# Disaster Debris Management in Post-tsunami Situation in Sri Lanka

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## Executive Summery of Literature Review

by

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# Introduction

## Background

26th December 2004, longest day in the Sri Lankan history where thousands of people died, many thousands made homeless and million worth personal and public assets ruined with in just two hours, when tsunami hit Sri Lankan coastal areas in more than three quarter of its span. This devastating disaster forced to the all the experts in the country and the experts interested on the development of the countries in the Asian region to rethink about the different aspects of people centred urban development activities and many successful interventions are being carried out.

Intermediate Technology Development Group (ITDG Sri Lanka) also puts their attention on this and many of their interventions also diverted to the post tsunami reconstruction and rebuilding activities. Integrated Urban Development Project of ITDG South Asia identified the lack of information and practices currently familiar to the Sri Lankan context and observed the consequences of it, since the huge amount of debris accumulated in the coastal area has been interfered the post disaster relief activities and rebuilding process. Situation becoming worst since the country does not hold a proper mechanism even to dispose solid waste. Therefore, IUD of ITDG has identified the importance of collecting, compiling and presenting of information on disaster debris management and facilitates the relevant responsibilities to develop disaster debris management guidelines to use in an emergency.

This paper is fabricated by collecting information from the experiences of foreign countries down loaded from the Web and the experts' ideas.

## Characteristics of Disaster Debris

Many researchers in different parts of the world have shown their interest on disaster debris management since the debris resulting from a disaster may high as the amount of solid waste accumulated in an area in dozens of years. But the characteristics and the quantity of debris may change with the size & type of the disaster and topography of the area etc.

According to the report prepared by the Gabriela Y. Solis et al (1995); three types of debris are associated with a disaster:

1. Debris generated directly by the disaster, e.g., rubble, roofing, and insulation.
2. Debris generated indirectly by the disaster, e.g., spoiled food due to power failure or excessive donations.
3. Debris generated by abnormal patterns of life, e.g., greatly increased consumption of bottled water and canned food.

Following table will summarize the major debris categories that can be resulted from different types of disasters. It is important to note that the total debris management approach is highly influenced by the debris type.

Table: 1. Major Debris Categories by Disaster Type

| Disaster Type | Damaged Buildings | Sediments | Green Waste | Personal Property | Ash and Charred Wood |
|---|---|---|---|---|---|
| Hurricane | √ | √ | √ | √ | |
| Earthquake | √ | √ | √ | √ | √ |
| Flood | √ | √ | √ | √ | |
| Fire | √ | | | √ | √ |
| Tsunami | √ | √ | √ | √ | |
| Tornado | √ | | √ | √ | |

Examples of debris that might be generated by a disaster include the following:

### A. Debris Subject to Putrefaction

- Animal corpses: Cattle, pets and wild animals
- Food remnants: Meal leftovers or food spoiled as a result of power failure

## B. Vegetation

- Leaves
- Branches
- Uprooted shrubs and trees

## C. Inert Environmental Debris

- Dirt
- Mud
- Rocks
- Sand

## D. Construction Debris

- Acrylic
- Asphalt
- Blinds
- Brick
- Carpet
- Concrete
- Drywall
- Electrical wires, lamps, bulbs
- Glass and mirror
- Insulation materials (fibreglass, Styrofoam, etc.)
- Masonry
- Metals (steel, iron, aluminium, copper, brass, etc.):
- Tiles
- Pipes
- Plastic
- Rubble
- Vinyl
- Wood

## E. Appliances, Household Equipment and Furniture

- Beds and mattresses
- Upholstered furniture
- Computer equipment, telephones, typewriters
- Desks, chairs, chests
- Lamps
- Sofas
- Washing and drying machines, refrigerators, dishwashers, stoves, hot water tanks, furnaces

## F. Personal Items and Objects

- Art work
- Books and papers
- Clothing
- Cooking utensils, china, glassware

## G. Hazardous Wastes

- Asbestos
- Biomedical wastes
- Cleaning agents
- Combustibles
- Explosives
- Fertilizers
- Oils
- Paints
- Pesticides
- Radioactive substances
- Solvents
- Other toxic substances or materials

Gabriela Y. Solis has further shown Debris and Risk Estimate methods to be used in an emergency. According to her report, reasonable estimates of the amount of debris by type will improve the overall clearance efficiency, for example:

- Define resource needs
- Adequate resource allocation
- Evaluate disposal capacity of existing sites
- Estimate hauling time

The level and variety of methods and technologies required to estimate the amount of debris generated will depend on the type, magnitude and extent of the disaster, for example:

1. Visual Inspection:
   - Terrestrial: vehicular and pedestrian
   - Aerial: aircraft and helicopters
2. Photography:
   - Common
   - Aerial: aircraft and helicopters with photo/video capability
   - Satellite

It is very important to estimate the amount of debris as precise as much and come to a numerical value to develop well planned debris management system rather going for general terms such as "a lot of rubble" which is not support for the decision makers.

Federal Emergency Management Agency (FEMA) has also conducted many works on emergency debris management and pointed out the importance of development and implementation of Debris Removal and Disposal Operations Plan if the disaster debris is a significant component of a disaster.

According to the FEMA the basic information required for this plan includes:

1. The quantity, type and location of debris.
2. Management responsibility (local governments, state agencies,)

FEMA has also proposed many methods to estimate the quantity of debris generated from a disaster. The following paragraphs will be presented from quoted facts from the FEMA findings.

General: Initial quantity estimates are difficult to make, due to a number of factors:

- The type, Magnitude, and geographical location of the disaster
- Geographical extent of the debris
- The types and mix of debris
- And the sometimes difficulties in gaining access to the affected areas.

It is important, however, to make as accurate an estimate as possible, and refine that estimate as work continues. Become familiar with the general results of various types of disasters. Hurricanes and tornadoes can produce large quantities of yard waste and construction materials scattered over a large area. Floods create large amounts of debris that may be buried in silt. In the process of estimating the debris amount it is vital to ensure that necessary equipment is available, including:

- Digital (preferred) or Polaroid camera
- 100 foot tape or roll-off wheel
- Calculator, notepad, sketchpad
- Maps of area
- Aerial photographs (preferably before and after the disaster)
- Dedicated vehicle and mobile communications

## Following Reminders made by FEMA to improve the accuracy of Debris estimation:

The following reminders may be of assistance when performing debris estimates:

- Look beyond the curb into side and backyards and at the condition of the homes. Most of the debris in these areas will eventually move to the curb.
- Wet storms will produce more personal property (household furnishings, clothing, rugs, etc.) debris if roofs are blown away.
- Look for hanging debris such as broken limbs after a storm.
- Flood-deposited sediment may be compacted in place. Volume may increase as debris is picked up and moved.
- Using aerial photographs in combination with ground measurements will help determine if there are any voids in the middle of large debris piles.

- Treat debris piles as a cube, not a cone, when performing estimates.

Pre-planning for a disaster will greatly increase control of debris management and reduce costs. A good disaster recovery management plan will take an interagency approach to plan development. A few of the items a plan should address are:

- Identification of potential equipment needs and suppliers,
- Identification of collection and storage sites, and
- Segregation of hazardous materials etc.

## Debris Management

Debris management deals with debris collection, transportation, and disposal. It must take into account the special treatment of hazardous waste, as well as the environmental implications related to debris management.

### Access to Debris

Debris salvage may interfere with the overall debris clearance. Affected individuals may claim their right to recover their possessions, to retrieve documents and inventories, or to salvage building materials and appliances. Contractors may demand right-of-way and space for debris collection. A planning strategy is required to provide a framework for all of those likely to be involved.

An access-to-debris policy should specify procedures to:

- Priorities and define management responsibilities, e.g. Local government, central government etc.
- Priorities debris access, e.g., owners first, contractors second, pickers third.
- Identify debris ownership, e.g., witnesses, identifications.

### Collection

The identification of a debris collection method will depend on the following criteria:

- Amount of debris generated
- Type of debris
- Urgency of site clearance
- Disaster site characteristics
- Debris recycling possibilities
- Geographic complications

Debris collection tools and equipment are mainly for collecting, segmenting, and lifting. The same equipment is used by the construction and heavy-duty industry, e.g. bulldozers, front-end loaders, cables, cranes, cutting torches, hand tools (shovels, picks, hammers, handcarts, etc.), mechanical shovels, saws, and vacuum equipment can be used in debris collection operations. With the Sri Lankan experiences of post tsunami debris cleaning, community participation is highly helpful for manual separation, allowing to continue appropriate management practices and obtain as much as usages from the debris. When heavy vehicles (front end loaders etc.) are used all type of waste get mixed and making it difficult to separate.

Hence, it is important to priorities the collection activities as hazardous materials to be collected at first, organic and perishable wastes second and rubble third. Sufficient attention should be paid on protective clothing and equipment for workers before starting the ground implementation.

## Transportation

The efficiency of debris transportation will depend on the hauling time, i.e., time expended to travel between the debris clearance areas and the disposal sites.

Following strategies are possible to improve the transport efficiency just after the disaster.

- Establish a transportation network with well-defined uses. Classify roads according to their:
  - Use (general public, debris transportation) o Vehicle Speed (emergency vehicles)
  - Destination Linkage (highways, disposal sites)
- Vehicles used in the transportation of debris (government, contractors, volunteers and others) could be identified by an easily identifiable permit to ensure unimpeded access to disaster areas.
- Debris is accumulated at temporary accumulation sites.
- Debris volume is reduced before hauling.
- Multiple disposal sites are established.
- Volunteers and the general public are separated from contractors at disposal sites.
- Access to disposal sites is restricted and controlled.
- Small vehicles may be needed where access is limited.
- Maps showing designated zones, contractors, debris concentration points and other relevant information are published through the media ('recovery information' newsletter).

## Temporary Accumulation

In a disaster situation the establishment of temporary debris accumulation sites may be required. This could be due to significant problems such as: disposal site congestion; excessive queuing at permanent disposal sites, and insufficient collection and/or transportation equipment or sudden need of disposal site until decide about the different management practices. The use of temporary accumulation sites substantially increases the overall debris clearance costs, since debris is essentially managed twice, i.e. from the generation point to the temporary accumulation site and from there to final disposal. Strategies to reduce the costs might involve the location of temporary accumulation sites:

- On or near primary roads, with in-out access, manoeuvring space, and where obstructions are not likely to occur.
- In areas not affecting other response activities, e.g., avoid garbage near temporary accommodation
- In places not to be used by any other disaster response component, such as tent shelters, ambulatory hospital, etc.

## Disposal

Debris disposal could be one of the major challenges of the overall debris management during a disaster, not only because the volumes generated could be overwhelming, but also due to potential hazards to the environment. In major disasters total clearance may take months or years.

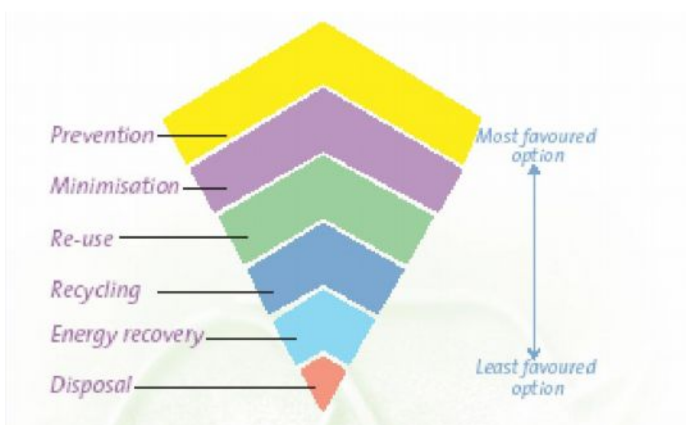
Some strategies that could be used when faced with debris disposal problems include:

a. Increase number of disposal sites, e.g., gullies, natural or artificial cavities, etc.

b. Increase disposal methods, e.g., incineration, land filling, etc.

c. Reduce debris volume, e.g., reusing, recycling, grinding, chipping, crushing, granulating, mulching, etc.

Even it is difficult to apply waste hierarchy for debris management in an emergency situation some of its concepts still valid in managing disaster debris. Mainly the re-use, recycling, energy recovery options are appropriate before thinking to dispose the waste.




Source: Construction Industry Federation

## Hazardous Wastes

Hazardous substances may be released in an area affected by a disaster. Examples are retail supplies of fuels, pesticides, paints and solvents, cleaning materials and dry cleaning solvents. Bio-medical wastes are also possible.

College and university science and engineering labs, and similar labs in secondary schools, have a variety of dangerous materials that may be released or spilled in a disaster. Managing hazardous wastes requires prompt action in identifying:

- Sources of hazardous substances
- Potential risks
- Isolation measures
- Handling and disposal requirements

**Following table emphasis the common techniques practiced internationally to identify hazardous materials**.

| Material | Testing Technique |
|---|---|
| Asbestos | Visual inspection by a consultant trained and experienced in asbestos abatement |
| Lead-based Paints | An experienced consultant may use a portable X-ray fluorescence detectors may be used for detection at the site by or samples may be sent to a laboratory for analysis. |
| Polychlorinated Biphenyls (PCBs) | Field screening kits are available for initial assessment, laboratory analysis is the only way to verify the presence of PCBs |
| Chemical and Petroleum Wastes | Inspection and characterization of containers, tanks, and vessels containing chemical products. Laboratory analysis will be required where labels are missing |
| Mercury | Visual inspection after removing switch and equipment covers |
| Building Materials | Sampling and laboratory testing of flooring materials in high risk areas (plating rooms, hydraulic equipment, etc.) |

Table 2 : Hazardous Material Testing Techniques (Burgess and Giroux, 1997)

### Environmental Concerns

Relevant authorities (CEA, Ministry of Environmental) should take leading role in the disaster debris management and should provide the temporary accumulation sites and disposal sites to facilitate the entire debris management operations. But the attention should pay in planning to concern to relax the normal environmental codes, practices, and regulations which may be facilitated the removal of debris. Health and safety should be paramount where any flexibility of regulations is exercised.

## Recycling options

The major concerns on debris recycling are on two aspects;

- Maximize resource recovery
- Minimize environmental impacts.

These two aspects have inverse relationship where, maximizing the resource recovery minimizes the environmental impacts.

## Re-use and Recycling

A decrease in disaster debris management costs could be achieved by increasing re-use and recycling efforts. On the other hand it will be an appropriate solution for the shortage of construction raw materials in the rebuilding process after a disaster. Rebuilding process of the country currently is being suffered from huge shortage of building materials especially fine and coarse aggregates for cement blocks, concrete and masonry. Re-use and recycling are already becoming a priority for many other countries as a tool to address the rising costs and environmental impact of construction and demolition waste disposal. Re-use and recycling are very complex issues and cannot be relied on as the sole means of addressing a disaster debris problem; however, they can reduce adverse impacts by diverting significant portions of debris away from more expensive disposal options.

There are many researches have been conducted on construction and demolition waste management in the world, since the C & D waste is a significant issue in many parts of the world. Reuse and recycling is the major concerns of C & D waste management in those regions. Scientists have proved the effectiveness of same technologies to be used to reduce the amount of disaster debris also.

Re-use of materials on site is one of major important opportunities for waste reduction. For example, leftover masonry materials can be crushed on site and used for fill or as bedding material for driveways. Re-use of materials through salvage is also available.

Recycling materials by processing them for new uses is being done elsewhere in the many parts of the world. The processing of source-separated C&D debris can usually be accomplished at a lower capital cost and with a greater recovery rate than the processing of commingled materials. In the case of both C & D waste as well as disaster debris, the prime importance is the need to minimize contaminants, which will affect the marketability of the material.

Building residues after a disaster, such as mortars, concrete, bricks, tiles and soil fraction from excavations are considered as components of the “inert” fraction of the composition. The unusable proportion of the debris which should be diverted to disposal sites is called Garbage. After the sorting process, some materials can be commercialised, as is the case with glass, the metal scrap, papers and cardboards, and plastics. These reusable materials are forwarded for reusing or recycling outside of the Selection and Transfer Area. Plastic is sold massively to recycling firms. Metal scraps are sold to companies that later forward them to metallurgical industry. Papers and cardboards sorted out in the affected area are sold to scrap sellers, who resell them to the paper and cellulose industry. Glass sold to recycling companies.

Once all reusable forms of materials have been separated, then have to think about the largest category of disaster debris that is building waste (i.e. Concrete and masonry). Recently, scientists tried to fabricate aggregates at different diameters by using disaster debris, especially using concrete and masonry waste. The studies concluded many important findings, while proving the effectiveness of aggregates to use in non-structural concretes.

Inert

garbage

Once all reusable forms of materials have been separated, then have to think about the largest category of disaster debris that is building waste (i.e. Concrete and masonry). Recently, scientists tried to fabricate aggregates at different diameters by using disaster debris, especially using concrete and masonry waste. The studies concluded many important findings, while proving the effectiveness of aggregates to use in non-structural concretes.

Normal gravel crushers can be used to crush the inert and obtain the aggregates.

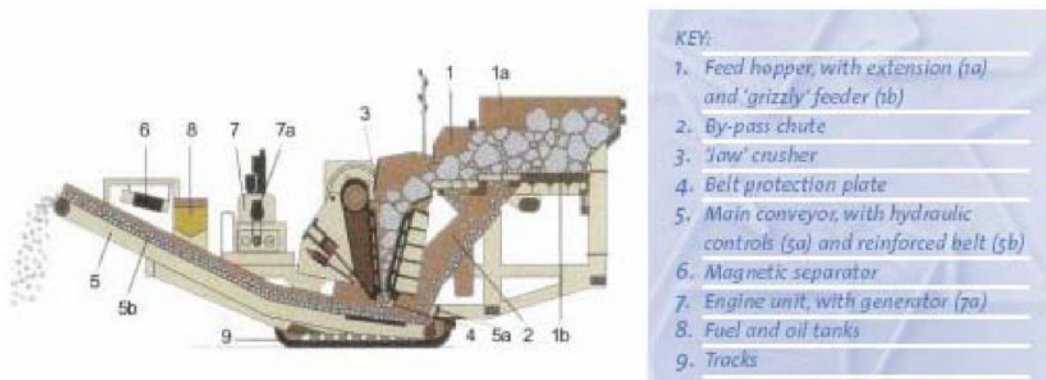



Figure: Cross sectional view of a Jaw Crusher

Source: Construction Industry Federation

Crushing Machine

Caterpillar and sieves system

Material processed in this system has been presenting regular granulometry, which allows its use as coarse and fine aggregate in the production of non-structural concrete and mortars. Residue from the crushing process is being employed as sub base material used in the paving of streets and roads.

Coarse aggregates

Fine aggregates

Residues from trammel

There are number of studies have been conducted around the world on the use of aggregates on construction industry. Suárez C.J. and Malavé R.E., (School of Civil Engineering, Central-Western University "Lisandro Alvarado"), in Venezuela have also conducted many researches on recycling and reusing of construction and demolition debris. Their finings are very important in the disaster debris management since the main concerns of their researches are on concrete and masonry reuse, which is a significant portion in the disaster debris too.

According to the Suarez and Malave's study "WAYS OF PROCESSING C&D WASTE AND COST OF RECYCLED AGGREGATES", they have shown the use of aggregates in different purposes. The two Venezuelan scientists recommended two processing methods to obtain aggregates from the concrete and masonry debris.

## 1. Industrialized processes

- Dry process: standard crushing and sieving plant for aggregate production
- Wet process: standard crushing and sieving plant with washing equipment for aggregate production

## 2. Manual process

- Manual sieving of masonry construction waste at job site
- Cost of recycled aggregates
- Aprox. 35% less than natural or virgin aggregate

Following table is presenting the some uses of aggregates that fabricated by using above methods.

Table 03: Possible uses of Aggregate from recycled concrete & Masonry

| No | Aggregate types | Usage |
|---|---|---|
| 01 | Coarse aggregate (14mm - 30 mm) | low-strength concrete |
| 02 | Gravel (6 mm - 12 mm) | low-strength concrete and concrete blocks |
| 03 | Fine aggregate (less than 6 mm) | low-strength concrete and concrete blocks |
| 04 | Coarse sand (less than 4 mm) | masonry works |
| 05 | Fine sand (less than 2 mm) | finishing stucco works |

Suárez CJ. and Malavé R.E. have further researched on the effective ratios for different mixes for concrete and mortar production and possible usages of the low strength concretes & mortar mixes produced by using recycled aggregates.

### Examples of different mixes

**In masonry operations** (block laying and rough stucco work):

- 1 vol of cement
- 3 vol of coarse sand (less than 4 mm)

**In finishing stucco operations:**

- 1 vol of cement
- 1 vol of lime
- 6 vol of fine sand (less than 2 mm)

**In concrete block production**:

- 1 vol of cement
- 10 vol of fine aggregates (less than 6 mm)

**Alternative mix in concrete block production:**

- 1 vol of cement
- 7 vol of fine aggregate
- 3 vol of gravel

### Suggested applications for Low strength concrete applications

Design mixes tested: 15 – 18 MPa

- Floor levelling for finishing operations
- Sidewalks
- Gutters
- Concrete and plastic tube protection
- Concrete furnishing in kitchens, bathrooms, closets, and outdoor equipment
- Non-structural building members

## Final Disposal of Disaster Debris

It is obvious that, even the resource recovery effort has being maximized still we get large amount of garbage, which cannot be eliminate from above methods that should divert in to final disposal. The material can be used for filling/ leveling of low lying areas (Land filling). However, the site should be selected carefully to minimize the environmental impacts. In the industrialised countries, special landfills are sometimes created for inert waste, which are normally located in abandoned mines and quarries, which also can be used in emergencies.

It is important to note that the following places should avoid when selecting disposal sites.

- Marshy lands
- Water bodies
- Beach side
- Any other location with possibility to contaminate ground water or increase environmental pollution

However, proper sampling of the material for its physical and chemical characteristics has to be done for evaluating its impact on the environment

## Sri Lankan Experience on Debris Management

Few INGOs with the participation of Government agencies and local NGOs are currently working on the Debris clearing in the southern coastal area. It is important to note that due to lack of guidelines or information on disaster debris management the current practices may create more problems in the future. Poor source separation and the careless handling of the debris may cause to contaminate the whole piles of debris and make difficulties to effectively dispose.

An INGO is implementing community participated debris cleaning program with the participation of a local NGO, which also seems to be suffered from the lack of awareness and information to properly handle the large amount of debris.

All these cases should take into the proper considerations and develop guidelines to effective debris management practices to be implemented.


Manual sorting

Used machineries in collection

## Guidelines to disaster debris management

- Maximize the resource recovery
- Careful handling of hazardous waste. Do it as the first step
- Organic and degradable waste should handle second
- Other materials should handled finally
- Planned demolition should be implemented for partially damaged buildings to recover materials as much as possible
- Sorting of materials is vital in the process of resource recovery
- Proper sites for disposal should be identified
- Dealers involved in recycling of plastics, glasses, paper and metal should be identified
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