

### System Architecture — Major Process Units

| Unit / Section                                            | Equipment                                                | Design Parameters                                                    | Function                                                                         |
|-----------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------------------------|----------------------------------------------------------------------------------|
| U-01: Waste Intake & Weighing                             | Platform weighbridge + barcode scanner + bin lifter      | 900 kg/hr rated   0.1 kg resolution                                  | Record bag-level traceability; verify category before charging                   |
| U-02: Charging System                                     | Hydraulic bin lifter + chamber trolley                   | Interlocked door   750 kg/cycle capacity                             | Eliminate operator contact with untreated waste                                  |
| U-03: Pre-Vacuum Autoclave Chamber (Primary Process Unit) | KERONE Twin-Chamber Pre-Vacuum Autoclave                 | 3,200 L per chamber   134°C   20 min hold   4-pulse vacuum   SS 316L | Core sterilisation — fractionated vacuum air removal and moist-heat inactivation |
| U-04: Steam Generation                                    | Dedicated fire-tube steam boiler                         | 500 kg/hr steam   8 bar rated   dual fuel (diesel/biogas)            | Supply saturated steam to chamber and jacket                                     |
| U-05: Vacuum System                                       | Liquid ring vacuum pump skid                             | 2 x 7.5 kW   -0.9 bar(g) capability                                  | Execute fractionated vacuum pulses for air removal                               |
| U-06: Cycle Monitoring                                    | Fibre-optic probe array + chart-free electronic recorder | 6 in-chamber points   1-sec logging                                  | Continuous verification of cycle parameters; automatic reject logic              |
| U-07: Discharge & Shredding                               | Trolley tipper + twin-shaft shredder                     | 35 kW   < 25 mm output   900 kg/hr rated                             | Render treated waste unrecognisable; volume reduction                            |
| U-08: Air & Condensate Handling                           | HEPA H13 chamber vent filter + condensate cooling loop   | ≥ 99.95% at 0.3 µm   condensate to site ETP                          | Prevent aerosol release; safe disposal of condensate                             |
| U-09: Process Control & Validation                        | PLC/SCADA with electronic batch record system            | Siemens S7 / Allen Bradley   5-year data retention                   | Cycle control, electronic batch records, SPCB audit reporting                    |

Table 5: Process unit descriptions — KERONE 750 kg/cycle twin-chamber pre-vacuum autoclave plant | U-03 is the primary process unit; all others are ancillary

## Core Equipment Specification — KERONE Pre-Vacuum Autoclave

The KERONE Twin-Chamber Pre-Vacuum Autoclave is the heart of the medical waste treatment system. Designed and manufactured in-house at KERONE's Ambernath facility, it directly scales the validated laboratory parameters from KRDC trial 65/KRDC/LAB/22 to industrial throughput while maintaining the identical vacuum-pulse sequence, temperature profile and hold time that produced the 5.4 log<sub>10</sub> spore inactivation result.

| PRE-VACUUM AUTOCLAVE — CORE SPECIFICATIONS |                                                                           |
|--------------------------------------------|---------------------------------------------------------------------------|
| Design Throughput                          | 750 kg/cycle per chamber   6 cycles/hr effective (twin-chamber staggered) |
| Sterilisation Temperature                  | 134°C (max design: 138°C)                                                 |
| Hold Time                                  | 20 min (adjustable 10–40 min via PLC recipe)                              |
| Vacuum Pulses                              | 4 fractionated pulses, PLC-sequenced, -0.9 bar(g)                         |
| Chamber Dimensions                         | ID 1,400 mm x L 2,600 mm per chamber (SS 316L)                            |
| Chambers                                   | 2 independent chambers, staggered cycling                                 |
| Steam Pressure                             | 2.2–2.4 bar(g) saturated (corresponds to 134°C)                           |
| Door System                                | Hydraulic sliding door, interlocked, dual-safety                          |
| Installed Power                            | ~95 kW (total connected load, excl. boiler)                               |
| Shell Material                             | SS 316L chamber, MS jacket cladding                                       |
| Insulation                                 | Mineral wool 100 mm with SS 304 cladding                                  |
| Validation Ports                           | 4 sealed ports per chamber for biological indicator and probe insertion   |

Table 6: Core equipment specification — KERONE Twin-Chamber Pre-Vacuum Autoclave, 750 kg/cycle

## Utilities & Ancillary Requirements

| Utility             | Specification                             | Consumption (at 4.5 TPH effective)                    | Source                   |
|---------------------|-------------------------------------------|-------------------------------------------------------|--------------------------|
| Electrical Power    | 415V, 3-phase, 50Hz                       | ~95 kW connected   ~74 kW avg demand                  | Site utility             |
| Steam               | 8 bar rated, dual-fuel boiler             | ~460 kg/hr saturated steam                            | Dedicated on-site boiler |
| Water (boiler feed) | Softened, < 50 ppm hardness, DM preferred | ~500 litres/hr                                        | Site softener / DM plant |
| Cooling Water       | 30°C supply   closed loop                 | 4 m <sup>3</sup> /hr   38°C return (vacuum pump seal) | Cooling tower            |
| Compressed Air      | 6 bar dry   instrument grade              | 12 Nm <sup>3</sup> /hr                                | Air compressor (site)    |
| Space Requirement   | Enclosed building / covered bay           | L 20m x W 9m x H 5.5m                                 | New shed or existing bay |

## Emission, Effluent & Occupational Compliance

| Compliance Point | Parameter           | Expected Level        | CPCB / Statutory Limit                        | Status    |
|------------------|---------------------|-----------------------|-----------------------------------------------|-----------|
| Chamber vent     | Bio-aerosol release | Not detectable        | HEPA H13 mandatory                            | COMPLIANT |
| Treated residue  | Spore log reduction | 5.4 log <sub>10</sub> | ≥ 4 log <sub>10</sub> (G. stearothersophilus) | COMPLIANT |

| Compliance Point     | Parameter               | Expected Level                   | CPCB / Statutory Limit     | Status    |
|----------------------|-------------------------|----------------------------------|----------------------------|-----------|
| Treated residue      | Recognisability         | Fully shredded < 25 mm           | Unrecognisable (BMWM 2016) | COMPLIANT |
| Condensate discharge | pH, suspended solids    | Within ETP inlet limits          | CBWTF ETP norms            | COMPLIANT |
| Work area            | Steam / pressure safety | Interlocked doors, relief valves | IBR boiler regulations     | COMPLIANT |
| Work area            | Noise level             | < 75 dB(A)                       | 85 dB(A) (8-hr TWA)        | COMPLIANT |

Table 7: Compliance summary — emission, residue quality and occupational exposure against statutory limits

## Mass Balance & Energy Analysis — 4.5 TPH Effective Operation

### Detailed Mass Balance — Per Hour at Full Load

| Stream                | Material                                   | Flow Rate (kg/hr) | Notes                                                                            |
|-----------------------|--------------------------------------------|-------------------|----------------------------------------------------------------------------------|
| Feed (IN)             | Segregated red / white category waste      | 4,500             | As-received, ~18% moisture, bagged; 6 cycles/hr x 750 kg                         |
| Steam (IN)            | Saturated steam for sterilisation & jacket | ~460              | Latent heat transfer; partial condensation into load                             |
| Condensate Loss       | Steam condensate to ETP                    | ~210              | Routed to site effluent treatment plant                                          |
| Residue (OUT)         | Sterile shredded residue                   | ~4,290            | Includes retained condensate; < 25 mm fragments                                  |
| Recoverable Polymer   | Sorted PP / PE fraction                    | ~640              | ~15% of residue; sold to authorised recycler                                     |
| Landfill / Co-process | Non-recoverable sterile residue            | ~3,650            | To secured landfill or cement co-processing                                      |
| Filter Retentate      | HEPA vent captured particulate             | < 2               | Recycled back into feed at next cycle                                            |
| Volume Basis          | Bulk volume reduction                      | —                 | Inlet ~ 45 m <sup>3</sup> /hr → outlet ~ 11.3 m <sup>3</sup> /hr (75% reduction) |

Table 8: Mass balance — 4.5 TPH effective twin-chamber pre-vacuum autoclave plant | Based on validated KRDC lab data scaled to industrial throughput

### Energy Consumption Estimates

| Energy Category       | Equipment / Unit                               | Power (kW)                      | Load Factor | Consumption (kWh/tonne)   |
|-----------------------|------------------------------------------------|---------------------------------|-------------|---------------------------|
| Steam Generation      | Dual-fuel fire-tube boiler (thermal, fuel eq.) | ~320 kWh eq.                    | 65%         | ~46                       |
| Vacuum System         | 2 x liquid ring vacuum pumps                   | 15                              | 50%         | ~17                       |
| Shredding             | Twin-shaft shredder drive                      | 35                              | 40%         | ~31                       |
| Conveyance & Handling | Bin lifter, trolley drives, discharge conveyor | 14                              | 75%         | ~23                       |
| Air Handling          | Chamber vent fan + HEPA system                 | 8                               | 90%         | ~14                       |
| Cooling & Utilities   | Vacuum pump seal water, controls, lighting     | 13                              | 80%         | ~23                       |
| TOTAL                 |                                                | ~85 kW electrical + boiler fuel |             | ~154 kWh/tonne equivalent |

Table 9: Energy consumption estimate — 750 kg/cycle twin-chamber autoclave plant | Based on KERONE engineering estimates; actual values to be confirmed during detailed engineering

At an industrial electricity tariff of INR 8/kWh and diesel-equivalent boiler fuel cost, the specific energy cost works out to approximately INR 1.85 per kg of waste treated. Adding labour, consumables, maintenance and boiler operation provision brings the fully loaded treatment cost to approximately INR 4.20 per kg — against INR 9.80 per kg for the gravity-autoclave route the system replaces.

## Treated Output Specification & Downstream Applications

| Parameter                                    | Test Method                               | Untreated Waste                        | KERONE Treated Residue          | Statutory Requirement           |
|----------------------------------------------|-------------------------------------------|----------------------------------------|---------------------------------|---------------------------------|
| <b>G. stearothermophilus</b> spore reduction | Biological indicator, 48-hr rapid readout | 0.0 log <sub>10</sub>                  | 5.4 log <sub>10</sub>           | ≥ 4 log <sub>10</sub>           |
| <b>B. atrophaeus</b> (secondary check)       | Biological indicator, 7-day incubation    | 0.0 log <sub>10</sub>                  | ≥ 5 log <sub>10</sub>           | Reference control               |
| <b>Vegetative bacteria</b>                   | Standard plate count                      | 10 <sup>7</sup> –10 <sup>8</sup> CFU/g | < 10 CFU/g                      | ≥ 6 log <sub>10</sub> reduction |
| <b>Particle size</b>                         | Sieve analysis                            | Intact articles                        | < 25 mm                         | Unrecognisable                  |
| <b>Bulk density</b>                          | IS 4032 method                            | ~85 kg/m <sup>3</sup>                  | ~380 kg/m <sup>3</sup>          | N/A                             |
| <b>Moisture content</b>                      | Gravimetric                               | ~18%                                   | ~24%                            | N/A                             |
| <b>Chemical indicator response</b>           | Class 6 integrator                        | Fail (unexposed)                       | Full colour change (pass)       | Pass required                   |
| <b>Classification</b>                        | BMWM Rules 2016                           | Infectious — Red / White               | Sterile, non-infectious residue | Disposal permitted              |

Table 10: Treated output specification — untreated waste vs KERONE-processed sterile residue vs statutory requirement

### Downstream Routes for Treated Residue

- **Recyclable Polymer Recovery**

The shredded, sterilised fraction contains recoverable polypropylene and polyethylene from tubing, IV sets and syringe bodies. Post-treatment sorting recovers roughly 15% of residue mass for sale to authorised recyclers, subject to State Pollution Control Board authorisation for the recycler.

- **Cement Kiln Co-Processing**

Sterile shredded residue with a calorific value of approximately 3,800 kcal/kg is accepted by cement plants as alternative fuel and raw material (AFR) under CPCB co-processing guidelines, reducing landfill dependency and attracting a gate-fee saving.

- **Secured Landfill Disposal**

Where co-processing capacity is unavailable, the 75% volume-reduced sterile residue is landfilled at a fraction of the original transport and tipping cost, directly reducing vehicle trips and per-tonne disposal charges.

- **Extension to Hospital-Based In-House Sterilisation**

The same validated pre-vacuum platform is deployable for in-house sterilisation at large hospitals and diagnostic chains seeking to treat red-category waste on-site before CBWTF collection, at chamber sizes from 100 to 500 kg/cycle.

- **Multi-Site CBWTF Contract Expansion**

The doubled effective throughput allows the operator to bid for additional third-party biomedical waste collection contracts within the same shed footprint, converting freed-up capacity directly into new treatment-fee revenue.

## Financial Analysis & Return on Investment

### CAPEX Estimate — 750 kg/Cycle Twin-Chamber Plant

| Cost Head                                                      | Scope                                                | Estimated Cost (INR Lakhs) | Notes                                                         |
|----------------------------------------------------------------|------------------------------------------------------|----------------------------|---------------------------------------------------------------|
| <b>Pre-Vacuum Autoclave — Twin Chamber (Primary Equipment)</b> | KERONE supply, factory tested                        | 42–48                      | FOT Ambernath; includes doors, jackets, vacuum skid, controls |
| <b>Steam Boiler System</b>                                     | Dual-fuel fire-tube boiler, 500 kg/hr                | 14–16                      | IBR-certified, includes feed water treatment                  |
| <b>Twin-Shaft Shredder</b>                                     | Low-speed high-torque, hardened cutters              | 10–13                      | Includes spare cutter set                                     |
| <b>Vacuum System</b>                                           | Liquid ring vacuum pump skid, redundant              | 5–6                        | 2 x 7.5 kW with seal water recirculation                      |
| <b>Waste Handling &amp; Charging</b>                           | Bin lifter, chamber trolleys, discharge conveyor     | 6–7                        | Interlocked, contact-free charging                            |
| <b>Electrical &amp; Instrumentation</b>                        | MCC panel, SCADA, cabling, transformer               | 7–8                        | PLC/SCADA by KERONE; site electrical by client                |
| <b>Validation &amp; Monitoring Package</b>                     | Fibre-optic probes, electronic recorder, BI test kit | 3–4                        | Includes IQ/OQ/PQ documentation                               |
| <b>Civil &amp; Structural</b>                                  | Foundation, shed, utility connections                | 6–8                        | Client scope; KERONE to provide layout drawing                |
| <b>Commissioning, Training &amp; Startup</b>                   | KERONE commissioning team, 15-day site support       | 3–4                        | Includes operator training and performance validation run     |
| <b>TOTAL CAPEX</b>                                             |                                                      | <b>INR 96–114 Lakhs</b>    | <b>Approx. range; detailed quote on enquiry</b>               |

Table 11: CAPEX estimate — 750 kg/cycle twin-chamber pre-vacuum autoclave plant | All figures indicative; formal quotation on receipt of detailed enquiry

### Revenue & OPEX Model — Annual Basis (4,800 hr/yr at 80% loading)

| Item                                    | Basis                                    | INR/Year (Lakhs) | Remarks                               |
|-----------------------------------------|------------------------------------------|------------------|---------------------------------------|
| <b>REVENUE / SAVINGS</b>                |                                          |                  |                                       |
| <b>Treatment Charges Realised</b>       | 4,320 t/yr x INR 11,000/t                | INR 475          | CBWTF tariff for red/white category   |
| <b>Recovered Polymer Sales</b>          | ~648 t/yr x INR 18,000/t                 | INR 117          | Subject to recycler authorisation     |
| <b>Additional Third-Party Contracts</b> | Capacity headroom monetised              | INR 38           | Enabled by doubled throughput         |
| <b>TOTAL REVENUE / BENEFIT</b>          |                                          | <b>INR 630</b>   |                                       |
| <b>OPERATING COSTS</b>                  |                                          |                  |                                       |
| <b>Steam Fuel (Boiler)</b>              | 154 kWh-eq/t x 4,320 t/yr x INR 6/kWh-eq | INR 40           | Dual-fuel boiler; diesel/biogas blend |
| <b>Electricity</b>                      | 85 kW avg x 4,800 hr/yr x INR 8/kWh      | INR 33           | Based on INR 8/kWh industrial tariff  |
| <b>Labour (Operations)</b>              | 3 operators/shift x 2 shifts x 12 months | INR 18           | At INR 25,000/operator/month CTC      |
| <b>Maintenance &amp; Spares</b>         | 4% of CAPEX per annum                    | INR 4            | Shredder cutters, door seals, gaskets |

| Item                      | Basis                                      | INR/Year (Lakhs)  | Remarks                                                |
|---------------------------|--------------------------------------------|-------------------|--------------------------------------------------------|
| Consumables               | BI/CI test kits, boiler chemicals, filters | INR 8             | Includes validation consumables                        |
| Validation & QC Testing   | Weekly BI challenge + annual revalidation  | INR 6             | NABL-accredited laboratory                             |
| Miscellaneous & Overheads | Admin, insurance, utilities                | INR 7             |                                                        |
| TOTAL OPERATING COST      |                                            | INR 116           | Equivalent to ~INR 4.20/kg treated                     |
| NET BENEFIT BEFORE TAX    |                                            | INR ~514 Lakhs/yr | Payback ~1.8 years on INR 105L CAPEX including ramp-up |

Table 12: Revenue & OPEX model — 750 kg/cycle twin-chamber plant at 4,800 hr/yr | Indicative figures; actual returns depend on prevailing CBWTF tariff, waste mix and recycler realisation

## Cumulative Cash Flow — 5-Year Projection

| Year   | Capital Outflow    | Net Annual Benefit        | Cumulative Position |
|--------|--------------------|---------------------------|---------------------|
| Year 0 | INR -105 L (CAPEX) | —                         | INR -105 L          |
| Year 1 | —                  | INR +180 L (50% ramp)     | INR +75 L           |
| Year 2 | —                  | INR +360 L (70% loading)  | INR +435 L          |
| Year 3 | —                  | INR +514 L (full loading) | INR +949 L          |
| Year 4 | —                  | INR +514 L                | INR +1,463 L        |
| Year 5 | —                  | INR +514 L                | INR +1,977 L        |

Table 13: Cumulative cash flow — 750 kg/cycle twin-chamber autoclave plant, 5-year projection | Break-even at approximately 1.8 years including utilisation ramp

## Project Execution & KERONE Scope of Supply

### Implementation Timeline

| Phase                                           | Activity                                                                                                  | Duration            | KERONE Deliverable                                                                           |
|-------------------------------------------------|-----------------------------------------------------------------------------------------------------------|---------------------|----------------------------------------------------------------------------------------------|
| <b>Phase 0 — Pre-Order</b>                      | Technical consultation, site visit, waste characterisation, process design freeze, commercial negotiation | 3–5 Weeks           | Process Design Basis (PDB), GA drawing, utility list, commercial offer                       |
| <b>Phase 1 — Engineering</b>                    | Detailed engineering: mechanical, chamber and vacuum system design, electrical, civil layout, P&ID        | 5–7 Weeks           | Complete engineering package, vendor drawings, DFM approval                                  |
| <b>Phase 2 — Procurement</b>                    | Long-lead items: SS 316L chamber plate, boiler, vacuum pumps, shredder, hydraulic doors                   | 8–10 Weeks          | Material test certificates, QC inspection reports, FAT invitation                            |
| <b>Phase 3 — Fabrication</b>                    | Chamber fabrication, door and jacket assembly, shredder build, SCADA panel                                | 10–12 Weeks         | Factory Acceptance Test at KERONE Ambarnath; client witness invited                          |
| <b>Phase 4 — Installation</b>                   | Equipment erection at client site; steam, water, electrical and instrument hook-up                        | 3–4 Weeks           | KERONE site supervision; civil, boiler-house and electrical by client as per KERONE drawings |
| <b>Phase 5 — Commissioning &amp; Validation</b> | Cold trials, hot trials with actual waste, biological indicator challenge, IQ/OQ/PQ, operator training    | 3–4 Weeks           | Commissioning report, validation protocol and report, O&M manual, training records           |
| <b>TOTAL PROJECT TIMELINE</b>                   | <b>Order to validated commercial operation</b>                                                            | <b>~32–42 Weeks</b> | <b>From purchase order to first compliant treated batch</b>                                  |

Table 14: Implementation timeline — order to validated commercial operation

### KERONE Scope of Supply & Services

| Category                          | KERONE Scope (INCLUDED)                                                                      | Client Scope (EXCLUDED from KERONE supply)                                                        |
|-----------------------------------|----------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| <b>Process Design</b>             | Process design basis, mass and energy balance, vacuum-pulse sequencing model, P&ID           | Waste segregation discipline; plant operating schedule                                            |
| <b>Primary Equipment</b>          | Twin-chamber pre-vacuum autoclave (complete), shredder, boiler, conveyance, discharge system | Weighbridge and barcode tracking system if not included in enquiry scope                          |
| <b>Vacuum &amp; Steam Systems</b> | Vacuum pump skid, steam piping and traps within battery limits                               | Boiler-house civil structure and chimney if not in enquiry scope                                  |
| <b>Controls &amp; Validation</b>  | PLC/SCADA, MCC panel, fibre-optic probe array, all field instruments, IQ/OQ/PQ protocols     | Routine biological indicator procurement after handover; NABL testing contract                    |
| <b>Civil &amp; Structural</b>     | Foundation load drawings, GA layout, anchor bolt drawings                                    | All civil work, sheds, platforms, drains, effluent connection                                     |
| <b>Commissioning</b>              | FAT, site commissioning, performance validation run, operator training (15 days)             | Consumables (water, fuel) and waste feedstock for trials                                          |
| <b>Documentation</b>              | P&ID, GA drawings, O&M manual, spares list, validation report, test certificates             | Client-side approvals, BMW authorisation, regulatory consents, insurance, IBR boiler registration |

## Conclusions & Why KERONE

The KERONE-designed 750 kg/Cycle Twin-Chamber Pre-Vacuum Autoclave System represents a validated, commercially sound solution to a widespread limitation in India's installed biomedical waste sterilisation base. The process is built on rigorous KRDC laboratory data — not theoretical projections — and the industrial design directly replicates the exact vacuum-pulse sequence and process conditions that produced measurable, biologically certified results on the client's actual waste stream.

- **Proven Technology**

Every process parameter in the 750 kg/cycle plant — 134°C, 20-minute hold, four fractionated vacuum pulses — is directly derived from KRDC lab trial 65/KRDC/LAB/22 on the client's actual waste composite. No extrapolation; no assumptions.

- **Quantified Outcome**

A 5.4 log<sub>10</sub> reduction of *Geobacillus stearothermophilus* spores against a statutory 4 log<sub>10</sub> requirement, with 75% volume reduction, are measurable and biologically certified results — not marketing claims.

- **Commercial Clarity**

The financial model demonstrates a payback period of approximately 1.8 years at conservative CBWTF tariffs, more than doubling effective treatment capacity within the same shed footprint.

- **Compliance by Design**

HEPA-filtered venting, fractionated vacuum air removal, electronic cycle records with five-year retention and integral shredding are built into the KERONE supply scope — the system is designed to BWWM Rules 2016, ISO 17665 and CPCB CBWTF guidelines, not retrofitted for compliance after the fact.

- **Validation Support**

KERONE supplies complete IQ/OQ/PQ protocols, biological indicator challenge procedures and the documentation package required for SPCB authorisation and periodic revalidation — an area where most autoclave suppliers leave the client unsupported.

- **Full Ownership**

KERONE designs, manufactures, supplies, installs, commissions and validates the complete plant from a single point of accountability — eliminating multi-vendor coordination risk between chamber, boiler and shredder suppliers.

- **Scalable Platform**

The pre-vacuum autoclave platform is scalable. A 750 kg/cycle twin-chamber system creates the reference installation for single-chamber 250 and 500 kg/cycle systems and larger multi-chamber 1,500 kg/cycle systems serving CBWTF operators and hospital groups across India and internationally.

### ENQUIRE ABOUT YOUR MEDICAL WASTE TREATMENT PROJECT

KERONE Engineering Solutions Limited | KRDC — Kerone Research & Development Centre

B/47 Addl. MIDC, Anand Nagar, Ambarnath (East), Thane - 421 506, Maharashtra, India

Tel: +91-251-2620542 / 13 / 44 / 45 / 46 | Email: [info@kerone.com](mailto:info@kerone.com) | Web: [www.kerone.com](http://www.kerone.com)

*To initiate a project discussion, please share: waste category mix + daily tonnage + site location + required treatment standard*

ISO 9001:2015 | ISO 14001:2015 | ISO 45001:2018 | CRISIL Rated Company | AIMCAL Member | IHEA Member | EMItech Certified | 50+ Years of Engineering Excellence

DISCLAIMER: All financial projections are indicative and based on prevailing market conditions as of July 2026. Process performance figures are derived from KRDC laboratory data (Report 65/KRDC/LAB/22) conducted on MediClean Waste Management Pvt. Ltd. feedstock. Actual industrial performance may vary with waste composition, moisture and packing density. Statutory compliance remains subject to the applicable State Pollution Control Board authorisation and IBR boiler registration. This document is intended for discussion purposes; a formal quotation will be issued following detailed enquiry.