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Title: The SHIPO and Mzuzu drill method.
Two low cost and locally produced hand drilling technologies for tube wells to 50 metres deep.

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Abstract/Summary

To reach the SDG6, some 3.3 million waterjobs are needed in developing countries. (IWA 2016) A large part of these jobs are pump mecanics and well drillers. An important tool to reach the SDG6 (safe and affordable water for all), is reducing the cost of tube wells and one way to do that is to scale up manual drilling options. Manual drilling of wells can provide low-cost, but high quality water supplies and organisations like UNICEF and others are now promoting manual drilling at global level. The cost of manual drilling is significantly lower than for machine drilled wells, at 10 to 25% of the cost. (Danert. RWSN. 2015) An example of an innovative and low cost option is the SHIPO drill method which was adapted to the situation in southern Tanzania where groundwater levels range from 10 to 45 meters deep. The SHIPO drill combines sludging, percussion and jetting and with tungsten drill bits it can drill in hard layers like sandstone and laterite. Some 800 tube wells in East Africa have now been drilled with this and similar methods with depths to 45 meters deep. The drill sets are made by a local metal workshop and a complete SHIPO drill toolset for 45 metres deep cost ca 700US$ (Kaduma. 2016). The cost of a tube well made with this option, including a 4 inch PVC casing, is 500 – 1500 US$ depending on geology and depth.

Another low cost option is the so called Mzuzu drill. This is a combination of a "Soil punch" and a "Tube bailer". No tripod, pulley or drill pipes are needed. Some 60 tube wells till 18 metres deep have been made with this method. The cost of a Mzuzu drill tool set is around 80 US$ and can be made with local materials. The Mzuzu drill is also used to deepen hand dug wells that have dried up. Both the SHIPO drill and Mzuzu drill methods are disseminated by SMART Centres in Tanzania, Malawi, Mozambique and Zambia and are considered SMARTechs.
SMART Centres are WASH training centres and SMART is an abbreviation of Simple, Market-based, Affordable, Repairable Technologies. With large scale capacity building on this and other low cost drilling technologies there is much potential to reach the SDG6.

Introduction

Hand dug wells are a common water source in rural and peri urban areas and there are probably 3 to 5 million hand dug wells in sub Saharan Africa. The advantages and disadvantages compared to drilled tube wells are described in technical notes made by Enterprise Works (EW) and Practica foundation.(UNICEF 2009). An advantage of hand dug wells is that they are simple to make with local skills, have a low cost and in less permeable aquifers they have a storage capacity because water seeps in during the night. A disadvantage is that in general they less hygienic, cannot go deep into the aquifer (the ground water layer) and often dry up in the dry season. Making hand dug wells can be dangerous in soft soils because of collapsing of the wall. This can be avoided by using cement well rings but in general this is costly. Another option To deepen hand dug wells is using "Underlining", a technique that uses bricks to make well rings inside the well. A problem with hand digging is the lack of fresh air in wells deeper than 5

meters. (To solve this problem hand powered well ventilators were developed by the SMART Centres in Tanzania and Malawi.)
The other option to reach ground water layers are Tube wells also called boreholes. In general boreholes for communal water supply are made with drilling machines and cost from 3000US$ to 15000 US$ (UNICEF, EW, Practica 2009). However in areas with water levels of 50 meters or less and without hard bedrock layers, tube wells can also be drilled with manual drilling. It has now been proven that, if done well and in similar situations, manual drilled tube wells have the same quality and the same pump capacity as machine drilled wells. The advantage of manual drilled wells is that, for the same depth range, they can be 2 to 5 times cheaper than machine drilled wells. (Practica. 2015)
Options like augering and jetting for sandy soils were successfully introduced by EW in countries like Niger. They were mainly used in areas with shallow (3 to 8 meters) ground water levels and a well cost 150 - 250 US$ including a Treadle pump. Rotary jetting became very popular in Nigeria where a large part of the water supply of Lagos comes from thousands of wells made with this technology. (Danert, 2015), The Rota-sludge technology was with success introduced in Chad and other countries by the Practica foundation. The EMAS method, a simple jetting technique, was introduced in Bolivia and other countries and tens of thousands of mainly householdwells were drilled by local companies at a cost of 7- 10US$ per meter, including casing and an EMAS pump. (Buchner). Another and similar technique developed in Bolivia by Water for All international is the Baptist drilling method which combines sludging and percussion and instead of metal drill pipes uses only one heavy drill pipe of metal at the lower end and all other pipes are PVC pipes. (Waller). Both these technologies can drill down to 80 meters or more, can be locally produced and cost 100 to 300US$ for a complete well of 10 to 30 meter deep including casing and a hand pump like the EMAS pump.

Another innovation is the Rota-sludge, a technology based on the Indian sludge method, developed by Practica in Nicaragua in 1995 and lateron introduced in countries like Chad and Tanzania. Different from the Baptist method, the Rota-sludge does not use a valve at the bottom but the drill pipe at the top is closed by hand, which can be a bit muddy for the driller. The options mentioned have scaled up and there are thousands of wells drilled by local private companies. There are also technologies that have not scaled up like the Vonder rig that was introduced some 40 years ago in Zimbabwe and Malawi but is hardly used anymore.
Reasons for not scaling up seem to include that the technology was heavy to use and was not seen by companies as an interesting business.

Besides cost reduction for Communal wells, manual drilled wells also have much potential to increase Self-supply (family wells). A recent study in Zambia and Zimbabwe indicates that Self-supply is essential to reach the remote living families where machine drilled communal wells are to expensive. By improving existing and making new Self-supply wells the cost of reaching 100% coverage can be even less than coventional communal supply and can result in cost savings of 330 million US$ in Zambia and more than 260 million US$ in Zimbabwe. (Olschewski 2016)
Besides access to an improved water source, Self-supply wells can help to reduce rural poverty. Studies in Malawi and Tanzania indicate that the effect of Self-supply is increased family incomes of between 50 and 500 US$ per year (Maltha 2015).

Context, aims and activities undertaken

In 2003 the Rota-sludge drill method was introduced in Tanzania by the organization SHIPO in Njombe with training from the Practica foundation and funded by the Dutch organization Connect International. In the so called TAZAMO project some 1500 tube wells were drilled with this technology. Since the weight of the 2 inch diameter metal drill pipes becomes quite heavy for wells deeper than 20 meters SHIPO became interested in the Baptist method from Bolivia.

This method uses a heavy metal drill pipe of 3 meter length with a valve drill bit at the bottom. The rest of the drill pipes are 4 mm thick walled 1¼" PVC pipes so the total weight is low and even at depths of 40 meters all drill pipes can still be lifted by two people. Another advantage of the PVC pipes is that the percussion impact is not on the joints (sockets) of the drill pipes but on top of the drill bit where it is has most effect. The result is less pipe or joint breakage than with metal drill pipes. The Baptist drill method was adapted to the local situation with different drill bits and larger diameters. To drill hard ground layers like laterite, drill bits with tungsten tips were made. The SHIPO method is now also combined with jetting using locally available standard engine pumps with a 2 inch outlet. The limitation of a standard pump as compared to a special mud pump is that the pumpseal has to be changed every 3 to 5 wells depending the soil type. The advantage however is that these pumps are widely available at a cost of around 150US$. Experiences in Malawi indicate that the fuel cost to drill 20 meters is 5 to 10 US$ per well.

Master driller in Tanzania

Creating skilled drillers in Tanzania has been a long and winding road. For instance of the 20 people trained by SHIPO in the years 2005 to 2010 only a few became successful in starting a commercial drilling company. One company is the so called Uvino group who now employs 10 to 20 people, including drillers that were trained by SHIPO. There are 2 to 5 drilling teams working in the field to do the drilling and a person trained by SHIPO who now is master driller, does supervision but also the management, making contracts etc.

Because of his experience and skills, this masterdriller now also gives drilling training to others. In cooperation with the SHIPO SMART Centre he has trained drillers from 8 different regions in Tanzania and trained drillers in Malawi, Uganda, Mozambique and Kenya.

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The SHIPO drill, how it works

With a tripod, a pulley and a rope the drill pipes are pulled up by 2 to 4 people. At the bottom of the lower 30 kg metal drill pipe there is a valve bit which closes when going up and opens when going down. The drill mud lifts sand, clay or stone particles to the surface. The particles stay in settling pits and 'clean' drilling mud is flowing back in the tube well. In hard soils first a 2 inch hole is drilled and later on reamed to the desired hole diameter which can be 3 to 8 inch. When the well is deep enough in the aquifer, a filter screen and gravel pack is installed. The casing is made of standard thick walled (3mm) PVC pipes with diameters of 2 to 6 Inch. After installation of a gravel pack and cleaning of the well, a pump is installed. With this and similar methods some 800 tube wells have been made in Tanzania, Malawi and Mozambique. The knowledge of this method is disseminated via SMART Centres in these countries. The tube wells drilled with this technology can be combined with piston pumps like Afridev, Indian Mark 2 or submersible pumps. In most cases the tube wells are combined with locally produced Rope pumps and used by schools and small communities of maximum 150 users per pump. Because of its low cost, Rope pumps are also purchased by families (Self-supply) for domestic use or irrigation as is proven in Tanzania where some 5000 families paid for a Rope pump.

The cost of 30 metre tube well for Communal supply and made with this option, is 500 – 1500 US$ depending the casing diameter, geology and depth. If combined with a Rope pump, apron and soak pit, total cost are 700 – 2000 US$. For Self-supply cost in general are lower because of shallow wells, smaller casings. smaller aprons and the installation of an economy model.

	
Drilling a tube well of 30 meters deep with the SHIPO drill method	The SHIPO drill combined with jetting
	
One of the drill bits used for SHIPO drilling. It uses shafts of a bicycle as drill teeth and a 'floating valve' as foot valve.	New brill bit using tungsten tips. These drill bits can drill hard layers like sand stone and laterite without getting blunt.

Advantages of the SHIPO drill compared to the Rota-sludge drill method

1. 40 to 60% lighter in weight for the same depth so easier to transport
2. 30 to 50% cheaper; a complete drill set and 4 drill bits cost 500 - 800 US$ for 30 meter
3. Drilling is a "cleaner " job since the valve is at the bottom
4. Less breakage of pipe threads since the drill pipes are PVC
5. Can be combined with an engine pump so used for jetting
6. The new SHIPO drill sets have tungsten drill bits so can drill in hard layers
7. The light weight, low cost and high efficiency make it attractive for small businesses

Disadvantages of the SHIPO drill compared to the Rota-sludge drill method

1. Less indication of the material that is pumped up
2. Slower in clay layers. (The Rota sludge can pump up big chunks of clay)
3. Less well known

Mzuzu drill

Another and very low cost drill technology is the so called Mzuzu drill which was developed by the CCAP SMART Centre in Mzuzu (Malawi). It consist of a "Soil punch" and a "Tube bailer". No tripod, pulley or drill pipes are needed. The soil punch is made of a pipe with slot and a hard drill bit welded to a pipe of 1.5 inch which is partly filled with sand. In this way the weight of the

soil punch is some 15 kg and it can crush hard layers like sandstone and bring up small boulders up to 6 cm. With extensions the Soil punch can make holes to 7 meters deep with diameters of 2 to 8 inch. Than an open PVC pipe with a filter screen (the casing) is placed in the well and is lowered by bailing (pumping) inside the pipe with the Tube bailer, a pipe of 2 to 3 inch with a bottom valve. Instead of a rope the Tube bailer uses a Poly tube. In this way it can be forced up and down and fills up with clay, sand or small gravel. Each time the casing lowers 1 meter a new casing pipe of 1 meter is added. A weight can be connected to the casing to force it downwards. When the casing with filter screen (2 to 6 meters) is in the aquifer, a pump and apron can be installed.

Making a Tube well with the Mzuzu drill Method, The first 3 to 7 meters is made with a Soil punch

The Soil punch can be emptied by hammering the 2 inch pipe.

Making a Tube well with the Mzuzu drill. After a first hole with the Soil punch the casing is placed and lowered by using a Tube bailer which pumps out sand inside the casing.

In this case in Maputo the 6 meters deep Tube was made in 1 day and a Rope pump is installed on a prefabricated slab

Some 60 tube wells have been made with the Mzuzu drill in Mozambique, Tanzania and Malawi with depths till 18 metres deep. The cost of a complete Mzuzu drill set is 60-100 US$ and can be made with local materials. Both technologies are promoted by the SMART Centres.

Well deepening

Besides making new wells, the Mzuzu drill can also be used for deepening existing hand dug wells. If a well dries up and there is the danger of collapsing of the wall when it is made deeper

than the Mzuzu drill can be used in the following way. A PVC pipe with a filter screen is placed on the bottom of the well and inside the pipe sand is taken out with the Tube bailer. This can be done either from the top of the well or inside the well. Deepening wells with a Tube bailer is safer, faster and often cheaper than placing concrete well rings under in a well.

Main results /lessons learned

1. With the SHIPO drill type of drilling some 800 tube wells (depths 20 - 48 m) have been drilled in Tanzania Malawi and Mozambique.
2. The cost of a SHIPO drill set to 30 meters has reduced to ca 700 US$ in Tanzania
3. The cost of tube wells in areas like in Njombe has reduced from 4000US$ to ca 1500 US$ by shifting from machine drilled boreholes to SHIPO drilled boreholes.
4. With the Mzuzu drill some 60 wells were made ranging from 6 to 18 meters deep
5. The cost of a Mzuzu drill set is 60 – 100 US$
6. The cost of tube wells drilled with the Mzuzu drill are 100 to 500 US$ depending on cost of transport, depth type of casing.
7. There is much misunderstanding about manual drilling and new options are hardly known by Governments, NGOs or local entrepreneurs in Africa.
8. If well done and in similar geological conditions, the quality (Pump capacity, water quality etc.) of manual drilled wells is similar to machine drilled wells.
9. Good drillers are not necessarily good businessmen.
10. Simpler drilling technology and cheap drillsets increase the interest to make it a business.
11. Even for a low cost 700US$ drill set often a loan is needed.
12. The SHIPO drill with jetting goes 20 to 50% faster than without jetting.
13. The cost of an engine pump is earned back with 3 to 5 drillings because of less cost for labor. Another advantage of Jetting is that the drill company looks “more professional”.
14. Although manual drilling seems simple, a hard lesson learned is. ‘Simple is not easy” It takes a long time and good follow up training before local well diggers understand the underground, the hydrogeology which is essential to make a good quality tube well.
15. In general it takes 20 wells with good quality before a driller can be considered as a qualified driller.

Conclusions

1. New manual drilling technologies can reduce average cost of tube wells by 50% or more
2. A challenge now is massive capacity building and dissemination of this knowledge.
3. Because of the lower cost of wells for Communal water supply, more wells can be drilled with the same budget which should be interesting for Governments and NGOs
4. Manual well drilling has tremendous potential to reach “the last mile” (SDG6), the yet unserved, and make wells where machine drilled wells are too expensive.
5. More local drilling companies results in increased local employment including youth.
6. Because of the income generated by drilling wells there is a “profit based sustainability”, because drillers will go on after training and projects stop.
7. The simple drilling options like the Mzuzu method can be a first step for a driller to start drilling shallow wells and wells for Self-supply. Lateron he can learn more, invest more and drill deeper wells for communal supply.
8. The new drilling options make tube wells affordable for (some) families, (Self-supply)
9. Scaling up Self-supply, has positive impact on food production and reduction of rural poverty. (Mekonta. 2015, Maltha. 2015, Holtslag, 2015)

Recommendations

10. NGOs and others interested in reaching the SDG6 should invest in large scale capacity building, installing examples in real situations, and create critical mass in each district.

11. Those interested in reaching SDG6 should invest in WASH Training centres like WET Centres (CAWST), SMART Centres (MetaMeta) or others.
12. The WASH Training centres should include their knowledge in national vocational training
13. Compare different drilling options in similar geological situation to see which option is the most cost-effective and has the potential as a business for the local private sector
14. More funds are needed for R&D to further improve low cost drilling technologies. Each dollar less in the cost of a drill set, each detail that results in simplifying the technology increases the market for these technologies.
15. Explore the possibility for manual drilling by making 'drillability' maps for each country

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