How to Select the Proper Human-Powered Pump for Potable Water

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by

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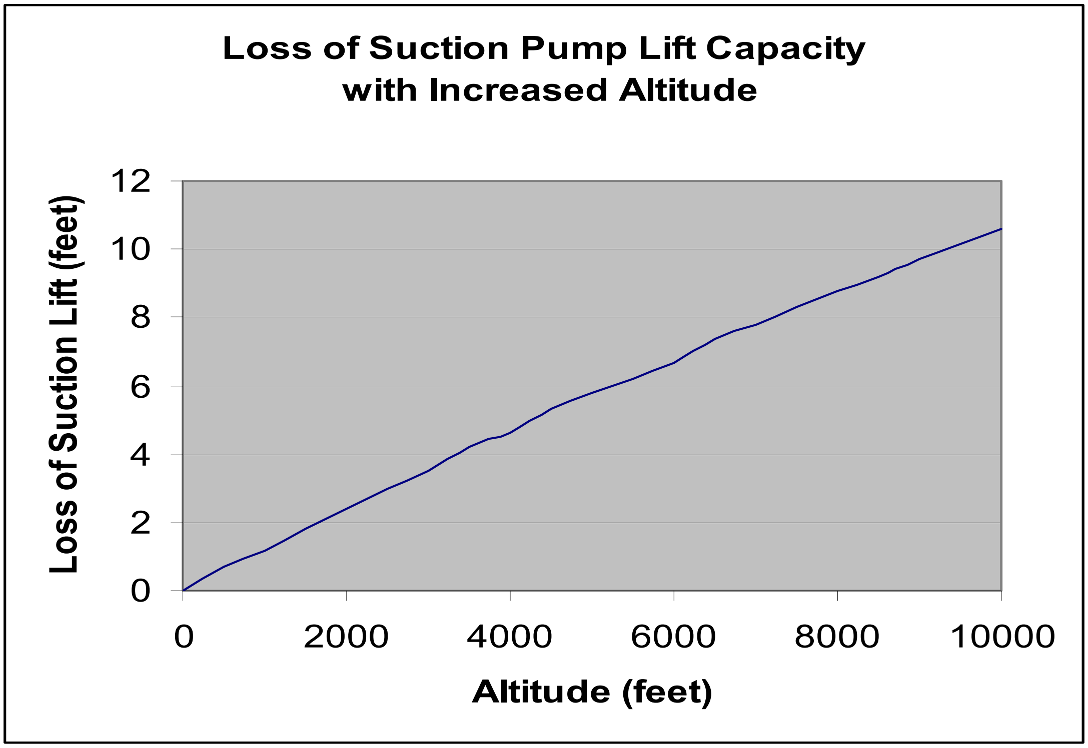
Human-Powered Pumps

Pumps are a common means of lifting water from a clean groundwater source to a useful point of access, but all pumps have moving parts and are therefore destined to break. Failure often makes the water source inaccessible until the pump is repaired. Proper selection of a pump will reduce undesirable downtime and will empower the local community to manage their water source. Selection of a pump for lifting potable water in a developing country involves investigation of the groundwater depth, water characteristics, capacity demand, preferred method of operation and maintenance sustainability. All of these parameters affect the total lifetime cost of the pumping system. The goal of this report is to provide information useful for selecting the most economical and functional pump for various installation conditions. The types of pumps discussed in this paper include the following:

Type	Depth Range	Distinguishing Features
	Shallow	
Row pump	6 m (19 ft)	Easy to make of PVC pipe
Suction hand pump	7 m (23 ft)	Very common traditional design
Foot Pedal (Treadle) pump	7 m (23 ft)	Powered by your legs instead of arms
	Intermediate	
Direct Action Plunger pump	12 m (39 ft)	Lower cost direct action pump
Bucket pump	15 m (49 ft)	Many buckets on a continuous loop
Direct Action pump	15 m (49 ft)	Discharges water on up and down stroke
	Deep	
Diaphragm pump	45 m (148 ft)	May work in curved bore holes
Rope & Disk pump	60 m (197 ft)	Easy to make in low income countries
Progressive cavity pump	60 m (197 ft)	Continuous output from rotary motion
Piston pump	90 m (295 ft)	Deepest capability

Shallow Well Pumps

Groundwater depths around 7 m (23 ft) or less may be considered shallow. Some common types of pumps used for shallow wells are the traditional suction (pitcher) pump, foot pedal (treadle) pump and row pump. All of these pumps apply suction to the air or water in the rising main which in turn lifts water from the groundwater table up into the pump and out the spout. These pumps cannot lift groundwater deeper than 7 m because of their limitation in applying enough suction called net positive suction head (NPSH). This takes into account atmospheric pressure at sea level (1 atmosphere = 33.9 ft. of water at 4 C) friction losses, minor seal leakage and the normal temperature range of groundwater. A large increase in altitude will decrease atmospheric pressure, decrease NPSH and affect the performance of any suction pump. A graph of the loss of suction capacity versus altitude is provided for correction in such situations. If for example a treadle pump is promoted as capable of lifting water from 23 ft. at sea level, the graph indicates that at 8000 ft elevation a loss of 8.8 ft. of suction capacity will result. The pump used at this elevation is now capable of lifting water from a depth of approximately 14 ft.



Adapted from Suction Lift Correction table published by Pacific Liquid & Air Systems

A mechanic can easily access the critical moving parts in these pumps since the piston is in the top housing. The foot valve (one way check valve) down in the rising main allows water to be sucked up into the rising main but not go back down into the well. This part will not be as easy to reach, but the relative simplicity and accessibility of suction pumps makes them ideal for low cost applications. These pumps often must be primed before use to get a good seal or they will not suck water up to the piston. The quality of available priming water must be considered if this type pump is to be used. A treadle pump uses two pistons at a time with one going down as the other rises. The principle is the same as a hand pump, but the energy applied to move the pistons comes from foot action instead of arms. There is less physical exertion using leg muscles since they are stronger than arms. The treadle pump is promoted heavily as a small farmer irrigation pump, but is used some for pumping potable water. The open top design of present models leaves the pistons completely exposed to the air and elements so that contamination is likely without care. The top portion of the row pump or rower pump is mounted at an angle of approximately 30 degrees from horizontal so the user may pull the T bar handle in a rowing motion to lift the water up and out of the well. Most rower pumps need priming and they are limited to a

NPSH of 6 m (19 ft) at sea level. The handle end of the pump is not sealed so care should be taken to avoid contaminants entering the top of the pump.

Intermediate Depth Pumps

Direct action and bucket pumps are appropriate for reaching groundwater to depths of 12 to 15 m. The handle is connected to the lifting mechanism that is submerged in the groundwater so NPSH is not an issue. The direct action plunger pump operates by up and down motion of a PVC pipe (called the plunger pipe) inside a stationary PVC pipe (called the tail pipe). Both pipes reach the groundwater level and have check valves at their lower ends allowing water to enter but not exit. As the plunger pipe is lifted, it sucks water into the bottom of the tail pipe. Both pipes gradually fill with each up stroke of the pumping cycle until water overflows out the spout near the top of the tail pipe. The weight of the water being lifted restricts the reach of this pump to 12 m depths. This design but does not require a cup seal between the plunger and the tail pipe. Direct action pumps and the bucket pump are used to depths of 15 m. The direct action pump has a pump rod connecting the handle to a piston that has a cup seal creating a tight seal inside the rising main. Several direct action pump models have a hollow PVC rod that remains full of air which provides buoyancy to counter some of the weight of the water column being lifted to the surface. As the pump handle is lifted, water is lifted up through the rising main and out the spout, and at the same time water at the bottom of the well is sucked up through a one way foot valve filling the space evacuated by the plunger. When the handle is pushed down the volume of the rod displaces water trapped by the foot valve causing water to rise up and out the spout so water comes out on both the up and down stroke. A bucket pump is similar to the old tried and true windlass and bucket except there are multiple buckets on a chain loop. As the handle of the windlass wheel at the top of the well is turned, full buckets are lifted and empty buckets are lowered. A large diameter well is required to fit the width of the buckets.

Deep Well Pumps

Deep well pump types capable of reaching groundwater to depths of 45 m include the rope pump (lift disk or chain and washer pump), diaphragm pump, progressive cavity pump (helical rotor pump) and piston pump (lever-operated reciprocating action pump). A rope pump operates like a bucket pump, but instead of buckets on chain it is made of a loop of rope with rubber washers along its length. As the windlass turns the rope travels into the PVC pipe and the washers force water into the pipe and up to the point of discharge. This is an old pumping method that has been adapted and improved in recent years. It is now used not only in large diameter wells, but also in boreholes. The PVC riser pipe which carries the water up is one inch diameter, the washers fit closely inside without too much friction and a guide pipe of larger diameter also fits in the borehole to guide the rope down into the water. Two-person rope pumps (with handles so two people can turn the wheel) are used in Nicaragua to depths of 60 m. A diaphragm pump uses an expandable diaphragm in the submerged pump cylinder to push water up and out of the rising main when pressure is increased by means of a mechanism such as a foot pedal. When the diaphragm air pressure is released, water enters the pump cylinder for the next cycle.

Since there is no up and down rod movement, it may be possible to use a diaphragm pump in crooked wells where other pumps might not work. A progressive cavity pump has a special shaped synthetic rubber lined cylinder (stator) fitting closely around a steel rotor that twists as the operator turns a crank or handle. As the rotor turns it squeezes the water up and out of the cylinder which then flows up through the rising main to the surface. This provides continuous flow of water with continuous rotation and can be fit with a motor to provide water under pressure for a distribution system if desired. The piston pump operated similar to the traditional suction pump with the foot valve and piston submerged in the groundwater. A long rod connects the piston to a handle for operation.

There are some deep well pumps capable of reaching groundwater deeper than 45 m. It is not unusual to have a hand pumps at these depths, but it takes more energy to operate and there are greater demands for robustness of pump and well casing parts. Special equipment may be required for extraction of deep pump parts for repair. A study has shown that “all handpumps have more breakdowns with increasing depth and number of different users.”(Rural Water Systems) Oxfam developed a pump for depths of 80 m by creating a hybrid of the Afridev and India Mark II handpumps. It uses a PVC rising main that is supported from the bottom of the borehole instead of hanging it from the top. This prevents pipe stretch and reduces stress on the pipe and joints.(Briscoe & McMurdie, 2001)

Manufacturers from various countries advertise very deep well pumps. The Mololift progressive cavity pump may be used to a depth of 60 m. The India Mark IV piston pump is a modified Mark II that is promoted as being capable of reaching 90 m. The Mark IV pump has an extra long handle for increasing the torque, a T bar so two people may operate it at the same time and counter weights placed on the long lever arm in order to assist in pushing the lever down to lift the heavy column of water from these depths. The Bush pump B type has been used in applications as deep as 100 m (328 ft). The Volanta piston pump is operated by a large diameter wheel instead of a lever arm. It has been installed to depths of 110 m (361 ft). This is not an exhaustive list, nor a recommendation for particular pumps.

Water Characteristics

Water characteristics such as high grit content and very low pH can shorten the useful life of a pump. Proper well development is necessary to remove grit or sand from a borehole. If it is necessary to install a sand trap or strainer down in the hole to prevent rapid wear on pump parts, the pump system must be capable of fitting this accessory and access to clean the trap/strainer will be required. In some locations of West Africa the groundwater pH is as low as four. This can cause severe corrosion of steel or galvanized iron pump parts resulting in pump failure in less than one year, but most groundwater does not have such low pH conditions.(Allen) Stainless steel pump rods and rising mains are corrosion resistant and stainless rising mains are thinner and therefore lighter and easier to remove than galvanized. Glass-fiber pump rods are strong, light and corrosion resistant but not yet used widely because of high cost. PVC pipe is corrosion resistant and has been used for direct action pump rods and rising mains for deep well pumps. Since clean water with neutral or high pH will not rapidly corrode pump parts it is cost effective to determine the water characteristics and purchase the pump suitable for the water, instead of assuming the worst and purchasing more expensive wear and corrosion resistant equipment. Note that quality control of materials is important and not all materials such as PVC pipe or galvanized iron parts are fabricated to the same standards around the world. It will be important to ask the pump supplier about the warranty for the pump and its suitability in the specific application. If a sand trap type device is recommended or required, it should be purchased from the same supplier that sells the pump so there will be no discontinuity in sizing or blame shifting should a problem arise over time.

Pump Capacity

Water usage often increases when closer access to clean water is made available, and health and hygiene may improve with increased water supply.(Shaw, 1999) Because of the increased work required, pump output is usually reduced by increase in well depth. Consideration of these factors will help determine the number of wells and pumps to be installed the meet project objectives. The table below provides reported pumping capacities in liters per minute at various depths for some representative pumps.

Brief Table of Human-Powered Pumps, Their Reported Performance and Characteristics

Name	Type	Depth (meters) and corresponding Capacity (l/min)	Corrosion Resistant	Village Level Operation and Maintenance	Location of Origin or Successful Use
Rower pump	Suction-row	6m=80 l/min		Yes	Nigeria
New No. 6	Suction	7m=36		Yes	Bangladesh
Swiss Pedal	Suction-treadle	7m=60	yes	Yes	Cambodia
NZ/Canzee	Direct/Plunger	12m=20		Yes	Ghana
Bucket Pump	Bucket pump	15m=10		Yes	Zimbabwe
Tara	Direct action	7m=24, 15m=23	yes	Yes	Bangladesh
INTI	Direct action	15m=?	yes	Yes	Bolivia
Afridev	Direct action	7m=26, 15m=22	yes	Yes	Kenya
India Mark II	Piston	7m=12, 45m=12		No	India
India Mark III	Piston	45m=?		Yes	India
Consallen	Piston	7m=14, 45m=14	yes	Yes	Liberia
U3	Piston	45m=10	yes	Yes	Nigeria
Afridev	Piston	24m=22, 45m=15		Yes	Zimbabwe
Vergnet	Diaphragm	7m=24, 45m=15		No	France
Abi-ASM	Diaphragm	45m=?		No	Ivory Coast
Monolift	Progressive Cavity	25m=16, 60m=9		No	So. Africa
Rope pump	Rope & disk	10m=40, 60m=8		Yes	Nicaragua
Bush pump-B	Piston	10m=30, 60m=9		Yes	Zimbabwe
India Mark IV	Piston	90m=?		Yes	India
Volanta	Piston	80m=4, 110m=<4		Yes	Niger

Operation and Maintenance

The most common low cost means of operating a pump in the developing world is by human power -- either hand or foot. This requires minimal infrastructure for the water to be made available to the operator. If a higher level of service is desired such that water is to be lifted to a storage tank or pumped into a distribution system, then more investment of design and cost will be necessary. Animal power, windmill, water wheel, photovoltaic solar, combustion motor and electric are appropriate for some locations. If powered pumping is to be used, one should consider what is successfully used in the region, why other power sources are not being used, if the local community desires higher technology and if higher technology affordable.

The use of self priming and hygienically sealed pumps is recommended for most applications. The row pump, suction pump and treadle pump may require priming. A source of clean water near the pump will be necessary before the pump will work. The bucket pump, treadle pump and row pump are not sealed from the environment so that blowing dust, rain or contaminants could get into the pump and contact the water. In some locations a cover is built over the pump to reduce contamination. The more robust steel pumps are sealed and durable for public locations with multiple users.

Pump maintenance has been a subject of much investigation and debate in recent decades. Village Level Operation and Maintenance (VLOM) is a term that has been coined to label pump systems that can be operated and maintained by the local village community. These pump systems must be durable including some level of corrosion resistance and the pump and spare parts must be affordable. The promotion of local community involvement in maintaining pumps has improved the operation of many water projects. A pump that is completely fabricated with local parts and labor is more easily repaired than a pump fabricated elsewhere, but there are benefits to selecting a very high quality more expensive pump that lasts for years without a major repair. It is reported that "implementation of handpump programmes in accordance with VLOM criteria have been only partially successful and the VLOM approach to maintenance has been very difficult to realize in the field, especially in Africa."(Colin, 1999) In Africa it is critical that the system of repair which includes spare parts flow, availability of local mechanics and payment methods for both be investigated before a technical selection is made.

There are different degrees of VLOM. Manufacturers and development agencies have modified pumps to improve low cost sustainability. One change is to reduce the number of different parts so it is cheaper to have spares on hand. An example is the use of identical parts for a piston pump foot valve and discharge valve. Some pumps have been designed with features that make repair easier. An example is the open top cylinder that uses a rising main with a larger diameter than the piston cylinder so the rod and deep well piston may be removed without pulling out the rising main pipe. The rope pump, treadle pump and row pump are reported to be simple to make in developing countries. The Bush pump was designed to be manufactured by local skilled mechanics so that all parts and repairs would be local. However, it uses a synthetic cup leather that is manufactured at low cost in industrialized countries. The quality of the locally made replacement part will be lower than if one is shipped from an outside supplier. The Afridev deep well pump is another example of a pump designed to be made with local skill, but it uses nylon bearing-bushes, foot valve and plunger. If the selected pump is not made locally, multiple pump suppliers should be contacted to determine what is available and who is going to support the equipment after purchase. Ask if there will be special tools to repair their pump, special equipment to lift parts or pipe from the well, and if they will train local mechanics to install and repair. Request a list of suggested spare parts from the supplier and confirm their materials are suitable to the water characteristics. Ask for a guarantee of performance from the supplier.

Handpump standardization has improved the overall utility of pumps in many countries. Standardization reduces the number of pumps local mechanics need to know how to fix, promotes the use of proven pumps and provides a sufficiently large market for a reduced number of spare parts so that local parts suppliers can exist. If there are standardized pumps in your area, it would be wise to select the most suitable pump from that list. Since many deep well (45 m) pumps are also suitable for shallow applications, one type of deep well pump could be used for a project that has a variety of pumping depths. This will increase the initial cost of a multiple pump project since shallow pumps are less expensive to buy and repair.

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