PLASTIC WASTE INSULATION FOR HIGH ALTITUDE AREAS

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Abstract – The increasing amount of plastic waste (PET bottles, packaging material and shopping bags) in remote mountain areas is having a negative environmental impact. Littered about, it is an eyesore and usually disposed of by burying or burning. At the same time, there is a need for thermal insulation material in building constructions and the cost of imported insulation material is high. The re-utilisation (recycling) of "clean" plastic waste as high grade thermal insulation for buildings and installations is an economical option. This paper provides examples for its use in cavity walls and ceilings.

Key Words: Plastic waste, PET bottles, re-utilisation and recycling, thermal insulation for buildings.

1. INTRODUCTION

Thermal insulation is very important in high altitude areas where the cold climate increases heating requirements. Improved insulation of houses results in better comfort and a reduction in firewood consumption. Importing insulation material in (remote) mountain areas is expensive, whereas plastic waste (PET bottles, packaging material and shopping bags) is in abundance. Such plastic waste materials can be reutilised to thermally insulate houses by placing it under the roof, under the foundation and inside cavity walls.

About 2 million Nepalese, or more than 300,000 families, live in high mountain areas (over 2000m) and are annually influenced by the winter cold, being severe at the very high altitudes (over 3000m). This population is highly dependent on firewood for its energy needs (cooking, warm water and space heating). About 3-4 tons of firewood is consumed per family per year, an amount that annually is becoming more difficult and costly to collect due to the continuous deforestation. Per family more than a full month of hard labour is required to collect the firewood from the hills.

Many Nepalese in high altitude areas live in remote to very remote areas, meaning that it requires several days' walking to reach the villages. The direct effect is that all goods being brought from the lower regions to the remote villages become very expensive in either labour (walking/carrying) or purchase costs. An indirect effect is that all packaging and containers of food items brought into the area eventually end up as waste and are either buried, burned or thrown haphazardly away, polluting the hillsides.

Especially in trekking areas where large amounts of food items and plastic drink bottles are imported, these waste materials can be seen littered about. It is becoming an eyesore and having a negative environmental impact on the area if not collected and properly disposed of by the local organisations. In the two most popular trekking regions, Annapurna Conservation Area and the Sagarmatha Conservation Area, local organisations are involved in organising the local population in waste collection.

This paper explains how plastic waste can serve perfectly as thermal insulation in housing. Especially for applications that are not exposed to the direct sunlight, the waste material can be reutilised as a very durable insulator solving five issues at the same time. (1) Getting rid of plastic waste; (2) Thermally insulating houses and installations; (3) No importation and transportation of expensive insulation materials; (4) Reducing firewood consumption because of increased thermal comfort; and (5) No burning.

- **Housing.** Thermal insulation of a house or hotel will substantially increase the comfort level during winter and at the same time considerably reduce firewood consumption for space heating. It saves energy by maintaining the warmth inside the rooms so that constantly maintaining the (wood burning) fire becomes unnecessary. The most effective methods are insulation of the ceiling and under the roof.
- **Outside Water Installations.** Solar Water Heaters (SWHs) are very effective in high altitudes for warming shower water and pre-warming kitchen water. The piping system between the SWH collector and the tap point needs to be well insulated. If not, the water will cool down between these two points and the efficiency of the system will be considerably reduced. Plastic waste can be used for this insulation, covered with (thin) HDPE pipes having a large diameter (minimal 3").
- **No more burning.** Burying and burning are two practices being used to get rid of waste material. In very large cities facilities often exist to recycle most types of plastic. In Nepal this is currently rather limited and the cost of transporting plastic waste from the mountain areas back to Kathmandu for any recycling is prohibitive. In remote areas the plastics can be easily recycled (reused) as thermal insulation and become a valuable resource.

2. PLASTIC WASTE USUABLE FOR INSULATION

Two main forms of plastic waste are commonly present, plastic bottles and foil-type plastics, such as grocery bags and large fibre bags. Bottles without residues can be used directly as insulation material because they contain air. It is the air that provides the insulation.

PET bottles. The transparent polyethylene terephthalate (PET) bottles have become increasingly common and are used for mineral water, soda waters and soft drinks. In some areas (Khumbu) empty bottles are imported and bottled with clean spring water. Most containers are glossy clear transparent, while some are green in colour. In some high mountain areas importing these bottles is now being prohibited due to their pollutant aspects. With a collection system, prohibition is unnecessary.

HDPE bottles and containers. Many non-transparent liquid containers (juices, bleach) are made from high-density polyethylene (HDPE), being the most common plastic in consumer products. These bottles and containers are white or dyed in various colours. HDPE plastic water, gas and sewerage pipes are black, often already made from recycled HDPE plastic bottles.

LDPE bags and wrappers. Plastic grocery bags are often made from low-density polyethylene (LPDE). LPDE is also found in cellophane, cookie wrappers, noodle packages, etc. Polyethylene plastic has a density of 0.91-0.96 kg/dm^3 and will float in water. Although the plastic does not emit poisonous gasses when burned, it is better to use the plastic as an insulator. When it is to be used for thermal insulation, it must first be washed, sun-dried and crumpled up for packing between the plastic bottles.

PVC foil and bottles. Polyvinyl chloride is semi-rigid and glossy. It is used in bottles (shampoo and soap) and in transparent foils used for a wide variety of purposes. PVC transparent foils come in a variety of thickness (0.08mm = 200 gauge) but are not resistant to long-term exposure to UV light, being of high strength at high altitudes. Incinerating PVC causes poisonous gasses to be released into the atmosphere. The PVC plastic has a density of 1.2-1.55 kg/dm^3 and therefore sinks in water. This aspect can be used in both cleaning and separating the PVC from other plastics. PVC is excellent for use in thermal insulation, but it should be kept out of the sunlight.

PP bottle tops and containers. Polypropylene (PP) is mainly a semi-rigid plastic material with a low gloss, used for screw-on plastic bottle lids. Therefore it is only found in smaller quantities. PP is also used in automotive battery cases and PV deep cycle battery cases. The battery cases, if available in quantity and cleaned out (no acids or lead should remain), can be used under load bearing floors. The PP bottle tops can be kept on the PET, HDPE and PVC bottles to make them airtight and better insulators.

PP fibre bags and rope. Thin, narrow PP foil can be stretched to about two times it original length, until a resistant point is reached. Transport bags made from woven stretched PP fibre are used for cement, rice, grains and a variety of other agricultural products. The bags (called *bora*) are often reutilised for transporting goods on donkeys or yak and for transporting sand and gravel. After exposure to the sun for several months, the bags fall apart and become wastage. From the same fibre with added colour pigments rope is made, giving it an improved resistance against UV light. The bags, when in one piece, can be used for stuffing other plastic waste inside. However, the stuffed bags should not be placed in the sunlight, but used only in ceilings or cavity walls.

EPS or Styrofoam. Expanded polystyrene (EPS) is a very lightweight insulation material made up of large white granular beads. It is commonly used inside cardboard packaging to protect electrical/electronic equipment, for food packaging and cooled products. Sheets of EPS are also used in the building industry. EPS comes in several densities. The insulation value is very high (0.02 W/m.K) and water absorption is low. Shredded, it can be stuffed in bags.

EPP. Expanded polypropylene (EPP) is rather similar to EPS, but often comes in black material where the expanded beads have a higher density and strength than EPS. The material is even less water absorbing under continuous pressure than EPS and is used in shock absorbing materials, such as transport crates and lightweight safety helmets. Under-carpets, insulation blankets and camping mats are made from EPP foam, sometimes called PP foam. These sheets are 5-12mm thick.

2.1 Cloth and Rubber Waste

Especially in the trekking areas large quantities of cloth waste is produced and can be collected. Cloth waste often consists of PP fibre bags which were used for packing and transporting. Once the bags are ripped open, they often have little other use and become wastage. Other waste cloth consists of tarpaulin after it become porous and ripped. Garments may be minimal in quantity and very soiled. The most important issue is that the waste cloth material should not be biodegradable. Biodegradable materials (cotton, wool, leather, etc.) will first absorb moisture, grow fungi, get consumed by micro organisms, disintegrate and eventually lose their insulating effect.

PU foam. Polyurethane foam (PU) is commonly used for bedding mattresses and pillows. Although non-biodegradable, it is moisture absorbing. Discarded mattresses can be shredded and used as insulation material. Due to its water absorbing capacity, they should placed only above ceilings or under roof constructions.

Rubber goods. All types of rubber (boots, shoe soles, tents, water containers, etc.) do not absorb water. Therefore when put into bags, they can be used for insulation under floors. Moreover, burning rubber is not advised as it produces poisonous gasses. Large pieces should be shredded, but the foam rubber flip-flops (*chappal*) may be kept aside. Flip-flops can best be cut into squares (1" x 1") and used as washers for fixing corrugated GI roof sheets.

Fleece and nylons. In high altitudes fleece jackets have become a common clothing item for many people. When not reused as second-hand clothing, it can be shredded and used as thermal insulation material in ceilings and roofs. Several types of thermal insulation jackets have non-degradable filling, such as hollow-fibre, spun nylon, PU foam, etc. These fillings can also be used as thermal insulation. Soiled human clothing should not be used. If soiled garments are burned, it is recommended to use high burning temperatures to minimise poisonous gas emissions.

2.2 Useable and Non-useable Material for Thermal Insulation

In principle, all non-conductive materials that (in packed form) contain lots of air can be used for thermal insulation. However, for use inside foundations and cavity walls, they should be non-biodegradable and non-water absorbing. For use indoors in ceilings, the insulation material should be reasonably clean. Plastic waste can be easily washed and sun-dried to this effect. Bottles should be well drained after washing. Washing water should be discarded in a soak pit well away from flowing water or water sources. The following chart lists some materials that can be used or should not be used.

Can be used under ground floors, inside external cavity walls and for SWHs	Can be used in ceilings and under dry roofs of houses, provided it is reasonably clean and completely dry	Cannot be used for thermal insulation because it is biodegradable or has high thermal conductivity
Plastic bottles (empty/closed).	Plastic bottles (empty).	Metal cans and containers.
Plastic foil, bags (crumpled).	Plastic foil, bags (crumpled).	Aluminium cans, containers.
Plastic foam, PP, EPS (waterproof and shredded).	Plastic foam, PP, EPS (waterproof and shredded).	Hard and brittle PVC (as this may cut the container bags).
Rubber goods (shredded).	Rubber goods (shredded).	Glass bottles, (any size).
Cleaned battery containers (floors).	PU foam mattresses (shredded).	Earthenware.
	Fleece and nylon (shredded).	Cotton or wool, hair.
Wax paper, cookie bags, chip bags, bubble plastic, candy wrappers, shopping bags.	Glass wool, rock wool.	Paper or cardboard waste. Dirty or soiled materials. Leather, animal skin.

Note: Glass wool is made of spun glass and is an excellent insulator. It is commonly used in SWH and boiler storage tanks. However, the material compacts under pressure and can fill up with water, both negative aspects for outside use. Rock wool is rather similar to glass wool and is made of spun refractory material (stone).

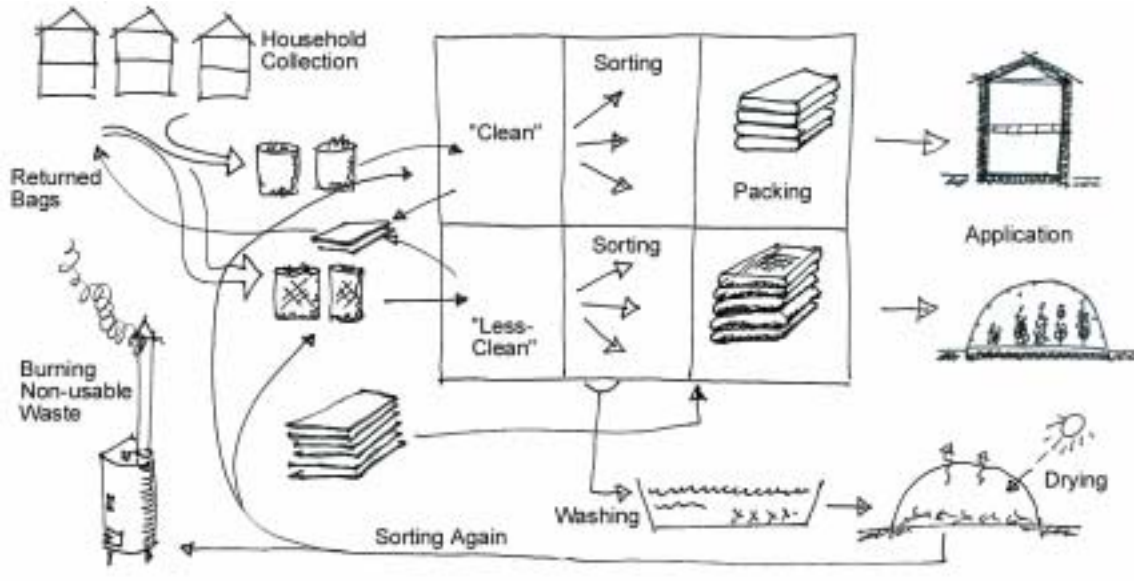
3. MAKING PLASTIC INSULATION

3.1 Types of Plastic Insulation

- **For use under floors and inside cavity walls.** The insulation material does not have to be very clean and can be used in cavity walls or under cement floors of a house. Collecting the material and stuffing the plastic (PET and HDPE) bottles and waste from plastic grocery bags (crumpled) into larger bags will be adequate.

- **For use inside the roofs of houses.** The insulation material needs to be reasonably clean from fats, proteins, liquids and sugars because these ingredients may attract either insects or cause smells when becoming very hot (under the roof). The best method is to make first a visual selection and then wash those materials that are not very clean but are still useful as insulation material. After washing these can be sun dried and stuffed into the bags.

For both types, a waste material collection system is required. In order to accumulate adequate quantities, all villagers must be active in the collection and stuffing of the waste material into larger plastic or PP fibre bags (*bora)*. When possible the caps of the PET and HDPE bottles should remain tightly screwed on.



3.2 Organisation of Collection

The collection and reprocessing of the plastic waste needs to be centrally organised. By asking a small price for the sorted and repacked insulation material, a substantial part or all of the collection and processing costs can be recovered.

A. The village collection committee can supply the large PP bags. Clean (new or white, non-printed) bags can be used for really "clean" material, such as PET water bottles with caps, washed HDPE bottles and clean grocery bags; while yellow or printed *bora* can be used for "less-clean" plastic waste material. The bags are available in large quantities in the bigger towns.

B. Each household can have one or two (free) bags (one for "clean" and one for "less-clean"), depending on the expected amount of waste, the planned use of the insulation material and the level of participation of the villagers.

C. Each participating household should attend a briefing and demonstration on what materials can be collected in the bags and what should not. The demonstration needs to show how the bags are filled so that the PET bottles are not crushed and the bags are well utilised. The demonstration can be supported with a small leaflet explaining the most important points.

D. Villagers who bring in a full bag should have their bag emptied immediately in a depot (one depot for "clean", one depot for "less-clean"). This allows an on-the-spot inspection of the quality of the material and the collector can provide immediate feedback to the villager and payment.

E. It should be possible for villagers to buy the PP packing bags if they want to collect the insulation materials for their own use in construction. Prices should be fixed for empty bags.

F. The villager should be paid a certain amount for the supply, depending on the volume. It is the total volume that provides the insulation, not the weight. This payment should provide the villager with sufficient incentive to continue the collection and at the same time keep the environment clean from plastic waste.

G. A filled *bora* is 45cm wide x 75cm long (1½ ft. x 2½ ft.) = 1/3m^2. When this bag is filled to 12.5cm (5") thick, it contains about 40 litres and has an insulation value comparable to 8cm glass wool. The value of 8cm glass wool in the city is NRs 200/m^2. The cost in Kathmandu of 1/3m^2 x 8cm glass wool would be about NRs 65. With a second-hand bag costing NRs 5, another NRs 10 can be paid for the "less-clean" content and NRs 15 for "clean" plastic content. The resale value can be NRs 20 and NRs 25 respectively, still being one-third the cost of the glass wool for the same insulation value.

H. The collection centre should fill the bags according to demand and use. The "clean" material can be packed immediately into insulation bags. The thickness of the bags can be about 7.5-8cm or 12-15cm, being thicker than the common PET bottle. Special large bags can be sewn from larger sheets of PP cloth, or larger bags can be made from sewing different smaller bags together.

I. The bags are sewn closed with PP rope and marked. Equally, the “less-clean” materials can be collected and marked differently and stacked for resale. Hard or sharp plastic articles need to be removed from the stock.

J. Plastic waste material not adequately clean needs to be separated and washed. Several types of plastic will float in water, while others will sink. Large pieces of EPS packing material need to be shredded. Flip-flops (*chappal*) should be kept separate for making roofing washers. Battery boxes can be collected separately for elevated floor constructions.

K. After washing the plastic waste it needs to be dried and redistributed into the “clean” and “less-clean” stock. It is possible that some elements remain too dirty. Either they can be cleaned in the next washing cycle or be rejected. Washing should be realised away from all other water sources and/or streams. The dirty water should soak away into the ground.

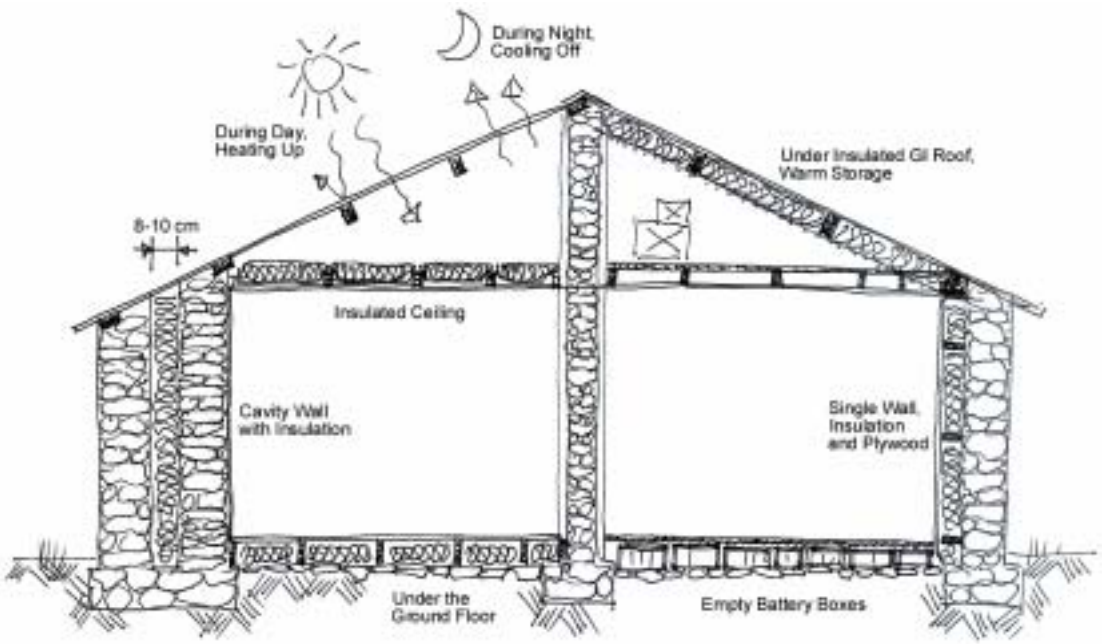
L. After washing the materials should be sun-dried. Sun drying can be difficult in the event of (strong) local winds. Most of the plastic grocery bags are so light that they float easily away in any wind. Netting or greenhouses can be used to keep the plastic in place.

M. Very dirty plastic can be burned, but care must be taken that the burning process has a sufficiently high temperature and combustion is complete. Complete burning may require supplementary firewood or fuel. Examples are clinic and hospital waste, latex gloves, soiled clothing, etc.

N. The collection organisation can also specialize in the application of the thermal insulation (inside the houses, around water installations, etc.) and by doing so will ensure correct application, high customer satisfaction and good firewood savings.

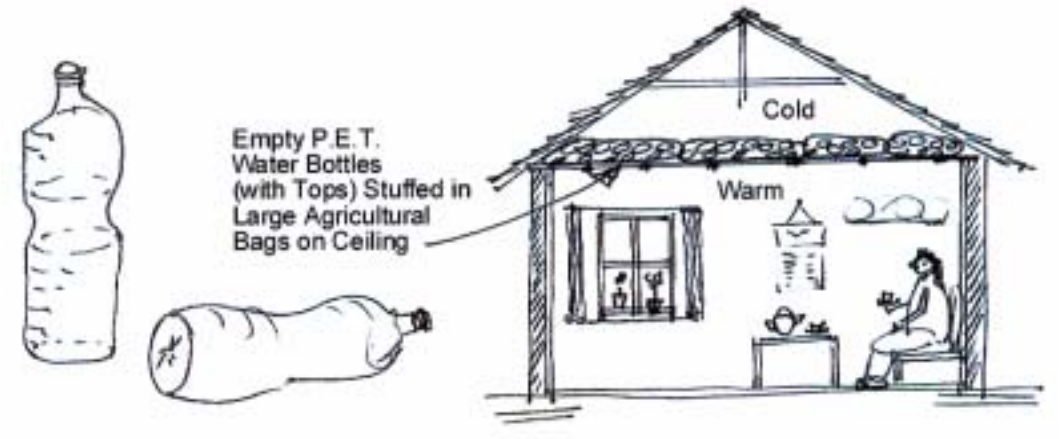
O. Once the collection centre has been in operation for a period of time and gained work experience, the most realistic prices can be set to keep the process going. After one winter season the demand for plastic waste insulation should pick up, once the villagers who applied the insulation realise the increased comfort or the firewood savings.

P. If a shortage of source materials occurs, contracts can possibly be made with nearby towns, but only washed waste should be contracted and the collection centre must organise a regular quality control before transport.



4. DOMESTIC APPLICATION

For inside the house, only the use of “clean” plastic waste is strongly recommended. Most effective is to apply the insulation above the ceiling of the heated room; secondly, inside cavity walls around the heated room; and thirdly, under the roof. Insulation under a sheet metal roof will also keep the rooms cooler during hot summers.



Depending on the design of the house, bags with insulation material can be placed under the ground floor, fixed with galvanised wires in between the floor beams or under the ceiling of the living room.

Flat bags of insulation can be applied inside against the living room walls that form the outside walls of the house. With the bags in place between the wooden supports, plywood can then be nailed onto the supports, thus providing a thick, lightweight filled cavity wall. The special advantage of this design is that the bags with plastic waste still allow the transmission of humidity from the inside of the room towards the exterior, while at the same time it acts as an excellent thermal insulation. The disadvantage is that the room will be reduced in size by the thickness of the wall insulation.

For new houses the insulation material can be applied directly inside cavity walls. Because most of the one-litre PET bottles have a diameter of about 7-8cm, the cavity should not be less than 7.5cm (3"). This will provide a high value insulation for high altitude dwellings.

NOTE: Complete report can be obtained from NRM Section, SNV-Nepal.

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