Plastic Waste Insulation

for

High Altitude Areas

Application in Houses, Greenhouses and Biogas Reactors

Field Visit – May 2003

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ABSTRACT

Plastic waste is increasingly becoming an eyesore and is polluting the environment, especially in high mountain villages where no garbage collection system exists. A large amount of plastic is being brought into the tourist trekking regions (PET and HDPE bottles, food wrappers, PVC and plastic bags used for transport and packing materials) and discarded or burned. This plastic waste can be perfectly reused as source material for thermal insulation. When separated into "clean" and "less-clean", it can be packed in PP fibre bags and utilized as insulation material inside housing, under greenhouses and around high altitude biogas reactors. The plastic waste can also be used to insulate water piping of solar water heaters. In this way a common waste product is turned into a high valued thermal insulator which is extremely needed in the high altitudes to conserve warmth and reduce firewood consumption. A comparative table of insulation values is include.

Note:
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List of Abbreviations

ACAP	Annapurna Conservation Area Project.
AEPC	Alternative Energy Promotion Centre, Department of MoST, dealing with RE.
BSP	Biogas Support Programme, project of SNV/N from 1995 till June 2003.
Dokha	Bamboo woven basked, carried on the back, holds about 30kg biomass.
EPS	Expanded Polystyrene. Light, white insulation material used in package industry.
EPE	Expanded cellular polyethylene foam. Closed cells expanded with LD PE resins.
HABR	High Altitude Biogas Reactor (over 1800m altitude).
HDPE	High Density Polypropylene. Plastic used in water and sewerage piping.
LD	Low Density, terminology used in plastic industry.
NRs	Nepalese Rupee. One Euro = NRs. 85 (at date of report date).
PE	Polyethylene plastic with density 0.91–096. May be burned, non-poisonous.
PET	Polyethylene Terephthalate, used for fully transparent water and soft drinks bottles.
PP foam	Polypropylene foam, commonly sold as under-carpet in Nepal, 5mm and thicker.
PVC	Poly Vinyl Chloride plastic with density 1.2 -1.55. Poisonous burning gasses.
RABR	Remote Area Biogas Reactor (more than one day's walking from road head).
RE	Renewable Energy.
RMP	Red Mud PVC, red mud is a by product of the aluminium industry.
SPCC	Sagarmatha Pollution Control Centre.
SWH	Solar Water Heater.

1. INTRODUCTION

This report provides information about the use of plastic waste materials in mountain areas for thermal insulation in houses, greenhouses and High Altitude Biogas Reactors (HABR). In houses the insulation can be placed under the roof, under the foundation and inside cavity walls. External and internal water piping of Solar Water Heaters (SWH) can also be insulated. Thermal insulation is very important in high altitude areas where the cold climate increases heating requirements. Improved insulation of houses therefore results in better comfort and a reduced consumption of firewood.

The following reports are related to the present paper:

- "Construction Options for Greenhouses", June 2003
- "Remote Area Biogas Reactor (RABR)", June 2003
- "Thermal Insulation for Houses in High Altitudes", March 2003

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. Due to this large firewood consumption, forests at high altitudes are not exploited in a sustainable way.

Many Nepalese in the 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 packages 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 hill sides.

Especially in tourist and 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 an 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 such as ACAP and SPCC (Sagarmatha Pollution Control Centre) are very much involved in organising the local population in waste collection.

- ❖ The more tourists, the more income for the local population, but also more waste[1].
- ❖ More tourists require more food (often imports) and more energy (often firewood).

This paper explains the main principles of thermal insulation and how plastic waste can serve perfectly as thermal insulation in houses and for external applications. Especially for external 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) Avoiding the importation of insulation materials; (4) Reducing firewood consumption because of increased thermal comfort; and (5) No burning.

[1] During the 2001/2002 season about 30 tons of non-degradable waste was collected in the Sagarmatha-Khumbu region by SPCC. About 10% of the solid waste consists of plastics which can be used as insulation material.

Housing

- Thermal insulation of a house or hotel is a good method to increase the comfort level during the 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 is not necessary. Insulating the ceilings and under the roof of houses are the most effective energy savers.

Greenhouses

- In high altitudes, food can be grown locally in greenhouses during many more months than normally would be possible on the "cold" farmland. Food for personal consumption, sale (tourists) and cattle (fodder) generates income and improves health. The greenhouse soil can be insulated from below with bags containing plastic waste, creating a thermal storage capacity of the soil and avoiding cooling at night. This allows continuous plant growth during cold periods.

High Altitude Biogas Reactors (HABR)

- For cattle owners the production of biogas from dung is possible, also at high altitudes. To guarantee good gas production, even during the winter, the biogas reactor needs to be thermally insulated from the surrounding ground. This can be accomplished by insulating the digester and slurry outlet with plastic waste.

Outside Installations

- Solar Water Heaters (SWH) are very effective in high altitudes for warming shower water and pre-warming kitchen water. The piping system between the SWH and the tap point needs to be well insulated to avoid cooling down, causing a reduction in the efficiency of the system. Plastic waste can be used for this insulation, covered with (thin) HDPE pipes having a large diameter.

No More Burning

- Burying and burning are two practices being used to get rid of waste material. However, these practices destroy the possible use of a technically valuable insulation material. In very large cities facilities often exist to recycle most of the different types of plastic. In Nepal this is rather limited and the cost of bringing the plastic back to Kathmandu is prohibitive to any reprocessing. However, in remote areas the plastics can easily be recycled (reused) as thermal insulation.

The plastic waste material can consist of empty PET water and soft drink bottles, empty wrappers of instant noodles, flimsy plastic shopping bags and used transport bags, among others. This report provides some details of various applications of plastic waste as thermal insulation.

Some figures are quoted from the Sagarmatha Pollution Control Centre (SPCC), but similar quantities may also be the case in the Annapurna Conservation Area Project (ACAP) supported region. Because of the large quantities of waste material already collected by SPCC, immediate application of thermal insulation from plastic waste can be easily realized. In other areas, however, it may take some time for community organisations to organise the collection of the material and will therefore need to begin with a limited application of the thermal waste insulation, for example, use in greenhouses only.

2. PLASTIC WASTE USUABLE FOR INSULATION

2.1 TYPES OF PLASTIC

Two main forms of plastic wastage are present in the area, plastic bottles and foil-type plastics, such as grocery bags and large fibre bags. Bottles without residues can be used directly as insulation 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 bringing in these bottles is now being prohibited because of their pollutant aspects. With a collection system prohibition is not necessary.

LDPE Bags and Wraps

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 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 extended 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. When not extremely soiled, PVC is excellent for use in thermal insulation, but it should be kept out of the sunlight.

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.

In supermarkets and grocery stores large amounts of HDPE containers are used for cleaning liquids. Often small amounts remain in the bottle when discarded. All HDPE bottles should therefore be considers as unclean because inspection is difficult. The bottle as a whole with top and spraying mechanism can be used for insulation in the ground around biogas reactors, under greenhouses and around water pipes.

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 perfectly 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 in 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 colouring pigments rope is made, having a better 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 underground, in ceilings or in 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. It can be shredded and stuffed into the insulation bags (see photo above). The shredded Styrofoam can be very well used as clean insulation material inside houses and around warm water tanks.

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.

2.2 CLOTH AND RUBBER WASTAGE

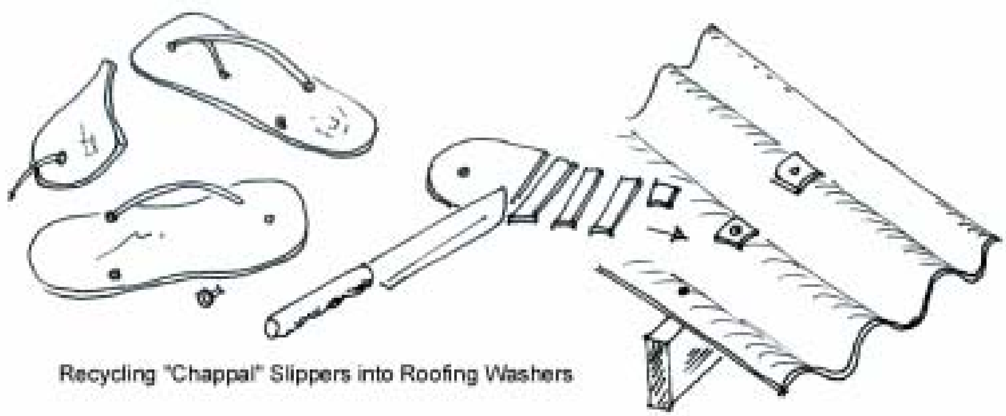
Especially in the trekking areas large quantities of cloth waste is produced and can be collected[2]. Cloth waste often consists of PP fibre bags which were used for packing and transporting. Once the bags are ripped open, they often have little other use and become wastage. Other waste cloth consists of tarpaulin after it become porous and ripped. When not terribly soiled this can also be utilized in underground constructions. Garments may be little 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. However, due to its water absorbing capacity, they should placed only above ceilings or under roof constructions. They should never be used for insulation underground in greenhouses or biogas reactors.

Rubber Goods

All types of rubber (boots, shoe soles, tents, water containers, etc.) do not absorb water. Therefore when put into the thermal insulation bags, they can be used for insulation underground. Moreover, burning rubber is not advised as it produces poisonous burning 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 nailing/fixing corrugated iron roof sheets. The market value of this recycled material used as such is much higher than as thermal insulation material stuffed into sacks.



Recycling "Chappal" Slippers into Roofing Washers

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. Very soiled human clothing should not be used. However, if the soiled garments are burned, it is recommended to use high burning temperatures to minimise poisonous gas emissions.

[2] SPCC collected during the 2001/2002 season about 30 tons of solid waste categorized under "Cloth Waste".

2.3 USEABLE AND NON-USEABLE MATERIAL FOR THERMAL INSULATION

In principle, all non-conductive materials that in packed form contain lots of air are useful for thermal insulation. However, for use outdoors (in the ground) they should be non-biodegradable and non-water absorbing.

For use indoors in ceilings, they 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 in underground bags under greenhouses and around biogas reactors	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.	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[3].	Paper or cardboard waste. Dirty or soiled materials. Leather, animal skin.

[3] 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. HOW DOES INSULATION WORK?

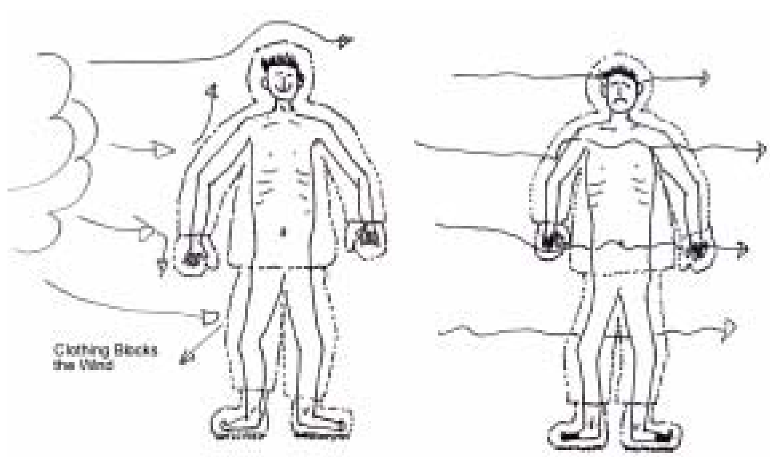
Each material has its own characteristics in thermal insulation depending on its own weight, the internal contact of that material and the conductivity.

The following general rules about insulation and humidity apply:

1. Thermal insulation is created by dry air, well contained in its location or in a vacuum.
2. Circulation or movement of air will reduce its insulation factor.
3. The thicker the insulation layer, the better it insulates.
4. Warmth or heat will escape through the least insulated area or surface.
5. The larger the temperature difference between two areas (rooms) separated by an insulator (construction), the faster will be the heat transfer.
6. Warmth moves upwards and will escape through the ceiling and roof.
7. Warmth or cold is stored in all materials. When the weight of the material is large, the heat storage capacity of that material will also be large.
8. Humidity and water are good heat conductors and thus poor insulators.
9. Humidity in the air can condensate on the coldest surface, depending on the temperature and humidity level. The higher the humidity or the colder the surface, the faster it condenses.
10. Humans constantly produce humidity by exhaling. This humidity must escape through the building construction or by means of ventilation.

Explanation of the above rules:

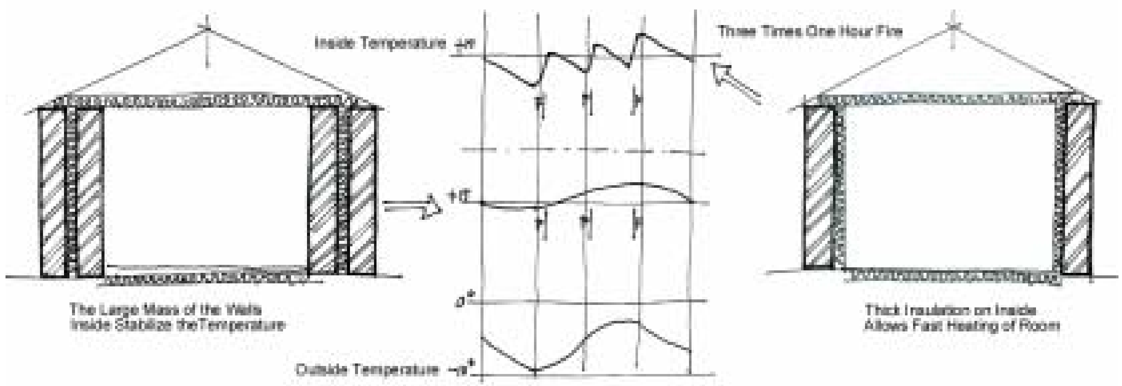
1. Thermal insulation of houses works like a warm coat; whilst the outside air is cold, you stay warm inside the coat. The fibres or wool keep the air in place and that trapped air avoids that the warmth of your body is lost. Vacuum or special dry gasses (Argon) insulate better than dry air because the absence of any material (air is a material) will eliminated transfer of heat. For example, thermos bottles having a double wall vacuum glass bottle inside are the best. Some SWHs have vacuum tubes; these keep the water inside warm, also with frost outside.



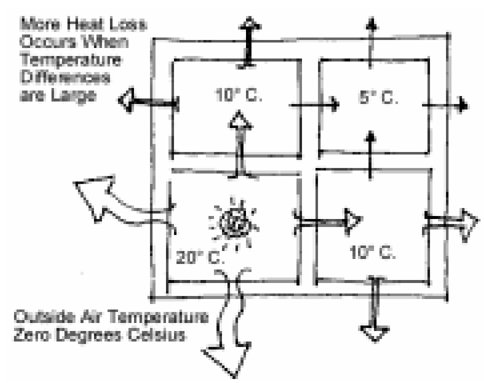
2. Thermal insulation works by trapping air in one place and not allowing it to move. It is the air that insulates, not the fibres of the coat. If it is windy, the coat should also be windproof. Otherwise, the cold wind will blow through the coat and take away the warm air inside. All insulation material is based on this principle; the more air it is containing in relation to its own weight, the better it insulates. The outside surface of the house should be without open joints between the stones.

3. The thicker the coat, the warmer you stay. The thicker the sleeping bag, the warmer it is. If a sleeping bag has been flattened, then it first has to be well shaken to give the inside more volume and become airy again; that way the sleeping bag will be warm. In a house 4" insulation works twice as good as 2" insulation. To insulate the house or a room, a thick layer of fixed air has to be packed around it. This can be on top of the ceiling, inside the walls or under the floor. For all three areas plastic waste material can be used.

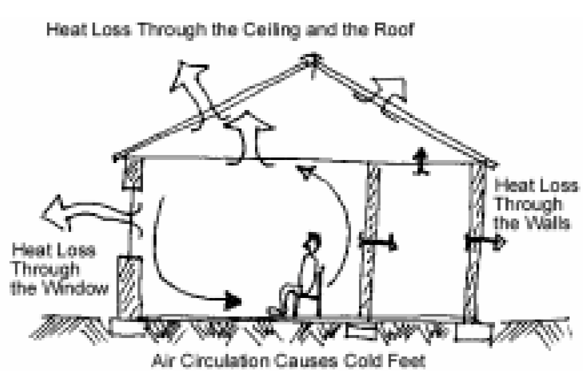
4. Temperatures in our environment want to equalize themselves and all heat flows automatically to the coldest areas. Thermal insulation does not produce warmth, it only contains it in its place. If the wall of a room is well insulated but has a glass window, all heat will escape through the window until the inside and outside temperatures are the same.



5. When a warm room has an inside wall adjoining another room and an outside wall cooled by the cold weather, more warmth will be lost through the outside wall than through the inside wall. This is because of the higher temperature differences inside the outside wall as compared to the inner wall (with similar construction of walls). For this reason outside walls should be better insulated than inside walls. When a cold wind is blowing, it will additionally cool the outside wall (see rule 2 above) and more heat loss will occur.



6. Because the air around us (or another warm surface) expands when warmed up, it becomes lighter and rises upwards. This creates air circulation in a room. When a window is cold, it will cool the air next to the window and that air will flow down towards the floor. In another area the warmest air will rise up to the ceiling. Because the warmest air is against the ceiling, the greatest heat loss will occur against the same ceiling upwards. That is why the ceiling or the roof of a building should be the first priority for insulation as the greatest heat loss will occur there.



7. A thick cold stone wall in a house takes a lot of time to become warm. This is because the mass (weight) of the cold stone is much larger than the mass (weight) of the warm air needed to heat up the stone. Air has to circulate for many hours along the heavy stone wall before it obtains the same temperature of the air. This works both ways. Once a heavy wall inside the house (or greenhouse) is warm, it releases the warmth slowly into the air. Thus the room will stay warm for a long period before cooling down. Heavy stone walls can therefore have a stabilizing effect on the inside house temperature.

8. When a coat gets wet, the moisture bridges your body with the cold outside air; and the coat will not insulate very much. You will lose heat fast. In order to keep warm you must remain dry and pack a thick layer of dry air around your body. When the foundation, wall or roof of a house is wet, warmth will pass faster through the wet construction.

9. Humidity exists in all air and will form little drops of water when becoming cold. Clouds in the sky consist of little drops that will fall down when the cloud rises higher and gets colder. When the glass window is the coldest place in the room and outside it is very cold, condensation can be seen on the glass, forming drops that eventually slide down. This same condensation will also occur inside cold walls, but is not visible. Walls which are wet inside can be easily identified because they lose far more heat than dry walls and therefore feel extra cold.

10. Our exhalation system evacuates humidity from our lungs. In poorly ventilated bedrooms, large amounts of condensation on windows and in walls can occur during the winter because all night the occupants increase the air humidity while outside the temperature drops. With condensation inside the walls, the wall temperature may further drop and condensation may appear on the inside surface. Certain wall designs allow the humidity to pass through, but with low air temperatures the air outside can absorb only small amounts of water. When inside walls are sealed with large plastic foil sheeting, sufficient ventilation must be assured to get rid of the humidity. The plastic waste allows the passing of humidity.

Wet walls greatly increase heat transmission and reduce the insulation capacity of the construction. Walls can become wet from outside influences (such as rain or ground water) and from the inside caused by the condensation of humidity (exhaled air).

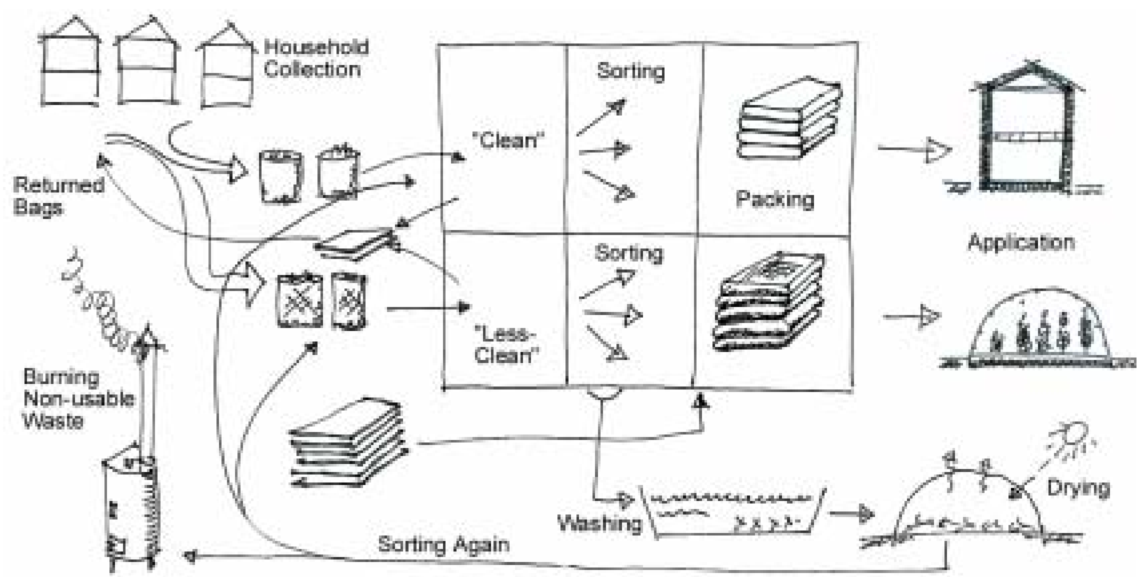
4. MAKING PLASTIC INSULATION

Types of Plastic Insulation

I. For outside use. The insulation material does not have to be very clean and can be used under the plant soil of a greenhouse, under the floor of a cowshed or around the digester bags of the biogas reactor. Collecting the material and stuffing the plastic PET and HDPE bottles and waste from plastic grocery bags (crumpled) into larger bags will be adequate.

II. For use inside the house. 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.



Organisation of Collection

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

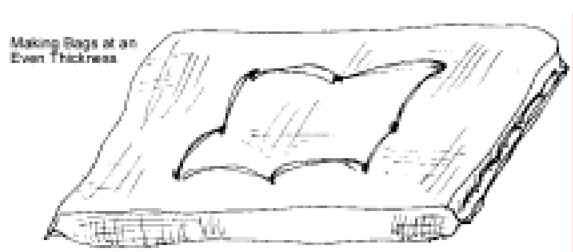
D. Villagers who bring in a full bag should have their bag emptied immediately in a depot (one depot for "clean", one depot for "less-clean"). This allows an on-the-spot inspection of the quality of the material and the collector can provide immediate feedback to the villager.

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, for example when they plan to build an insulated greenhouse. 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* of 45cm (1½ ft.) wide x 75cm (2½ ft.) long = 1/3m^2 with PET + HDP bottle plastic waste. This bag filled to 12.5cm (5") may contain 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 of 1/3m^2 x 8cm glass wool would be about NRs 65, not yet considering transport costs to the remote areas. With NRs 5 for the bag, another NRs 10 can be paid for the "less-clean" content and NRs 15 for the bag with "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 then 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.

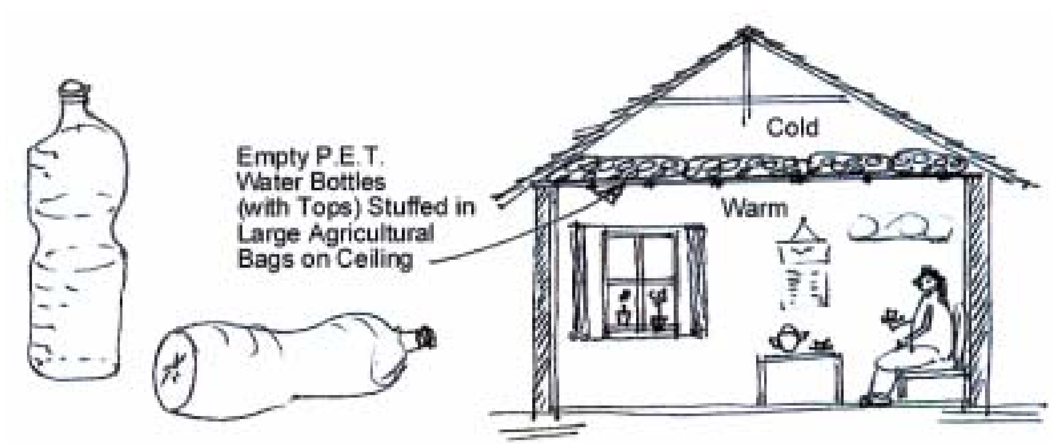
L. After washing the materials should be sun-dried. Sun drying can be difficult in the event of (strong) local winds. Most of the plastic grocery bags are so light that they float easily away in any wind. Netting or greenhouses can be used to keep the plastic in place.

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, under greenhouses, 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 realize the increased comfort or the firewood savings.

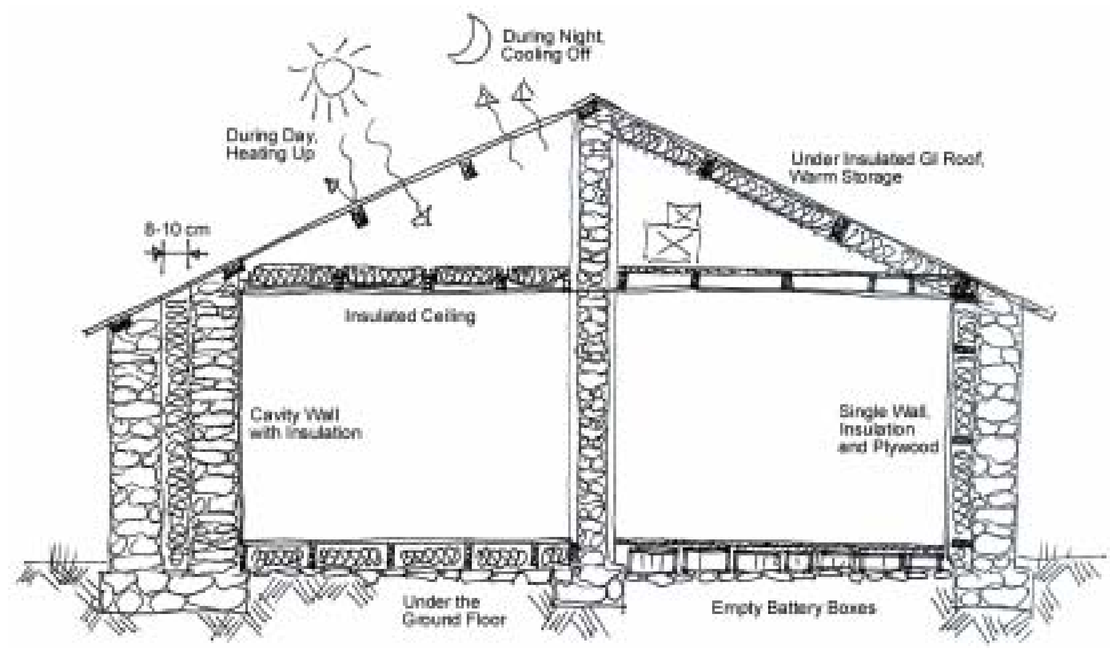
P. If a shortage of source materials occurs, contracts can possibly be made with nearby towns, but only washed waste should be contracted and the collection centre must organise a regular quality control before transport.



5. DOMESTIC APPLICATION

For inside the house “clean” plastic waste is strongly recommended.

Most effective is the insulation to be applied above the ceiling of the heated room. Secondarily, insulation under the roof should be applied. 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 or fixed with galvanised wires in between the floor beams, under 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 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.

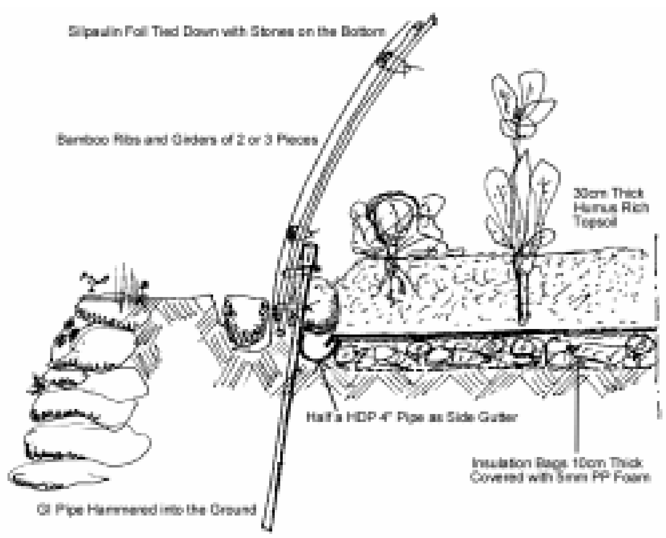
For new houses the insulation material can be applied directly inside cavity walls. Because most of the one litre PET bottles have a diameter of about 7-8cm, the cavity should not be less than 7.5cm (3"), providing a high value insulation for high altitude dwellings.

6. GREENHOUSE APPLICATION

Cultivation in greenhouses in both tourist trekking areas and other high altitude areas (over 1800m) is a means to supply fresh vegetables and other crops for most of the year[4]. Because of the higher humidity and temperature in a greenhouse, various types of vegetables can be cultivated while these cannot be grown in the open field. Vegetables such as salad greens, spinach, tomatoes, green beans and cucumbers can be used for own consumption or sold in local markets. The greenhouse, or part of the greenhouse, can also be used to produce green fodder for feeding the cattle during the winter period when other greens cannot be found.

The speed of crop growth inside the greenhouse is related to soil and air temperature, water and nutrients. Although the inside air temperature of the greenhouse is usually high during autumn and spring (up to 20ºC), the ground temperature still remains very low (2º to 5ºC). This is because the underlying soil remains cold, is humid because of watering and is in contact with the upper planting surface. Watering of the soil increases the conductivity of the soil. The temperature of the planting soil can only be improved if the topsoil layer is thermally insulated from the underground.

Points in the construction sequence of insulated greenhouse soil construction[5]:



A. The topsoil is dug out 40cm deep and kept separate. The topsoil needs to be mixed at a later stage with compost to provide the planting bed material.
B. (not essential but recommended). Along one or two sides of the outside of the greenhouse a 4" HDP pipe cut in half can be laid for capturing excess water from the plant bed. For this purpose the plant bed should be slightly elevated in the middle (curved for drainage to two sides) or all slightly sloping to one side (drainage on one side only).
C. The space between the sides (with or without half HDP pipes) is filled with 12.5cm (5") thick plastic waste stuffed into fibre bags (*bora)*. After applying the cover soil these bags will be slightly compacted to about 10cm (4").
D. Over the horizontal layer of thermal insulation bags, a 5mm thick PP foam is placed, sloping towards the gutter. This waterproof sheet will allow drainage of excess water sideways towards the half HDP gutter. The PP foam needs to enter the side gutters. To hold the PP foam in place, small stones can be laid on top of the gutters.
E. Over the foam the planting soil is applied, about 30cm thick. This will allow sufficient root-depth for most plants, including carrots.

A greenhouse of 4m x 10m will require 40m^2 stuffed bags, or minimal 4m^3 thermal insulation material. This means that the farmer who desires an insulated greenhouse needs to start collecting the material well in advance of his/her construction plans.

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[4] In high altitude areas local tea hoses and restaurants import fresh vegetables by airplane because at such altitudes certain crops can only be grown in greenhouses.
[5] For more details, see the document entitled "Construction Designs for Greenhouses in High Altitude Areas", June 2003.

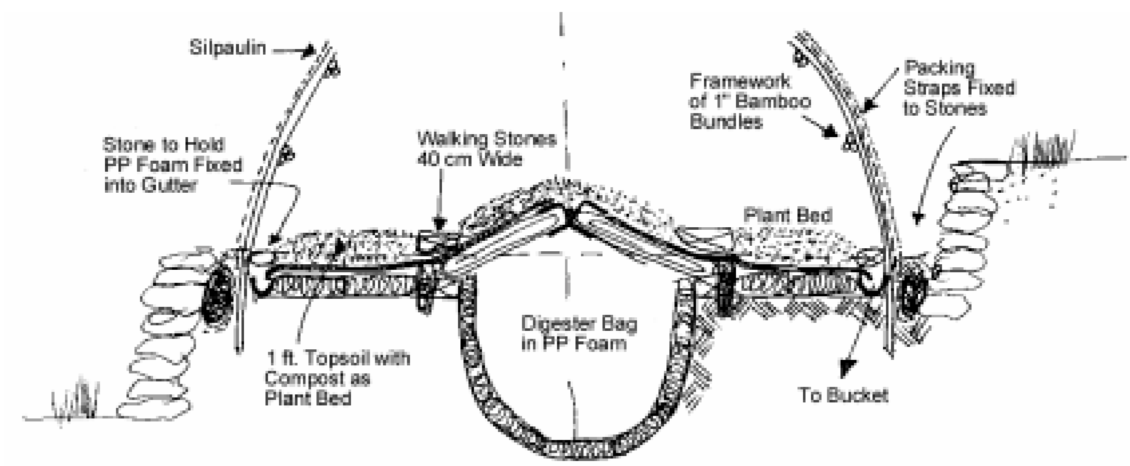
7. HABR APPLICATION

The High Altitude Biogas Reactor (HABR) requires a covering greenhouse[6]. This is not for the thermal insulation of the HABR, but foremost for better fodder production for the cattle, leading indirectly to a better gas production from the reactor. The design of the greenhouse is similar to the greenhouse mentioned above.

In the centre and over the length of the greenhouse a deep trench is made for the digester and slurry-outlet bags and lined with 10cm thick insulation bags. Because the bags under the digester bag are subject to considerable weight of the slurry, the pressure resistance of these bags need to be sufficient to bear the weight. The best method to test this is to stand on the bags after packing.

The strength of the bags can be improved by stuffing it only with PET and HDPE bottles which are airtight (capped). Newly manufactured PET bottles can be used for this purpose.

A biogas reactor in a greenhouse requires about double the amount of thermal insulation material than for the greenhouse alone. This means that the farmer who desires an insulated biogas reactor and greenhouse needs to start collecting the material well in advance of his/her construction plans.



[6] The design of the HABR in combination with the covering greenhouse construction is detailed in the report entitled: "Construction Options for RABR, Remote Area Biogas Reactor", June 2003.

8. SWH APPLICATION

Solar Water Heaters (SWHs) are excellent energy producers and savers of firewood. The efficiency of the installation depends largely on three aspects:

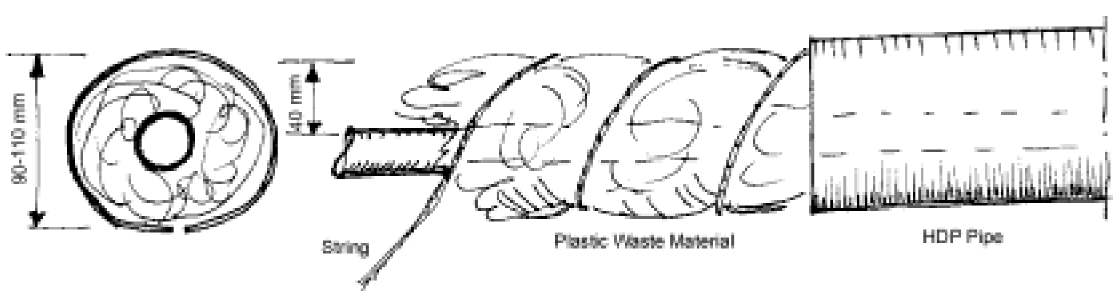
- The design of the collector panel with the warm water storage container.
- The total length of piping outside the building between the collector and storage tank and the total length of piping from the installation to the tap point inside the house.
- The insulation of the outside as well as the inside piping.

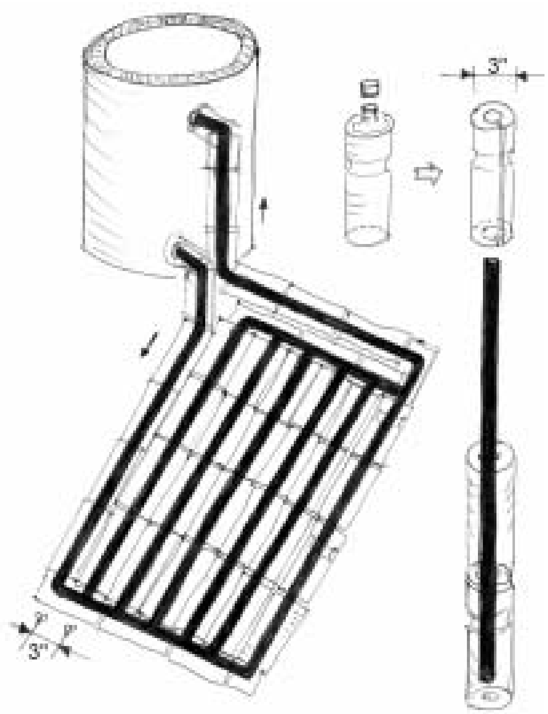
While the collector and its orientation can be of good quality and have an efficiency of about 60% (high), if the piping is too long and not well insulated, the overall efficiency of the system will rapidly reduce to 30% and even 15%.

Not only does the piping system outside need to be as short as possible, but both the piping outside and inside the building should be well insulated. For outside piping minimum 2.5cm insulation is recommended and for inside piping minimum 1cm.

The most economic method to insulate the external pipes is to wrap the pipes with at least 2.5cm (1") crumpled up plastic waste, loosely tie plastic foil around them with rope and then cover with a 10cm (4") diameter thin quality HDPE pipe. This can be done by cutting the pipe lengthwise and clipping it over the insulated pipes. Inside the house the pipes need to be packed with insulation material before these are masoned into the walls.

Although the company who installed this equipment has insulated the long external distribution pipes with yak skin, it may not prevent freezing. Poorly insulated and long external pipes will cause very poor efficiency of the SWH system.





Plastic insulation for warm water pipes masoned into the walls or used outside covered with large diameter HDPE piping can be made from knotting together empty plastic shopping bags. Strings should be not longer than 4 meters in length and then folded double to allow easy winding around the ½" metal pipes.

Contracts for the plastic bag strings can be made by weight. Two hundred grams of knotted shopping bag string equals approximately 80 meters of single length which can insulate about 4 meters of water piping. Each kg of knotted bags insulates therefore about 20 meters of warm water piping, being usually sufficient for a single house.

Transparent plastic (PET) water bottles can be used for the same purpose of warm water pipe insulation in new house constructions. The bottle neck is removed from the top, leaving a hole equal in diameter to the water pipe. The bottle is then cut open lengthwise with a strong scissor. Another hole of the same diameter is made in the bottom. The modified bottle is clipped over the warm water pipe before being covered by the masonry of the walls. The horizontal sections in the top and bottom of the plastic bottles prevents airflow around the pipes while the 1" air layer provides excellent insulation.

The same technology was used in India to make a low-cost solar water heater. Using black ½" HDPE water piping a grid was made following the above sketch. One-litre transparent PET bottles were attached over all the pipes. The black HDPE pipe captures the solar heat whilst the transparent bottles contain the heat by its insulating effect. The disadvantage of this model is that the bottles need to be regularly replaced (at least yearly) because in the full sun PET bottles deteriorate under ultraviolet light[7].

[7] This technology was field tested and implemented by Dietrich Bartel, a German engineer working in northern India.

ANNEXE I

The data presented below gives an indication of the different insulation values of the various construction materials. Calculation of the insulation value of each construction can be made based on the available information about thermal conductivity or resistance values in building materials[8].

TABLE OF MATERIAL CHARACTERISTICS

No.	**Material** *The highest resistance (best insulator) at the beginning.*	**Density of Material in kg/m³**	**Material Specific Thermal Conductivity λ = W/m.K**	**Specific Thermal Resistance R_m= m.K/W**
1	Expanded polypropylene (EPS)	20	**0.02**	50.00
2	Air, low humidity	1	0.026 - **0.023**	40
3	Rock wool/**glass wool**	150	**0.04**	25.00
4	**Waste plastic PET + HDPE bottles**	200	*0.06-0.07 Estimated*	*15.00*
5	Straw, reeds, thatch, agricultural waste	240	0.07 - **0.08**	13.33
6	Wood shavings, loosely packed / sawdust	250	**0.08**	12.50
7	Soft board, low density	300	**0.10**	10.00
8	**Waste plastic, crumpled bags only**	300	*0.10 Estimated*	*10.00*
9	Plywood, multiplex	530	0.14 - **0.12**	8.33
10	Medium Density Fibre (MDF) board	500-600	**0.14**	7.14
11	Gypsum plaster	900-1200	0.17	5.88
12	Linoleum, PVC flooring tiles	650	**0.186**	5.38
13	Hardboard, normal hard quality	800	**0.20**	5.00
14	Wood (pine, fir)	817	0.14 - **0.23**	4.29
15	Chip-wood panels, low density	450	**0.25**	4.00
16	Fibre cement, Eternit	800	**0.30**	3.33
17	Soil-grass (dry 1:1) lime water bonded	1000	*0.35 Estimated*	2.86
18	Terrazzo floors	1500	**0.41**	2.44
19	Adobe blocks (clay-soil, non-compact)	1100	0.48	2.08
20	Water	1000	**0.58**	1.72
21	Soil-cement mortar (10:1)	1400	0.6	1.67
22	Cement blocks, solid, low quality	2000	0.65	1.54
23	Burned brick masonry, inside	1500	**0.70**	1.43
24	Soil, not compacted	1300	0.71	1.41
25	Soil-stabilized, compacted, dry	1400	*0.75 Estimated*	1.33
26	Burned brick masonry, outside	1800	**0.87**	1.15
27	Glass, window glass	2500	1.05 - **0.81**	1.11
28	Sand-cement plaster (10:1)	1900	**1.3**	0.77
29	Two-stone wall in loose soil, 30% cavity	1600-1700	*1.5 Estimated*	0.67
30	Reinforced concrete (RCC), vibrated	2400	**1.5**	0.67
31	Reinforced concrete (RCC), not vibrated	2300	**1.6**	0.63
32	Two-stone wall in light mortar 30%	1800-2000	*1.7 Estimated*	0.59
33	Low-quality concrete, not reinforced	2100	1.7	0.56
34	Sandstone	2150	**1.75**	0.57
35	Two-stone wall in strong mortar (30%)	2200	*2.0 Estimated*	0.50
36	Ice	950	**2.21**	0.45
37	Stone, solid granite	2500-2600	**2.8-2.9**	0.35
38	Corrugated metal sheet, steel	7800	50 - **58**	0.02

[8] The bold printed figures are standard calculation data from the *Polytechnisch Zakboekje* (European Polytechnic Information), Koninklijke PBNA, Arnhem, The Netherlands (1980).

During the realisation of the wall construction in the house, other factors may be of influence to its conductivity, such as the wind-chill factor. A rough surface wall will cool faster in the cold wind than a smooth surface wall.

In the calculations of cavity walls or ceilings, the width of the cavity or the airspace between the two surfaces is important. The larger the width, the lower the insulating factor becomes due to the effect of air circulation inside the cavity. In this case, the standard air insulating factor cannot be applied.

TABLE OF RELEVANT CONDUCTIVITY FIGURES FOR CAVITIES[9]

Thickness of Air Layer in Centimetres	Thickness of Air Layer in Inches	Vertical Cavity Conductivity and Resistance		Horizontal Cavity with Warm Side Above (Hot Roofs)		Horizontal Cavity with Warm Side Below (Warm Rooms)	
		λ = W/m.K	R_m = m.K/W	λ = W/m.K	R_m = m.K/W	λ = W/m.K	R_m = m.K/W
1	½"	**0.065**	15.38	**0.064**	15.63	**0.066**	15.15
2	3/4"	**0.115**	8.69	**0.106**	9.43	**0.131**	7.63
4	1-1/2"	**0.221**	4.52	**0.187**	5.35	**0.252**	3.97
8	3- 1/8"	**0.448**	2.23	**0.350**	2.85	**0.492**	2.04
10	4"	**0.564**	1.77	**0.430**	2.33	**0.616**	1.62
15	6"	**0.861**	1.16	**0.632**	1.58	**0.913**	1.10
20	8"	**1.163**	0.86	**0.837**	1.19	**1.210**	0.826

The above table shows that an air cavity larger than 2cm (3/4") with λ = 0.115 will be far less effective than when the same space is filled with plastic PET + HDP waste in bags with λ = 0.075.

Also, an air space of about 7.5cm wide (3") has about the same conductivity as adobe (λ = 0.45). This means that when an air space is 2cm (¾") or larger, it is essential to fill the cavity with insulation material. Filling a 10cm underground cavity wall with dry earth has the same effect as leaving the cavity wall open.

The total R value (total thermal resistance of the wall) can be calculated by adding the various thermal resistance values of each wall element (or cavity) together.
The thermal resistance of each wall element is the R_m value multiplied by the thickness in meters of that wall element. For example:
10cm plastic PET + HDPE bottle waste: R_m 15 x 0.1m = 1.5
2 x 18" stone wall = 88cm = 0.88m
0.88m unmasoned stone wall with soil: R_m 0.67 x 0.88m = 0.59
Total resistance wall: 1.5 + 0.59 = 2.09
The 10cm plastic waste has a three times higher insulation value than the 88cm stone wall.
The same wall <u>without</u> the filling with plastic waste is 0.59 + (0.1m x 1.77) = 0.59 + 0.177 = 0.77 or about one third of the plastic insulated wall.

In addition the transfer resistance must be added **between the outside air and the wall** (R_{so} = variable) and the transfer resistance **between the inside air and the wall** (fixed R_{si} = 0.11).
The total resistance of the insulated wall = 1.99 + 0.11 + 0.10 = 2.2
The total resistance of the non-insulated wall = 0.77 + 0.11 + 0.10 = 0.98

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[9] Cavity walls are very common in cold climates, but need to be filled with a lightweight insulating material. These figures are standard calculation data obtained from the *Polytechnisch Zakboekje* (European Polytechnic Information), Koninklijke PBNA, Arnhem, The Netherlands (1980).

ANNEXE II

Austrian team relieves Annapurna IV of rubbish

Himalayan News Service

Kathmandu, October 29

An eight-member Austrian expedition team cleared some 250 kg of garbage from the Annapurna IV (7,525).

Organising a press conference here today, the team demonstrated a part of the non-combustible garbage, which the Kathmandu Metropolitan City would later dispose safely.

According to the team leader Reinhold Oblak, non-toxic, combustible garbage weighing about 150 kg was burnt at the base camp after sorting. The remaining 100 kg of non-processible garbage was transported to Hongde on donkey back which would further be transported to Pokhara via plane and then to Kathmandu by bus.

Oblak blamed the government officials' inefficiency in monitoring the mountaineers. "The officials never reached even up to the base camp and how can they monitor what is going on in the mountains just sitting in Kathmandu?" he questioned.

Members of an Austrian team display a part of the garbage they have collected from the Annapurna IV in Kathmandu on Wednesday. *Himalayan Photo*

The clean-up campaign that was organised by the Blue Sky Ltd was funded by Austria based Saubermacher Expedition.

"Being mountaineers, it is our responsibility to clean the garbage. We want all the mountaineers to follow our steps," he told this daily adding that he would come again to continue such campaigns.

He says that cleaning the famous mountains like Everest alone is not sufficient. "People should not ignore other mountains as well. They are not only the property of Nepal but of all the mountaineers," Oblak urged every mountaineers not to leave any rubbish in the mountains.

The clean-up team included team leader Reinhold Oblak, deputy expedition leader Ulrich Walser, doctor Edmund Wirbel, videographer Georges Beckinger and members Christopher Ryder, Peter Farmer, Andreas Pusswald and Alois Schimpfoessl.

Mt Dhaulagiri cleaner by 3 tonnes of rubbish

Himalayan News Service

Kathmandu, October 31

An expedition led by the French to clean waste from Mt Dhaulagiri has returned after clearing 3,000 kg of garbage from the base of the mountain. The 'Dhaulagiri Clean Up Campaign' involved over 37 individuals and was initiated by the Association Dhaula Gueri of France and the Kathmandu Environment Education Project (KEEP).

"This is the second time that the team has come to Nepal to clean Dhaulagiri, which shows the immense interest the French have in the mountains of Nepal," said Claude Ambrosini, the French ambassador, while congratulating the expedition members at a press conference at Alliance Francaise. Ambrosini also mentioned that France has a long history of cooperation with Nepal and that cleaner sites would attract more visitors to the country.

The waste comprised 2,380 kg of textile, plastic wares and paper which they burnt; 500 kg of metal, 100 kg of glass, and 20 kg of batteries. The metal and glass were brought down to Pokhara on 17 mules and sold to a *kabadi* shop which would send it to India for recycling. The batteries will be taken back to France for recyling.

"This campaign was just not to clean the mountain in Nepal, but also to create an awareness amongst our countrymen back home too," said Boize, the leader of the expedition. The team also communicated and updated their website daily, and coordinated with five schools in France that were following the progress of the campaign.

The clean up was conducted along the trail from Marpha to the base camp. The campaign targeted major camping areas including Alubari, Yak Kharka, Elevation Camp, Dampus Phedi, Hidden Valley and Dhaulagiri Base Camp.

The above two articles from the Himalayan News Service report the large amounts of garbage, including a substantial component of plastic waste, recently collected from high mountain trekking areas.
Much of the 2,380 kg of waste collected from Mt. Dhaulagiri and burned
could have been recycled for use as thermal insulation.
Transporting new insulation material to high mountain areas is very costly.

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