DESEA PERU PVC BIOSAND WATER FILTER CONSTRUCTION AND INSTALLATION MANUAL

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DESEA

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USE OF DOCUMENT

ABBREVIATIONS AND CONVERSIONS

mm = millimetre
cm = centimetre
m = metre
mL = millilitre
m^2 = square metre
L = litre
kg = kilogram
s = second
min. = minute
h = hour
lb. = pound
gal. = gallon
CFU = [bacterial] colony-forming unit
NTU = nephelometric turbidity unit

1 inch = 1" = 25.4 mm = 2.54 cm
½ inch = ½" = 12.7 mm = 1.27 cm
1 metre = 3.281 feet
1 kg = 2.2 lb.
1 L/min = 1000 mL/min = 0.264 US gal./min

COMMENTS

Please address any comments or questions regarding the DESEA Peru biosand filter to the author at info@deseaperu.org.

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1.0 INTRODUCTION

This manual has been prepared to outline the construction and installation procedures of a PVC biosand filter (BSF) designed by DESEA Peru for use in Andean communities. Detailed information pertaining to biosand filter operation and maintenance plus other water, sanitation and hygiene (WASH) matters are available online from the Centre for Affordable Water and Sanitation Technology (resources.cawst.org) in Calgary, Alberta, Canada.

The original biosand filter was designed by Dr. David Manz, P. Eng., at the University of Calgary in the early 1990s. The Centre for Affordable Water and Sanitation Technology (CAWST) – founded in 2001 to provide training and consulting to organizations working in drinking water and basic sanitation projects – further developed the biosand filter as a low-maintenance and durable concrete container designed to provide long-term household drinking water treatment. CAWST has estimated that, as of June 2013, there were 550,000 household biosand filters (including all models) installed in 55 countries (Ngai, pers. comm.).

Since 2008, DESEA Peru has been installing BSFs in homes and schools in rural communities in the Andes Mountains of southern Peru. Having installed 150 CAWST-style concrete filters, DESEA recognized the need for a lighter-weight filter for transportation to Andean homes which were inaccessible by road. In 2011, DESEA designed a biosand filter using 31.5-cm (12-inch) diameter PVC pipe which adhered to the geometry of the CAWST filter, but weighed only 10 kg (Figure 1). DESEA is currently installing these filters in homes and schools in remote Andean communities, and they would be equally well suited to communities elsewhere to which the concrete filters cannot easily be carried.

2.0 DESIGN DESCRIPTION

Figure 2 illustrates the design of DESEA's PVC filter, and Table 1 summarizes its design specifications with comparable data for the CAWST Version 10 concrete filter. The DESEA filter is constructed using a nominal 31.5-cm external diameter (S-25 grade), 6.2-mm thickness PVC drainage pipe. The pipe is cut to a 90-cm length, to which a custom-molded[1], 12-cm high, PVC end-cap is glued to serve as a sealed base. The 31.5-cm diameter pipe was selected to provide for ample treatment capacity, robustness, and filter stability.

A nominal ½-inch (12.7 mm) diameter PVC standpipe rises within the sand media and exits the filter wall at a depth of 10 cm below the sand surface in order to avoid disturbance of the biolayer within the surface sand. This interior standpipe positioning has been adopted in order to decrease the length of the external outlet pipe, and thereby reduce its exposure to external damage; to provide for easy repair of the outlet pipe (without excavation of the entire column of sand and gravel media); and to minimize the water pressure at the fitting where it passes through the filter wall.

The ½" diameter external outlet pipe is supported by PVC welding or gluing a molded segment of 6.2-mm PVC to the exterior filter wall. The outlet pipe segments are connected by threaded and slip-socket

[1] A PVC fabricator in Cusco molds the bases for DESEA, using an oven and press, at a cost of US$15.00 per cap. DESEA is investigating other, more universally available solutions for filter bases, including welding or otherwise affixing a flat disc.

elbows to allow for easy disassembly and repair. A compression fitting on the interior filter wall consists of a threaded universal union, a 4.0-cm (1½”) long ½” galvanized nipple, a rubber gaskets, a plastic gasket; and on the exterior wall, the fitting consists of a rubber gasket, a plastic gasket, and a galvanized elbow.

The filter has an effective reservoir depth of 18 cm and a reservoir volume (above the standing water level) of 12.9 L. The treatment sand column depth is 54.5 cm, and the sand pore space volume (equivalent to the water treatment capacity) is 15.7 L. The difference between water treatment capacity and the reservoir volume allows for variation in actual sand pore space volume with varying sand texture.

FIGURE 1. DESEA PERU PVC FILTER.

FIGURE 2. DESEA PERU PVC FILTER CROSS-SECTION.

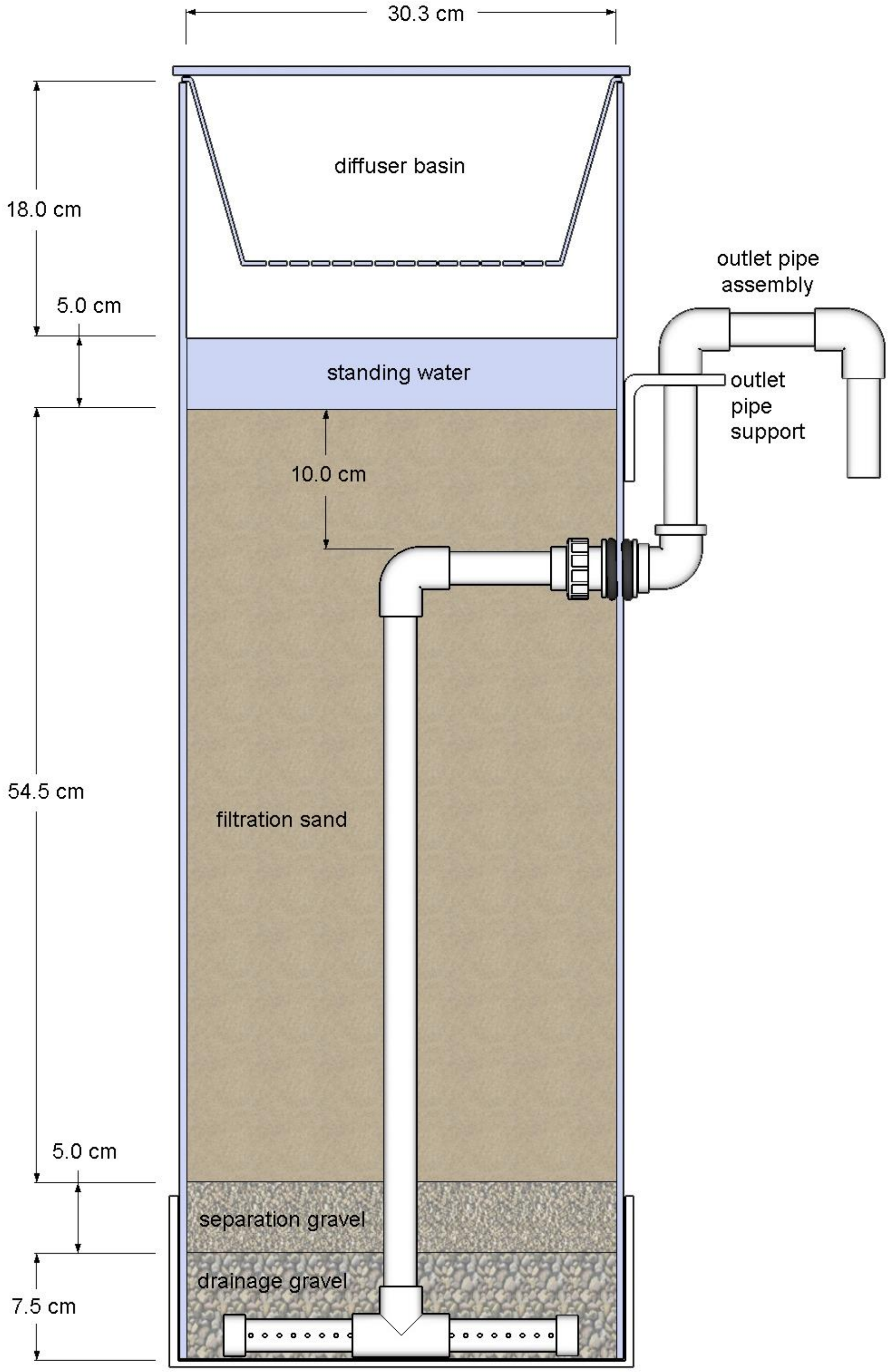

TABLE 1. DESEA PERU PVC FILTER AND CAWST V.10 FILTER SPECIFICATIONS.

DIMENSION	DESEA PVC	CAWST V.10*
internal diameter (cm)	30.26	n/a
external diameter (cm)	31.50	n/a
cross-sectional area at sand surface (cm^2)	719	590
internal height (cm)	90.0	87.4
total filter volume (L)	64.7	n/a
drainage gravel depth (cm)	7.5	5.0
drainage gravel volume (L)	5.4	±3.0
separation gravel depth (cm)	5.0	5.0
separation gravel volume (L)	3.60	±3.25
treatment sand depth (cm)	54.5	54.3
treatment sand volume (L)	39.2	±30.0
water volume in treatment sand (L)	15.7	12.0
standing water depth over sand (cm)	5.0	5.0
available water reservoir depth (cm)	18.0	17.8
available water reservoir volume (L)	12.9	12.0
loading rate ($L/h/m^2$)	400	400
maximum flow (L/min)	0.5	0.4
filter weight with outlet piping (kg)	10.0	95.0
diffuser basin depth (cm)	13.0	15.8
diffuser basin hole size (mm)	2.0	2.0-3.0
diffuser basin hole spacing (cm)	1.5	2.5

*Centre for Affordable Water and Sanitation Technology (2012); Baker, pers. comm.

3.0 FILTER EVALUATION

3.1 Filter hydraulics

3.1.1 Hydraulic tests

Tests were conducted to confirm that the DESEA filter is achieving a condition referred to as 'plug flow'; that is, that water passes slowly through the filter media and not more quickly along the filter wall nor along the interior standpipe as 'slipstream flow'. This testing was carried out by pouring a saline solution into the filter – a tracer dye can also be used – and then measuring the filter discharge and its electrical resistance until detection of the saline water at the outlet. If the calculated filter water treatment capacity (in this case, 15.7 L) is fully discharged prior to detection of the saline water, then it can be assumed that no slipstream flow is taking place.

For DESEA's tests, a solution of 120 mL sodium chloride in 11 L of tap water was prepared and poured into the filter. Electrical resistance of the filter discharge was measured at five-minute intervals with an ohm-meter to determine the rate of the solution passage through the filter. During this procedure, a constant discharge was maintained by fresh water addition to the filter every 10 minutes. In tests of the DESEA PVC filter, 15.8 litres of water were discharged prior to detection of the higher salinity water, thereby confirming that plug flow was being attained.

3.1.2 Filter loading and flow rates

The DESEA biosand filter has a cross-sectional area of 0.072 m^2, which is 22% larger than the CAWST Version 10 concrete filter (Table 1). At CAWST's recommended maximum loading rate of 400 $L/h/m^2$ (of cross-sectional area) the PVC filter has a maximum outflow rate of 0.5 L/min (Baker, pers. comm.).

3.2 Filter water quality

Table 2, from the Centre for Affordable Water and Sanitation Technology (2012), summarizes the treatment efficiency of the widely-tested, Version 9 concrete biosand water filter.[2] Removal of protozoa and helminths is virtually 100%, and bacteria removal is typically in the range 96.5-98.5%. Given that the key dimensions of DESEA's PVC filter are equal to or greater than the CAWST filter, it is expected to have an equivalent treatment efficiency.

Water quality analyses have been carried out to test the efficacy of the DESEA filter design. Individual tests were conducted by the Peru Ministry of Health (MINSA) laboratories in Calca and Sicuani – for MINSA itself, for NGO Soluciones Prácticas (Sicuani), and for DESEA Peru – of total and thermotolerant coliform bacteria counts. As well, DESEA has carried out in-house testing of water filter treatment of surface water with high E-coli and total bacterial counts (using Micrology Laboratories' *Coliscan Easygel* method) and had samples tested by a commercial laboratory in Cusco.

Test results to date have found the water treated by DESEA filters to be suitable for human consumption by MINSA standards (less than 1 CFU/100 mL water); nevertheless, further sampling may reveal some

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[2] Table 2 data are based on CAWST Version 9 filter which was superseded by Version 10 in 2009; testing of Version 10 by CAWST is currently being conducted and is expected to demonstrate improved bacteria removal.

passage of bacteria as suggested by the Table 2 data summary.[3] The results to date do suggest that the DESEA PVC filter is meeting or exceeding the treatment efficiency demonstrated for the CAWST biosand filter.

TABLE 2. BIOSAND FILTER TREATMENT EFFICIENCY.

	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Iron
Laboratory	up to 98.5%	70 to >99%	>99.9%	up to 100%	95% <1 NTU	not available
Field	87.9 to 98.5%	not available	not available	up to 100%	85%	90-95%

(from the Centre for Affordable Water and Sanitation Technology, 2012)

3.3 Filter assessment

Independent assessment of DESEA Peru's PVC filter model has been conducted at DESEA's shop and in the field on three occasions (in 2011, 2013, and 2015) by representatives of the Centre for Affordable Water and Sanitation Technology, and it has been found to meet the specifications for the CAWST Version 10 filter (Baker, pers. comm., 2011; Manzano, pers. comm., 2013 and 2015).

4.0 FILTER CONSTRUCTION

4.1 Materials, costs, and tools

Table 3 lists the tools used by DESEA Peru for filter construction. Simpler methods for cutting and assembling can also be used, particularly if few filters are being constructed.

TABLE 3. TOOLS FOR FILTER CONSTRUCTION.

belt sander and 80-grit sanding belts	C-clamps
electric drill	tape measure
drill bits - 2 mm, 3 mm	guide for cutting pipe
key-hole saws - 16 mm, 22 mm, 50 mm	guide for outlet pipe assembly
circular saw	120-grit emery cloth
fine-tooth, 8-10 cm wide back saw	PVC solvent cement
PVC welding heat gun	4-mm PVC welding rod
thread-cutting die for ½" PVC pipe	thread-seal tape
bench vice	clear silicone sealant

[3] As standard practice, CAWST recommends chlorination of filtered water as a final barrier to bacterial contaminants.

The principal filter components are the 31.5-cm diameter filter body with attached base and pipe support, ½" pipe and connectors, diffuser basin, plywood lid, and 20-litre bucket with spigot.
The total cost of filter materials, based on prices in Cusco at the time of writing, is US$52 (see Appendix 1). The time required for filtration media preparation and filter assembly (excluding purchase and transportation of materials) is approximately three person-hours.

4.2 Filter body

Six-metre-long, 31.5-cm diameter PVC pipes are cut into six, 90-cm sections (Part F1[4]) with the remaining 60-cm length being used for material to fabricate the outlet pipe support. In DESEA's case, the 31.5-cm (inside-diameter) cap used as the base is formed and glued in place by a PVC supplier in Cusco. These caps are available commercially; however, in Cusco, the fabrication cost is lower than the retail price.

The upper rim of the filter is leveled with a belt sander or by hand-sanding to eliminate gaps between the filter body and the plywood lid (F19).

A 22-mm hole is drilled in the filter wall at the height at which the interior standpipe exits the filter wall. This hole is typically 33 cm below the filter rim; however, the measurement is confirmed for each assembled standpipe. The inside edges of the hole are sanded to provide for a water-tight seal.

4.3 Diffuser basin

For a diffuser basin, DESEA uses a 13-cm deep, 31.7-cm outside diameter plastic basin (F18) which is commercially available in Cusco. In order to avoid any dimpling of the sand surface caused by streams of water through the diffuser basin, DESEA drills 2-mm holes in a grid with a 1.5-cm spacing. Some dimpling of the sand surface was encountered when using 2.5-mm holes, likely due to the shallow depth of the diffuser basin.

As a trial, DESEA has also fabricated a 16-cm deep diffuser basin in the form of a truncated cone using galvanized sheet metal. Although this was found to be a more expensive approach at the cost of sheet metal and labour, in other areas, where labour costs are low or plastic basins are unavailable, this might be a preferable method. A sheet metal basin would be more durable and can be shaped to the precise dimensions required.

Figure 3. Outlet pipe support.

4.4 Outlet pipe support

The outlet pipe support (Figure 3; F13) is a custom-built support arm designed to resist incidental forces applied to the outlet pipe that could result in damage to the outlet

[4] Filter components are illustrated in Figure 6 and numbered and described in Appendix 1.

pipe or to the accessories joining the interior standpipe to the outlet pipe. The pipe support is fabricated with leftover 6.2-mm thick PVC pipe that is heated and molded to produce a right-angled form which is glued and welded to the filter wall.

In the DESEA workshop, an inexpensive toaster-oven is used to uniformly heat a rectangular section of leftover PVC (5.5 x 11.5 cm) at 200°C for five min. This heated piece is placed in a custom-built mold and folded at a 90° angle. While the PVC material is cooling, C-clamps, metal plates, and a wooden form are used to shape curved and flat surfaces on either side of the bend (Figure 4).

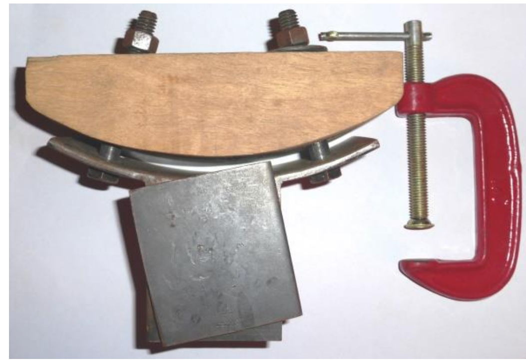

Figure 4. Outlet pipe support mold.

Once the molded pipe support has cooled, the edges of the piece are belt-sanded to yield a uniform 5-cm wide, 11-cm long, angled pipe support. A 22-mm diameter hole is drilled with a keyhole bit at a centered position in the horizontal portion of the pipe support.

DESEA uses PVC solvent cement to glue the pipe support at a position where the upper slip-socket PVC elbow (F15) of the outlet pipe will sit flush against the pipe support. Once the pipe support is glued in place, DESEA strengthens the union by PVC-welding the perimeter of the pipe support to the filter body using a heat gun and PVC welding rods (Figure 5). If PVC welding equipment is not available, DESEA recommends using high-strength glue and widening the surface area of the support which is in contact with the filter wall.

4.5 Interior standpipe and outlet pipe

The interior standpipe and exterior outlet pipe (Figure 3) are constructed with nominal ½" PVC pipe with 2.9-mm wall thickness (sold with threaded ends in Peru and exceeding Schedule 40 specifications). As connectors, the thicker-wall, commonly-available PVC pipe fittings are used, including slip-socket caps, slip-socket tees, slip-socket elbows, mixed (threaded/unthreaded) elbows, and threaded elbows. All pipe segments are cut to the precise length with a 14-point backsaw and de-burred with 120-grit sand paper. A jig or template can be used to ensure that assembled outlet pipe dimensions are consistent.

Interior standpipe and outlet pipe construction proceeds as follows (see illustration of components in Figure 6 and dimensions, part numbers, and descriptions in Appendix 1):

Figure 5. PVC welder and rod.

- The 11-cm, inlet segments of the interior standpipe (F2; Appendix 1) have four rows of radially-spaced, 3-mm holes drilled 1 cm apart and starting 1 cm from each end.
- Slip-socket end caps (F3) are glued to the outside ends of the two inlet segments, with the flat edges of the caps (if present) aligned to seat the intake pipe as close as possible to the filter base (to minimize drainage gravel volume when installing the filter).
- The inside ends of the inlet segments are glued to a slip-socket tee (F4).
- The 51-cm interior standpipe (F5) is glued to the slip-socket tee at its lower end.
- A slip-socket elbow (F6) is glued to the upper end of the interior standpipe, with the elbow alignment being the same as that of the inlet segments.
- A 10-cm, upper, horizontal segment of PVC pipe (F7) – with threads cut at one end using a thread-cutting die – is glued to the slip-socket elbow (F6) at the upper end of the vertical standpipe.
- A PVC universal union (F8) and a 3.8-cm galvanized nipple (F9) are tightened together (with thread-seal tape applied).
- ***It is recommended that the internal standpipe assembly not be screwed together with the universal union (F8) until the filter is at the installation site, in order to avoid damage during transport.***
- A silicone (or rubber, though not as long-lasting) gasket (F10), with silicone adhesive sealant applied to the side facing the interior wall of the filter body, is placed on the galvanized nipple. Depending on the stiffness of the silicone gasket, a semi-rigid plastic gasket (F11) can be placed between the union (F8) and the rubber gasket (F10) to serve as a spacer and to distribute the fitting pressure evenly. DESEA cuts plastic gaskets from wash basins using 22-mm and 40-mm key-hole saws.
- A galvanized elbow (F12) with silicone (F10) and plastic (F11) gaskets (with silicone sealant on the side facing the exterior filter wall) is firmly tightened together with the interior universal union and nipple, with the exterior elbow facing vertically upward.
- A 13.5-cm PVC pipe with lower end threaded (F14), is passed through the outlet pipe support (F13) and tightened (with thread-seal tape applied) into the galvanized elbow (F12).
- The upper segments of the outlet pipe assembly, comprised of two slip-socket elbows (F6), a 6-cm horizontal pipe (F15), and an 8-cm outlet pipe (F16), all glued together, are glued to the 13.5-cm pipe (which has been tightened onto the galvanized elbow) and the assembly is aligned to face directly outwards.

4.6 Filter lid

DESEA cuts hexagons from 4-mm plywood sheets (24 per sheet) to serve as lids for the filter (F19). Circular lids work equally well, although the cutting requires a jig saw and is more time consuming. The plywood lids, when varnished, have been found to be durable (having been in place for six years in DESEA's project areas at the time of writing).

The layout of the hexagon cut pattern is as follows (see Figure 7):

- draw parallel lines across the plywood sheet width with an alternating spacing of 9.5 cm and 19 cm along the length of the plywood, starting 9.5 cm from one end;
- draw parallel lines along the plywood sheet length with a spacing of 16.5 cm across the sheet width; and
- connect the intersecting points to form hexagons 33 cm across.

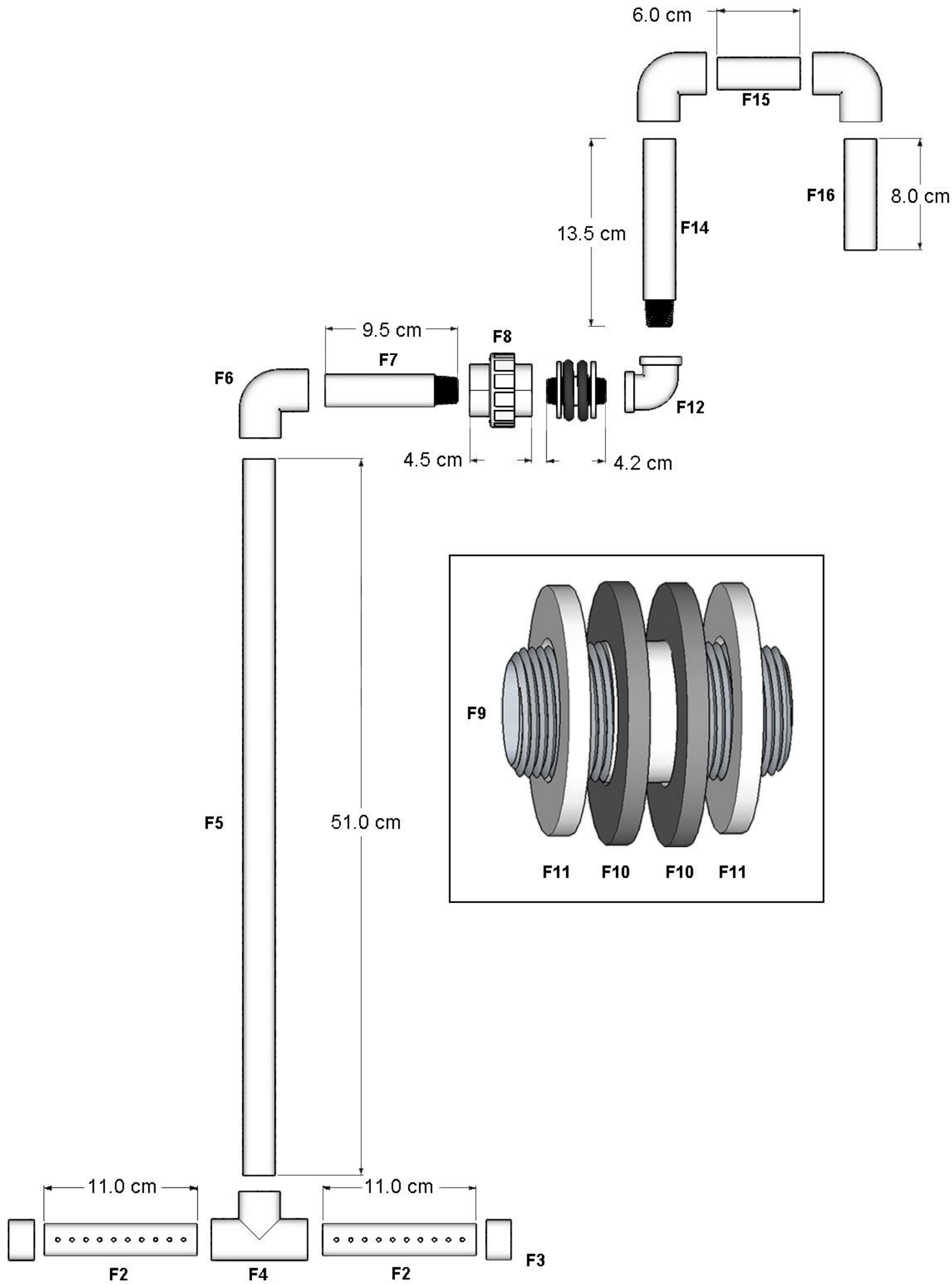

FIGURE 6. INTERIOR STANDPIPE AND OUTLET PIPE.

Many filter users place a sheet of plastic over the lid, outlet pipe, and bucket to keep the filter and bucket cleaner and free of insects.

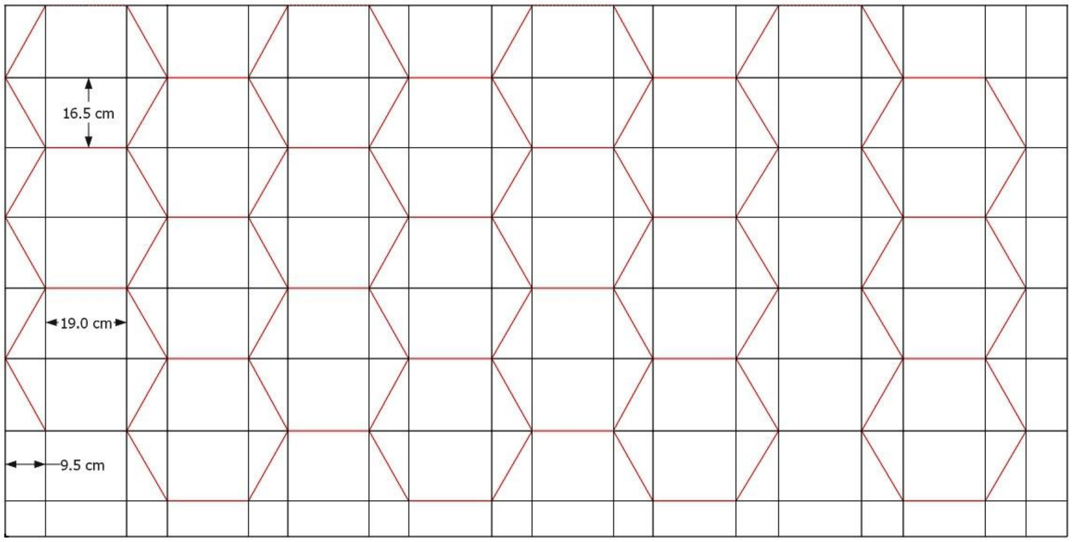

FIGURE 7. PLYWOOD LID CUT PATTERN.

5.0 INSTALLATION

5.1 Tools and materials

TABLE 4. TOOLS FOR FILTER INSTALLATION.

tape measure
25-cm spirit level
wash basin
small pick axe
1-m measuring stick (marked with depths of gravel layers measured from filter upper rim)
channel lock pliers or vice grips
crescent wrench
stopwatch
120-grit emery cloth
cleaning cloth

TABLE 5. MATERIALS FOR FILTER INSTALLATION.

filter body (F1)
3.6 litres of washed 6-mm gravel (5 litres of unwashed 6-mm gravel brought to site)
5.4 litres of washed 12-mm gravel (6.5 litres of unwashed 12-mm gravel brought to site)
40 litres of washed 0.7-mm sand (50 litres of unwashed sand are brought to site)
interior pipe assembly (F2-F7) – assembled in shop; installed at site
exterior pipe assembly (F8-F16) – assembled in shop; installed at site
diffuser basin
20-litre bucket with 16-mm drilled hole for spigot
bucket lid with 22-mm drilled hole for outlet pipe spigot
one 22-mm inside diameter rubber gasket (F10) to seal at bucket lid hole
PVC solvent cement
tube of clear silicone sealant
thread seal tape
33-cm width hexagonal plywood lid

5.2 Sand and gravel preparation

Methods for sand and gravel selection, sieving, and washing are outlined in detail in CAWST's filter manual (2012). In brief: the drainage gravel is the size fraction which passes a ½" (12.7 mm) screen, but not the ¼" (6.3 mm) screen; the separation gravel passes the ¼" screen, but not a 0.7 mm screen; and the filtration sand is the texture which passes a 0.7 mm screen. A fraction of the silts and clays within the fine sand matrix is then removed by washing of small quantities of materials at a time. Correct filtration sand texture can be checked with a jar test (refer to CAWST, 2012 for details) and confirmed by filter flow measurement. For the DESEA filter, the flow must be ≤0.5 L/min. and, for user convenience, ≥0.2 L/min. For proper filter functioning the flow must not exceed 0.5 L/min.

Depending upon road access and the quantity of filters to be installed, DESEA either sieves the filter media at its workshop or transports the unsieved materials directly to the field site for sieving with the assistance of filter beneficiaries. In all cases, washing of the sand and gravel media is carried out by community residents with guidance from the DESEA filter technician, nurses, or community health workers. Supervision is often required to ensure that the filtration sand is not too thoroughly washed, which can produce filter flow rates higher than the prescribed 0.5 L/min.

5.3 Transportation of filter and materials

Three or four people (or trips) are required to carry the filter, sand, and gravel (with horses often being used in the Andes). The 10-kg filter body, standpipe assembly, outlet pipe assembly, bucket and lid, diffuser basin, and plywood lid can be carried in a sling on one's back. The 50 litres of sand are most conveniently moved in three sacks (of approx. 25 kg each); and the 5 litres of 6-mm gravel and coarse sand and the 6.5 litres of 12-mm gravel are carried in separate sacks. Equipment for filter installation is easily carried by a single person. Filter recipients normally transport the filter and materials to their homes themselves.

5.4 Installation of filter

The first step at the installation site is the final assembly of the interior and exterior outlet pipe components. These components had been prepared and partially assembled in the shop, but not entirely glued and tightened together, in order to avoid damage during transport (see Section 4.5). Only the compression fitting, comprised of the universal union, nipple, silicone gaskets (with silicone sealant), plastic gaskets, and galvanized elbow, are installed in the shop.

- First, check that the universal union (F8), galvanized nipple (F9), and interior gaskets (F10 and F11), with silicone sealant applied on the interior filter wall, are fully tightened together with the exterior gaskets (F10 and F11, with silicone applied), the galvanized elbow (F12), and the vertical segment of the exterior outlet pipe (F14).
- Then screw the interior 10-cm segment (F7) and standpipe assembly to the universal union (F8), with thread-seal tape applied.
- Finally, glue the outlet assembly, consisting of two slip-socket elbows (F6), a horizontal segment (F15), and an outlet spout (F16), together with the inner, vertical segment of the exterior outlet assembly (F14).

A convenient filter location inside the home (or kitchen annex) is chosen with the resident, ensuring an adequate distance from open fires. The Andean homes in which DESEA installs filters have dirt floors, thus a firm, level base is excavated and the filter installed in a stable, vertical position.

To install the sand and gravel media, the filter is first filled with water to slightly less than half its depth. The cleaned, drainage gravel is then poured into the filter and a calibrated measuring stick (marked with depths of gravel layers measured from the filter upper rim) is used to level the gravel surface to a depth of 7.5 cm above the filter base (and 5 cm above the perforated inlet pipe). The cleaned separation gravel is then poured into the filter and leveled with the measuring stick to a depth of 5 cm above the drainage gravel layer.

The washed, fine sand is next poured rapidly into the filter ensuring that there is always sufficient water to cover the sand. The distance from the filter rim to the base of the horizontal segment of the exterior outlet pipe (F15) is measured in order to determine the water level depth within the filter during the pause period. The water level in the filter is maintained at the level of the lower side of upper horizontal pipe segment. The sand surface is initially leveled at a depth of 4 cm below this water level. This level allows for one cm of sand settlement to provide for the desired 5-cm water depth above the sand.

Upon completion of the installation, the filter reservoir is filled and the flow measured to confirm a flow not exceeding 0.5 L/min. At this final stage of the installation, a veneer of silts and clays may settle on the sand surface and cause the flow rate to be lower than desirable. In this case, additional water is added to the filter, the sand surface is agitated, and the turbid water is scooped out and discarded. This “swirl and dump” procedure (CAWST, 2012) may also be required periodically during filter use, especially if the raw water is turbid.

5.5 Water storage bucket

For water storage, DESEA uses 20-litre plastic buckets (F19) which had previously held cooking oil. These buckets are widely available, durable, low cost, and food-safe. The ½" PVC outlet pipe (F16) fits closely within a 22-mm hole which is drilled in the bucket lid. In the case of an irregular hole, a 22-mm inside diameter rubber or silicone washer (F10) can be placed around the pipe above the opening. An outlet spigot (F20) is inserted in a 16-mm hole near the base of the bucket; silicone sealant is placed on the inside and outside spigot gaskets; and the spigot is tightened in place.

In the homes in which DESEA is installing filters, the storage bucket is usually placed on two adobe blocks; bricks, stumps, and boards may work equally well, but the base must be solid and level. The bucket height is set to allow about 3 cm of the ½" outlet pipe to enter the bucket lid. To remove the bucket, the lid is raised along the outlet pipe and the bucket is removed outward. The lid is kept flush with the bucket, but not tight, to allow for frequent removal for cleaning. More than any other filter maintenance instruction, it is emphasized to filter users that a clean storage bucket is vital to maintenance of high drinking water quality.

5.6 Training, record keeping, and monitoring

Prior to installation of water filters in homes (and before residents sieve and wash their sand and gravel media) DESEA Peru nurses or filter technicians conduct a 1.5-hour workshop, with small groups of neighbourhood residents, concerning safe hygiene and sanitation practices and water filter operation. At the time of filter installation, additional instruction is provided to household residents concerning the maintenance of their filter and DESEA's monitoring program.

During installation, DESEA records the date, filter flow, resident names, community sector, GPS coordinates, and water sources. A poster is mounted near the filter to illustrate maintenance practices and for DESEA nurses and community health workers (resident women trained to inspect filters as part of a comprehensive community health program) to maintain a record of filter inspections (Appendix 2). DESEA staff return within one month to check filter condition and to provide further instruction, and then every three months for the first year. After this first year, DESEA's community health workers (CHWs) carry on the filter monitoring and hygiene and sanitation education. DESEA has found this on-going monitoring and education program to be essential to achievement of a high rate of correct filter usage.

Finally, DESEA Peru and the homeowner sign an agreement which stipulates DESEA's monitoring and training commitments and the homeowner's filter use and maintenance responsibilities. DESEA commits to a year of household visits. The family agrees to keep the filter and bucket clean, to add water daily, to immediately replace any broken components (such as the spigot, bucket, or diffuser basin) – all available for sale by DESEA CHWs – and not to move the filter without assistance from DESEA staff.

In the event that a filter must be moved, DESEA staff and residents carefully shift the filter, keeping it upright, onto the centre of a tarp or blanket. The filter can then be carried in a vertical position by four people with minimal disturbance of the filter media.

6.0 CONCLUSION

This manual describes the design, construction, and installation details for a PVC biosand filter designed by DESEA Peru for use in remote areas of the Peruvian Andes. At the time of writing DESEA had installed more than 450 filters in five Andean communities. Design specifications, hydraulic testing, water analysis, and field observations confirm that this filter meets the CAWST measures for water-borne pathogen removal and objectives for water filter use by households. This manual has been produced to enable organizations working in inaccessible areas elsewhere to construct and install PVC filters.

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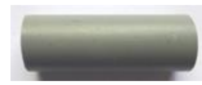
APPENDIX 1. DESEA PERU PVC FILTER COMPONENTS AND COSTS.

Part description	Dimensions	Part #	Units	Cost (USD)	Photo (not to scale)
PVC pipe with fabricated end cap glued in place (S-25 grade)	31.5-cm diameter; 90-cm depth; 6.2-mm thickness	F1	1	39.50	
standpipe inlet with 3-mm holes 1 cm apart	nom. ½” PVC pipe; 11-cm length	F2	2	0.22	
slip-socket end caps	nom. ½” PVC	F3	2	0.36	
slip-socket tee	nom. ½” PVC	F4	1	0.40	
vertical segment of interior standpipe	nom. ½” PVC pipe; 51-cm length	F5	1	0.49	
slip-socket elbow	nom. ½” PVC	F6	3	0.24	
horizontal segment of interior standpipe	nom. ½” PVC pipe; 10 cm length; threaded one end	F7	1	0.09	
universal union	nom. ½” PVC pipe; 4 cm length; threaded	F8	1	1.20	
galvanized nipple	nom. ½”; 4-cm length; threaded male ends	F9	1	0.60	
silicone gasket	4-cm O.D.; 2.2-cm I.D.	F10	3	0.60	
plastic gasket	4-cm O.D.; 2.2-cm I.D.	F11	2	0.05	
galvanized elbow	nom. ½”; threaded	F12	1	0.60	

Part description	Dimensions	Part #	Units	Cost (USD)	Photo (not to scale)
PVC outlet pipe support with 22-mm hole	11-cm length; 5-cm width; 6.2-mm thickness	F13	1	0.00	
inner, vertical segment of exterior outlet pipe	nom. ½" PVC pipe; 13.5-cm length; threaded one end	F14	1	0.14	
horizontal segment of exterior outlet pipe	nom. ½" PVC pipe;	F15	1	0.06	
vertical outlet spout	nom. ½" PVC pipe; 8-cm length; unthreaded	F16	1	0.08	
diffuser basin with 2-mm holes on 1.5-cm grid	31.7-cm O.D., 13-cm depth plastic	F17	1	1.60	
hexagonal plywood lid	33-cm width; 6 mm thickness	F18	1	0.68	
Bucket and lid (with 22-mm hole)	20 litre	F19	1	2.00	
spigot	NA	F20	1	0.70	
			Total cost	**US$ 51.92**	

APPENDIX 2. FILTER MAINTENANCE AND MONITORING POSTER.