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From emergency to development or vice versa? Key lessons from the innovation of a well drilling method

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Despite considerable differences between the relief setting and the developmental setting, it was concluded by PRACTICA during the S(P)EEDKITS[1] project that requirements of hardware used in both settings have a significant overlap. Robustness, independence of external supplies and cost effectiveness are just a few of them. The product development aimed to improve hardware for relief organisations to access groundwater cost effectively with a proven method from the developmental sector. By professionalizing the hardware of a manual drilling technique called Rotary Jetting the relief organisations are now able to drill wells independently of third parties up to 30 meters in unconsolidated formations with limited skills needed and durable equipment. By adding the requirement in the product development that all parts should be locally maintainable, replaceable or repairable, it was attempted to make the kit highly applicable to be transferred to the private sector or local organizations when emergency organizations phase-out.

Introduction

A staged approach to water source development is used in emergencies. The first stage is to develop sources for rapid water supply. Longer term developments come second (Davis and Lambert, 2002). Development of new groundwater sources is limited in the initial stages of the emergency because of time restrictions (House and Reed, 2004). It takes time to obtain the required equipment for digging wells or drilling boreholes, to investigate the geo-hydrological conditions and to have skilled people available.

When drilling is outsourced, contracting and tendering steps add time and difficulties. These constraints can lead to high investment costs, dependency on third parties, transport issues particularly when drilling in remote areas and dependency on spare parts which are often not available locally.

There are important factors that make groundwater use often favoured compared to other options (e.g. lakes, streams, rivers, springs, open wells, dams, rainwater harvesting etc.). It depends on multiple factors such as setup time, cost of source development, availability, quantity and ease of operation (House and Reed, 2004). Groundwater has the advantage that the water is likely to be free of pathogenic bacteria and will have a low turbidity. Groundwater often requires little or no treatment to be suitable for drinking whereas surface water generally needs to be (extensively) treated (WHO, 2006). In addition to this, groundwater wells can often be created on selected sites nearby the point of consumption while supplying large quantities of water. This significantly reduces operational costs and/or infrastructure investments.

The S(P)EEDKITS project[1] is a 4-year EU-funded project aimed at improving the hardware of relief organizations used in the first phases of emergencies (SPEED). Preferably the hardware should have the potential to be applicable in later phases of the emergencies and/or developmental settings (SEED). Within this project a range of new products are being developed collaboratively by a consortium of EU companies, universities, NGO’s and Relief organizations.

The applicability of manual drilling techniques in emergency settings was explored by PRACTICA to improve the available hardware for accessing groundwater. Manual well drilling is a proven borehole construction method in the developmental context. Drilling water wells by hand using local enterprises, can reduce the cost of a well by a factor 4 - 10 compared to a machine-drilled borehole. It allows local workshops to produce and maintain the equipment. As the name suggests, the drilling method uses manpower rather than machine based power to penetrate geological formations. The installation and finalization processes are identical to machine drilling and with skilled operators a similar quality can be obtained. It is well known for its simplicity, ease of transport, their independence of external supplies and cost effectiveness. Given the nature of the system, limitations are encountered in the depth of drilling and type of ground formation that can be penetrated. On average, wells are drilled between 15 and 40 meters in unconsolidated and weathered consolidated formations.

During the project it was concluded that these characteristics of manual drilling have a significant overlap with the requirements of hardware in emergencies making manual drilling likely to be suitable for emergency settings. And, given the constraints of well drilling in the first phases of the emergencies, potentially be able to shift the moment in which drilling can be favored closer to the very first phases of the emergencies.

In addition, by including the product requirement that all parts of the hardware should be locally repairable and/or replaceable, the kit gains robustness and applicability in challenging conditions as well as the ability to allow relief organizations to hand over the equipment and skills to actors involved in the developmental phase. This would empower all actors involved, from emergency agencies to developmental actors, to drill cheap and fast wells without the dependency of external supplies.

Manual drilling

When a borehole is drilled, different types of geological formations (soil layers) can be encountered. To drill through these diverse formations a range of different manual drilling techniques have been developed and are used around the world. In each case the drilling technique must (a) break or cut the formation, (b) remove the cut material (the soil) from the hole, and (c) if necessary provide support to the walls of the hole, to prevent collapse during drilling. Each drilling technique has been developed for either one or a range of specific formations (soil layers); therefore it may be possible that combinations of different drilling techniques are used to drill a single borehole (PRACTCA, 2010a).

Manual drilling techniques can be divided into hand augering, manual percussion, sludging and jetting (PRACTICA, 2010b). Each drilling technique has its own characteristics but share some in common as well and are often used in combination. Hand augering can be quite effective in soft formations, but becomes challenging when drilling deeper and below the water table. Percussion is a slow manual drilling technique-, but it is applicable for drilling in consolidated formations. Sludging is very effective in stiff clay soils but needs skills to operate properly and is slower than (rotary) jetting. Rotary jetting a very fast drilling method in clay soils and sandy soils, but needs considerable amounts of working water. An overview of the rotary jetting method can be found in Figure 1.

Jetting is based on pumping water through drilling pipes to the bottom of the borehole. The large volume of water has an erosive effect at the bottom and the ‘slurry’ (water and cuttings) is transported up between the drill pipe and the borehole wall. A motor pump is used to achieve an adequate water flow. The up and down or rotational movement of the drilling pipe or drilling bit helps to loosen the soil formation

Jetting can be divided into rapid well jetting and rotary jetting. Rapid well jetting[2] is also called ‘clear water jetting’ or ‘farmer jetting’ and consists of driving the casing directly down from the surface or from within a hand dug well using a large volume of water from a motor pump. The technique can be used up to 6-10 meter drilling depth in loose sandy formations.

Rotary jetting uses a swivel and a rotary arm to allow a clockwise rotational movement of the drill pipes with attached drilling bit. This movement provides a cutting action. Combined with the erosive action of the water, ground formations are penetrated. Drilling additives are applied to the water to make a drilling fluid. This will increase the viscosity of the working water to bring up the cuttings to the surface more easily and to prevent water loss by sealing the borehole wall. The water pressure prevents the borehole from collapsing. With rotary jetting drilling pipes can easily extended and allows the kit to drill deeper compared to drilling with rapid well jetting

On average, rotary jetting is used in Africa up to 30 meters. There are however examples where jetting is used to drill wells that are much deeper. In Chad, wells are drilled 50 or 60 meters deep. In Asia there are examples of wells that are 150 to 200 meters deep. These latter is only possible with a supporting tripod structure and very soft ground formations. The size of the drilling bit will determine the maximum allowable casing to be installed. Generally 140-180mm drilling bits are being used that will allow a 100-125 mm casing to be installed. Rotary jetting can be used in unconsolidated sedimentary formations that consist of loose sand, silt, clay or thin layers of small size gravel.

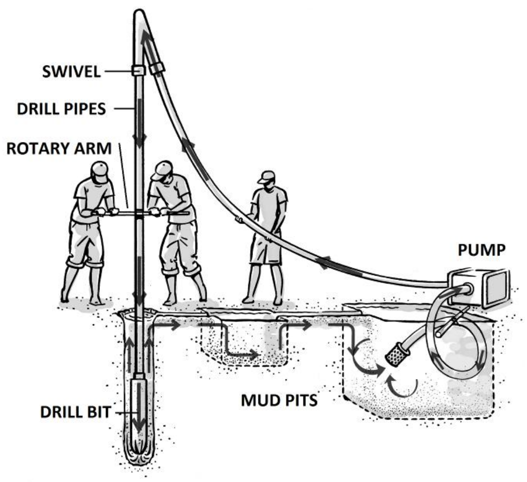


Figure 1. Overview of semi manual jetting

Source: PRACTICA Foundation, 2010a

In over 30 countries in Africa, local manual well drilling enterprises exist. In Asia it is even further established and millions of wells have been drilled by hand over the past decades. One of the pitfalls is often the quality of works and speed of mobilization which varies highly amongst drilling enterprises and practitioners. Furthermore toolkits are often incomplete, of poor quality and badly maintained. In emergency settings, the use of various technologies needs to have a high level of reliability, quick in action and applicability. For this reason, manual drilling is often excluded, though in Chad, UNICEF contracts skilled manual drilling enterprises to work in unstable situations as they are cheaper, easier to mobilize and contract and are often more accepted than foreign contractors.

Photograph 1. Rotary well jetting in developmental context[3]

In collaboration with the emergency agencies Red Cross Netherlands and Medecins sans Frontieres (MSF) in the S(P)EEDKITS project it was agreed that particularly rotary jetting was of special interest given the speed of drilling, the relatively quick learning curve and the fact that there is no rotary jetting kit on the market.

A manual drilling kit that is light in weight, very quick and simple in operation and of reliable quality would provide emergency organizations an attractive option to develop groundwater sources in suitable geo-hydrological conditions. Such a toolkit would be ideally placed as a SPEEDkit in the early stages of emergency, but also highly applicable to be transferred to the private sector or local organizations when emergency organizations phase-out (SEEDkit). This is especially true for equipment that can be repaired and replaced locally by building local capacity and ensuring knowledge transfer and cost saving.

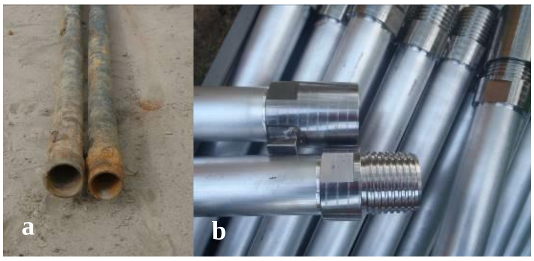
Overlap and differences in requirements

The three main factors which make manual drilling interesting compared to machine drilling are the ease of transport, the low costs and the simplicity (Danert, 2015). These requirements are shared in both the relief setting as well as in the developmental sector. Nevertheless, the aspect of hardware costs is different for the emergency context compared to the developmental sector. Within the emergency sector there is more focus on quality, reliability and direct availability. High quality and relative expensive materials are preferred above cheaper equipment with higher maintenance costs and risks of malfunctioning. In order to make manual drilling equipment suitable for use in emergencies, the main adaptation lies in the reliability and robustness of the materials.

Based on the set of requirements, the main leading principles for the development of the rotary jetting kit for relief settings have been the use of high quality materials combined with the ability to repair or replace these materials with local available materials. Off-the-shelf products of industry standard were used where possible. With a focus on technical robustness, simplicity, weight and production costs, the kit was further adapted to the need of relief organisations.

Development of the jetting kit

Current rotary jetting kits used throughout Africa are made with 1,5 or 3 meter long and heavy 1,5’’ or 2” GI **pipes** (Photograph 2a) that are connected during drilling with standard sockets to create a drill string (PRACTICA Foundation, 2010a). For the improved rotary jetting kit, the pipes are replaced by 1½ inch light weight high strength aluminium pipes that are connected with high quality steel **couplings** (Photograph 2b). The high quality steel couplings with tapered threads prevent wearing of threads and increase the speed of connecting and disconnecting of drilling pipes. The aluminium pipes are connected to the couplings using a BSP thread, so the pipes can be replaced by standard threaded GI pipes if needed.



Photograph 2. a) Drill pipes used in developmental context. b) Improved drill pipes.3

By reducing the total **length of the pipes** to about 75 cm, the pipes fit into a EURO crate, allowing easy transport. Furthermore, by reducing the length, the rotary arm can be connected more frequent at comfortable and ergonomically height (Photograph 4b). This was impossible in the original design. By using the flats of the couplings combined with a clap fastener a more secure and faster way of attaching the rotary arm could be achieved. It also prevents damage on the pipes. In the original design pipe wrenches are used to fasten, secure and lift the drill pipes which results in dents and cracks on the pipes and often sharp edges.

By using the BSP thread, the swivel and drill bits can be replaced by locally fabricated parts if needed. Both the swivel and the drill bit delivered in the kit use high quality industrial parts. The **swivel** comes from the dredging industry (Photograph 3b). It is specially designed to cope with the aggressive nature of sand.

The improved **drill bit** (Photograph 3d) is made with input from the drilling industry combined with field experiences in developmental settings. This resulted in an aggressive dimensioned drilling bit with tungsten carbide teeth to increase the speed of drilling and minimize wearing of the teeth. If these materials wear out over time, they can be replaced using locally fabricated parts. Drill bits currently made in Africa use leaf springs from cars or excavators (Photograph 3c). Common bearings and seals from cars and motorbikes serve as part for the swivel (Photograph 3a).

The pumps used for jetting in de developmental settings are, often, clean water pumps found on local markets. These pumps are often low quality pumps that are not applicable for pumping dirty water for a long period of time resulting in potential downtime due to damage of the mechanical seal. To avoid this in an emergency setting, a high performance **Honda WT 30 X thrash pump** has been used in the newly developed kit providing a high capacity flow to bring up the cuttings. This pump has been selected based on expert opinion of multiple manual drilling experts claiming good results with this pump. In case of damage, any locally available engine pump in the range of 4HP can replace the dirt pump.

Photograph 3. a) Swivel used in developmental context. b) Professionalized swivel. c) Drill bit used in developmental context. d) Improved drill bit.[3]

Three additional items are added to the original design. To lift and tighten drilling pipes in the development settings, pipe wrenches are used on the actual drilling pipes (Photograph 4a). A simple **'pitbox'** (Photograph 4b) is added that can be placed over the borehole. This can be used to hold the drill string in a safe way and decreases the chances of losing the drilling pipes. In addition, it prevents caving of borehole entry. Thirdly a simple **in- and outlet** is placed in the mud pit that allows a trouble free sucking of the water from the mud pit (Photograph 4c). A two way valve system is added on the outlet of the pump allowing water to circulate in the mud pit. This is particular helpful when the drill string is extended during drilling. The pump can keep on running, while the swivel is detached from the drill string. This increases the speed of drilling significantly.

For the transport of a 30 meter drill string, two euro crates of 40x80x12 cm are needed. All parts apart from the drill pipes fit together with the consumables such as polymers, in one additional 80x60x43 cm crate. Together with the pump, the total kit has a weight of approximately 225 kg and fits easily in a pickup truck.

An illustrated field manual has been written explaining the complete process of drilling with the rotary jetting kit step by step. Technical drawings and the explanation of the replacement of hardware made with local materials such as the drill bit and the swivel are provided. In addition a range of tips and tricks are given to replace high quality consumables such as drilling polymers and casings with locally obtainable materials making the kit even more (self) sustaining in the developmental context.

The design of the kit has been extensively tested and adjusted in the lab as well as in the field (Netherlands) on a range of wells. Significant improvement in handling and safety combined with setup and drilling time reduction has been achieved compared to the original design. Currently, testing in emergency settings and in longer term programmes is now being discussed with the project partners involved.

Photograph 4. a) Way of fixating drill string in developmental context. b) Improved fixation. c) Inlet and outlet in the mud pit.[3]

Conclusion

The developmental setting and the emergency settings have distinct characteristics. Different actors, time constraints and budgets are just a few of them. Yet during hardware development within the S(P)EEDKiTS project a remarkable overlap between requirements was found between hardware used in emergencies and the developmental setting. Robustness, ease of transport, minimal dependency of difficult to obtain spare parts, low cost, aim of supplying commodities, the use of proven methods, the ability of doing repairs and maintenance with local resources and simple to use are requirements for both settings.

In the development of a rotary jetting kit in the S(P)EEDKITS program, these overlaps in requirements resulted in a jetting kit that is light in weight, very quick and simple in operation and of reliable quality. It provides emergency organizations an attractive option to develop groundwater sources in suitable geo-hydrological conditions. The toolkit can be ideally placed as a SPEEDkit in the early stages of emergency, but is also highly applicable to be transferred to the private sector or local organizations when emergency organizations phase-out (SEEDkit). This is especially true as the equipment can be repaired and replaced locally by building local capacity and ensuring knowledge transfer and cost saving.

Although the kit is thoroughly tested and the principle of rotary jetting proved itself in the development settings, the kit still needs to fulfil its promise in the field during emergencies. Yet, given the process of the development and the product developed, it can be argued that success stories in the developmental settings can provide a valuable input for hardware development in emergencies.

Rather than focussing on the differences between the two settings, the focus on the similarities can provide valuable insights that lead to improved hardware. Further collaboration between relief organisations and the developmental sector in product development can therefore result in potential interesting product development which has the potential to allow relief organisations to have access to reliable hardware in the very first phases of an emergency allowing cost reducing interventions. And, as an added value, decrease the gap between the transition between relief- and developmental transition by giving it the ability to hand over the equipment without the dependency of external supplies for the receiving partners.

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Notes

[1] More information about the S(P)EEDKITS project can be found at www.speedkits.eu.

[2] For a complete overview of the jetting techniques: http://practica.org/wp-content/uploads/2014/07/Jetting-manual-drilling-PRACTICA-EN.pdf.

[3] Source of all photographs: PRACTICA Foundation.

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