

## The case for the rope-pump in Africa: A comparative performance analysis

P. A. Harvey and T. Drouin

### ABSTRACT

The conventional handpump is the most popular technology choice for improved potable water supplies in rural sub-Saharan Africa. To date, however, it has failed to deliver satisfactory levels of sustainability, largely due to inadequate maintenance capacity. An alternative option to standardised imported handpumps is the locally manufactured rope-pump, which is considerably cheaper and easier to maintain but has been rejected in the past due to fears of impaired water quality. This paper presents the key aspects of a study in northern Ghana which compared the performance of rope-pumps with that of conventional handpumps, to determine whether or not the rope-pump provides a viable alternative for community water supplies across the sub-continent. User interviews, sanitary surveys, water quality analyses and technical performance measurements were used to develop a comparative performance analysis for the two pump types. The findings of the study indicated that the rope-pump out-performed the conventional handpump on the majority of counts and that, contrary to widespread perceptions, there was no significant difference between pump types with respect to the impact on microbiological water quality. Consequently, the rope-pump provides a significant technological opportunity to improve water supply sustainability in Africa.

**Key words** | developing countries, pumps, rural water supply, water quality

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### INTRODUCTION

As a result of the International Drinking Water Supply and Sanitation Decade (1981–1990), governments and donors began to recognise the importance of handpump-equipped wells and boreholes as an appropriate technology for rural water supply in low-income countries (Arlosoroff *et al.* 1987). Consequently, over the past two decades groundwater has proved the most reliable resource for meeting rural water demand in sub-Saharan Africa (Macdonald & Davies 2000). There are an estimated 250,000 handpumps in Africa, the majority manufactured in and imported from Asia, but it is estimated that less than half of these are currently operational (RWSN 2004). Low levels of sustainability are due to a range of factors including restrictive policies, inappropriate project implementation, lack of willingness

to pay for maintenance among user communities, lack of spare parts and technical capacity, and inappropriate technology choice (Harvey & Reed 2004). Technology choice is a key determinant influencing the sustainability of rural water services. Operation and maintenance (O&M) greatly improves when communities are allowed to select a technology which they believe is within their financial, managerial and technical capacity to sustain. The conventional handpump does not always fit this definition and users often prefer simpler technologies (Breslin 2003). Consequently, where communities are not able to choose options for themselves and handpumps are forced upon them, these commonly fall into disrepair, meaning that rural populations are forced to return to unsafe water sources.

## The history of the rope-pump

The rope-pump, also known as the rope-and-washer pump, is not a new technology. The basic working principle was first applied at least two thousand years ago in China (Alberts 2000). The pump consists of a continuous rope, with pistons attached to it, which passes over a flywheel, down into the well or borehole, and up through a vertical pipe, the bottom of which is submerged in water. When the flywheel is turned the rope is pulled through the pipe and each piston traps a column of water inside and raises it to an outlet above the ground surface (Figure 1).

The rope-pump was simultaneously introduced to Africa and Latin America during the 1980s as a result of various water development projects; notable projects took place in Zimbabwe, where it was developed primarily for micro-scale irrigation (Faulkner & Lambert 1990) and

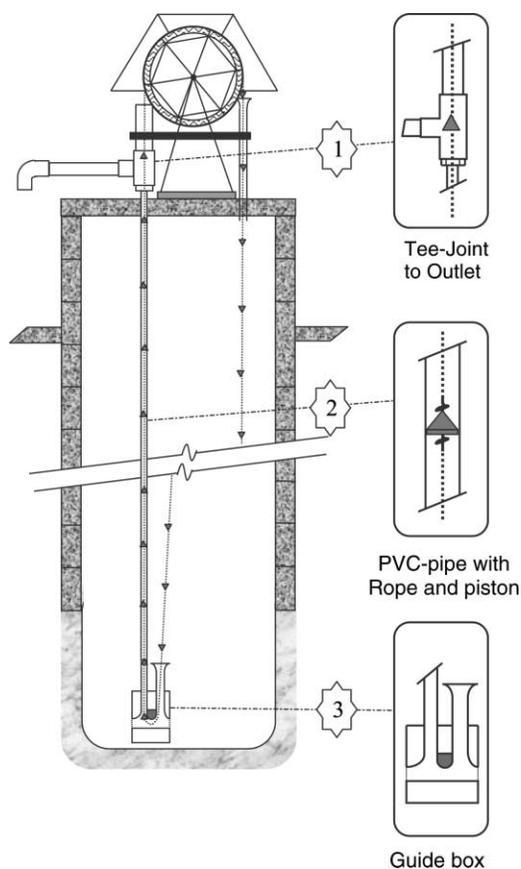


Figure 1 | Cross-section of rope-pump on hand-dug well.

Peru and Bolivia, where the pump was identified as meeting the Village Level Operation and Maintenance (VLOM) criteria (Arlosoroff *et al.* 1987). The VLOM criteria are that the pump is able to be easily maintained by a village caretaker (requiring minimal skills and few tools), manufactured in-country (primarily to ensure the availability of spare parts), robust and reliable under field conditions, and cost effective (Colin 1999). The Peruvian version of the rope-pump was easy to operate, maintain and manufacture locally, and provided a particularly high discharge rate, but was able to operate only at low heads of up to 6 metres (Arlosoroff *et al.* 1987).

A major evolution in rope-pump technology took place in Nicaragua in 1984 when a small workshop created a rubber washer made by injecting moulds (Alberts *et al.* 1993). This innovation allowed a dramatic increase in the operating head of the pump of up to 40 metres for the standard design. Subsequent adaptation of the design, including the use of smaller diameter pipes and a double crank led to an increased reach depth of 60 to 80 metres (Alberts 2004). This evolution transformed the pump from one used primarily to meet low-lift irrigation needs into a handpump suitable for raising even relatively deep groundwater for domestic use. Despite the development of washers that need to be made by equipped workshops, the technology remained cheap: around US\$150 for a complete pump. As a result, the pump spread quickly in Nicaragua which adopted it as a standardised pump in 1996. Consequently, more than 30,000 rope-pumps are currently in use in Nicaragua and provide water to approximately 25% of the total population (Alberts 2004). The rope-pump is a public domain design (Erpf 2002) and consequently there are no restrictions regarding who is able to manufacture it or where it can be manufactured.

The rope-pump was introduced to Ghana in 1999–2000 as the result of a technology transfer programme from Nicaragua supported by the Swiss Agency for Development and Co-operation and the Water and Sanitation Program (WSP) of the World Bank. This programme led to the development of two workshops manufacturing the rope-pump in Tema and Tamale and resulted in the installation of 100 pumps by 2000 (Bombas 2000). Despite some initial problems with the manufacturing quality and implementation strategy (Bombas 2001), the advantages of the pump

were recognised by other implementing agencies which led to the establishment of a further manufacturing workshop based in Bolgatanga, Upper East Region. Since its establishment in 2001 this has manufactured and installed more than 120 rope pumps in the region and also provides a repair service to users.

### Arguments for and against the rope-pump

It is generally accepted that the rope-pump has a number of advantages over conventional handpumps. These include:

- significantly lower initial cost;
- increased ease of local fabrication and manufacture;
- increased ease and lower cost of maintenance and repair (requiring no specialist skills or equipment);
- lack of reliance on imported specialist components; and
- higher delivery discharge rates.

Arguments against the pump are that it represents a retrogressive step in technology, that rural communities prefer conventional handpumps, and that it is suitable only for low usage (40–60 people per rope-pump rather than 250–300 people per handpump) (Harvey & Skinner 2001). However, the authors have found no documented evidence to support such claims. Undoubtedly, the most common argument against the rope-pump concerns microbiological water quality (Gorter *et al.* 1995). Resistance to the introduction of the rope-pump to sub-Saharan Africa has been based largely on the presumption that the pump is more susceptible to bacteriological contamination than conventional handpumps and that consequently water quality is impaired. The pumping principle applied in the rope-pump by which the rope passes in and out the well is often considered as not entirely satisfactory in terms of protection of the water source compared to conventional handpumps in which the water-contacting parts are enclosed (Bartle 2004). Such arguments have been reiterated by government officials within the Community Water and Sanitation Agency (CWSA) of Ghana (Harvey *et al.* 2002). It should be noted, however, that there are many vested interests involved in the international provision of conventional handpumps, and consequently, individuals or organisations that want to maintain the status quo may seek to find fault with local alternatives such as the rope-pump

and exaggerate limitations (Bartle 2004). While previous research has investigated the impact of rope-pumps on water quality in relation to open hand-dug wells and wells fitted with a windlass (Gorter *et al.* 1995), there are no well-documented studies which have compared rope-pumps to conventional handpumps.

### AIMS AND OBJECTIVES

In light of the issues described above the purpose of this study was to undertake an objective comparison of the overall performance of the rope-pump and that of a conventional handpump in Ghana, to determine whether or not the arguments against the rope-pump are valid and to assess the potential of the rope-pump for widened application in sub-Saharan Africa.

### METHODOLOGY

#### Selection of wells and pumps

The key criteria for identifying an appropriate project area were that rope-pumps and conventional handpumps should be installed on the same type of water sources, in identical hydrogeological and climatic conditions, and subject to identical or near-identical sanitary pollution risk and usage loads. Based on these criteria the Upper East region of Ghana was selected (Figure 2).

The first rope-pumps installed in the Upper East region were done so under the responsibility of CWSA, which is reportedly undertaking field tests on them but is yet to release any findings (Babisma 2004). Currently, the main promoter of the rope-pump in the region is Rural Aid, a local Non-Governmental Organisation (NGO) financed predominantly by the international NGO Wateraid. The water development programme of Rural Aid over the past decade has focused on the provision of improved hand-dug wells. The initial plan was to equip all wells with the Nira AF85 handpump, one of the four nationally standardised conventional handpumps permitted for use in Ghana. Each community in the programme was expected to make a financial contribution of 150,000 cedis (US\$15) and a substantial in-kind contribution to the cost of the water

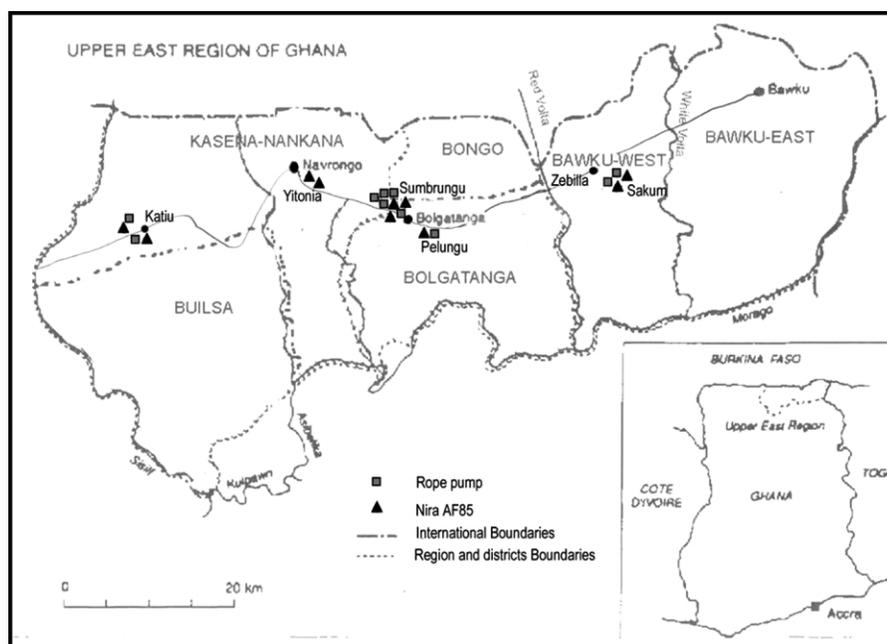


Figure 2 | Map of pump locations.

supply. The remainder of all costs was to be met by Rural Aid, the cost of a single Nira AF85 handpump being approximately US\$700 (Nampusuor & Mathisen 2000). Two thousand wells had been provided by the end of 2003, but one thousand two hundred of these were still not equipped with a handpump because Rural Aid was unable to afford the price of the Nira. Consequently, the NGO decided to purchase rope-pumps, at a cost of approximately US\$150 per pump, and to install these on some of the remaining hand-dug wells, while continuing to install a reduced number of Nira pumps.

This situation produced an ideal environment in which to undertake a comparative performance analysis of the two pumps. Since both pump types are predominantly used for low-lift applications on hand-dug wells it was deemed appropriate to select the Nira pump as a representative conventional handpump alternative to the rope-pump. Twenty hand-dug shallow wells were selected for the study, ten equipped with Nira handpumps and ten equipped with rope-pumps. Each rope-pump well was selected as close as possible to a corresponding Nira pump well to ensure similar hydrogeological settings and to maximise comparability potential. The wells ranged in depth from 6.1 metres to

12.1 metres (with no significant variation between the two types of pumps) and all had been fully lined by Rural Aid technicians. The hydrogeology of the study area is typified by a layer of weathered fractured sandstone of an average depth of 40 metres (ODI 1998). The age of the pumps varied from 1 to 5 years and sanitary surveys were conducted to assess the quality and state of repair of the well constructions to ensure that any degradation was considered.

### User interviews

User interviews were conducted in each community following a standard format. The interviews were designed to collect information about the construction of the well, the acceptance of the pump by the community, the uses of water, the number of people using the pump, the maintenance system and the costs of installation, operation and maintenance.

### Sanitary inspections

Sanitary inspections are necessary to support microbiological water quality assessment by identifying potential

pollution sources and contaminant pathways to provide an overview of the status of risk of the water source to contamination (WHO 1997; Howard 2002). In order to conduct assessments, sanitary inspection forms were developed in conjunction with Rural Aid staff after visiting pumps of both types. These were based on those developed by WHO (1997) but modified to the specific settings encountered in northern Ghana. One sanitary inspection was conducted for each well site in the study using a standard format (as shown in Table 1).

The equal weighting applied in this method is not entirely satisfactory as some factors may present greater risks than others but can be used to obtain an overall approximation of water source pollution risk (Lloyd & Helmer 1991).

### Water quality analysis

The main water quality parameter analysed was presumptive counts of thermotolerant coliforms, chosen as an acceptable alternative to *E. coli* (Dufour *et al.* 2003; Bartram & Ballance 1996) because of time and resource constraints. Analysis was conducted using the membrane filtration technique as employed by the Oxfam-Delagua water testing kit. The samples were cooled and filtered immediately after sampling and were incubated for 18 hours at 44° Celsius. A minimum of three water quality samples was analysed for each well collected on three separate occasions. Additional parameters analysed on site were turbidity, pH, colour and temperature.

Since previous research has indicated a significant relationship between microbiological contamination of shallow groundwater and rainfall, especially depth of rainfall in the previous 48 hours, (Howard *et al.* 2003) it was important that this variable was considered when taking samples for analysis. Consequently, equal numbers of samples from adjacent rope-pump wells and handpump wells were collected on each day of sampling.

### Cost assessments

In order to determine the initial and ongoing costs, interviews were conducted with communities, private sector suppliers and sector professionals. It was relatively easy to

**Table 1** | Sanitary inspection questions

#### Sanitary inspection questions

1. Is there a latrine within 10 m of the well?
2. Is the nearest latrine on higher ground than the well?
3. Is there any other source of pollution within 10 m of the well?
4. Is the drainage poor, causing stagnant water within 2 m of the well apron?
5. Is the drainage channel cracked, broken or in need of cleaning?
6. Is the apron less than 1 m in radius around the top of the well?
7. Is the fence around the pump missing or faulty?
8. Does spilt water collect in the apron area?
9. Are there cracks in the apron which could permit water to enter the well?
10. Is there stagnant water on the wellhead cover?
11. Are there cracks in the wellhead cover?
12. Is the hatch not, or badly, sealed?
13. Are the two pipes not or badly sealed in the concrete cover? (rope-pump) OR is the seal of the shaft loose? (handpump)
14. Is there water going back into the well through the down pipe? (rope-pump) OR are the two base gaskets damaged or badly placed? (handpump)

Score: Yes-1, No-0; Overall: 14 worst, 0 best.

determine initial capital costs, primarily on the basis of information provided by NGOs. Determining ongoing O&M costs was considerably more difficult, however. Responses from pump-user interviews were highly variable and it was not possible to compute realistic maintenance costs on the basis of these alone. Consequently, it was necessary to collate sales data from spare parts suppliers and service data from repair and maintenance service providers, to determine the average cost of O&M for each

pump type. Data from previous studies were also used to back-up these findings.

### Technical performance assessments

Simple technical assessments were conducted for each pump visited to determine the average maximum pumping delivery head (in metres) and the average maximum flow rate (in litres per minute) for each pump type. The results of these assessments were backed up with available technical data from manufacturers and impartial assessors. The maximum pumping head is an important indicator since it indicates the versatility of the pump for different pumping needs required for different groundwater depths. The flow rate is also important since it has a direct impact on the length of waiting times at the pump and consequently, the number of users that can be served.

### Comparative Performance Analysis method

The Comparative Performance Analysis (CPA) method utilised in this study was adapted from the basic principles adopted in multi-attribute utility-measurement for social decision making (Edwards 1976). The purpose of this method was to compare the performance of the two pumps on the basis of the following variable factors:

- Capital costs;
- Impact on microbiological water quality;
- Maintenance costs;
- Maximum pumping head;
- Flow rate; and
- Impact on turbidity.

Additional variables such as depth of wells, number of users, sanitary conditions, hydrogeological environment and rainfall were identical or near-identical for both pump types, and hence were excluded from the CPA method. A range of NGOs and communities was asked to rank the range of variables in terms of their relative importance. On the basis of the average results of this ranking exercise the importance of the different factors was then weighted. The least important parameter received a score of 1, then each factor was attributed a score corresponding to its relative importance ratio to the least important

parameter. The weight of each factor was then computed as follows:

$$W_i = \text{score for } i^{\text{th}} \text{ factor} / \text{sum of all factor scores}$$

Where:

$$W_i = \text{importance weight for the } i^{\text{th}} \text{ factor.}$$

A measure of location of each type of pump for each factor, on a scale from 0 to 100 was then used: 0 being the score for the worst plausible value and 100 the best plausible value. The location of each type of pump on the scale was then computed as follows:

$$S_{ij} = \frac{|worst_i - value_{ij}|}{|best_i - worst_i|}$$

Where:

$$S_{ij} = \text{scaled position of the } j^{\text{th}} \text{ entity on } i^{\text{th}} \text{ factor.}$$

$$Best_i = \text{best plausible value of } i^{\text{th}} \text{ factor}$$

$$Worst_i = \text{worst plausible value of } i^{\text{th}} \text{ factor}$$

$$Value_{ij} = \text{value of } j^{\text{th}} \text{ entity on } i^{\text{th}} \text{ factor}$$

Finally, the overall score of each pump was then computed as follows:

$$S_j = \sum_{i=1}^n (W_i)(S_{ij})$$

Where:

$$S_j = \text{overall evaluation score for the } j^{\text{th}} \text{ alternative (pump)}$$

$$J = \text{number of alternatives (2)}$$

$$W_i = \text{importance weight for } i^{\text{th}} \text{ factor (or parameter)}$$

$$n = \text{number of factors of value (6)}$$

$$S_{ij} = \text{scaled position of the } j^{\text{th}} \text{ entity on } i^{\text{th}} \text{ factor.}$$

## RESULTS AND DISCUSSION

### User issues

The number of users per pump was estimated by each of the communities visited in the study, and was found to vary from 125 to 300, with an average of 196 people per pump. An estimation of the average water consumption was determined as 35 litres per person per day. There was no

significant difference between the two pump types for either variable, disproving the assumption that the rope-pump can serve only family groups rather than entire rural communities.

In terms of user perceptions, again there was no measurable difference between the two pumps. The Nira and the rope-pump were each perceived as an advanced water supply technology compared to river water or the open wells that communities had been using previously. It was recognised that the rope-pump required more regular maintenance and repair than the Nira pump, but since repairs could be undertaken relatively quickly and cheaply this was not perceived as a major constraint. No particular preference between the two pump types was expressed by any community survey respondent.

### Sanitary inspections

The use of sanitary inspection forms involved a significant degree of informed subjectivity by the assessor. For example, it was necessary to determine what size of cracks in the well cover should be considered a pollution risk and what amount of water on the well head cover constitutes a risk. However, all sanitary inspections were conducted by the same assessor to ensure consistency. The scores of the sanitary inspections ranged from 7 to 10 on a scale of 0 to 14, and the average sanitary scores for both pump types were identical (Table 2).

### Water quality

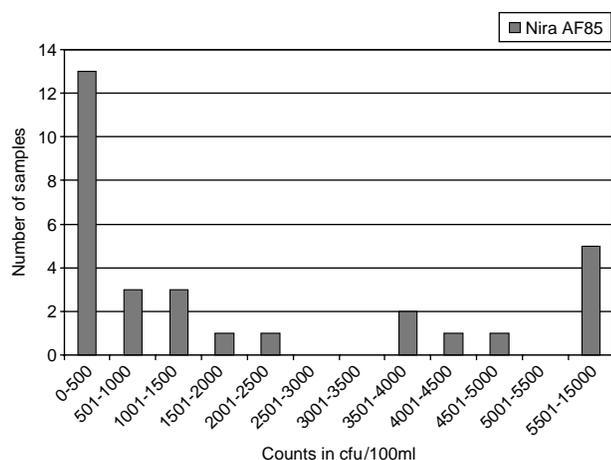
No major differences were encountered between the two types of pump concerning the measured physical water quality parameters, with the exception of turbidity. Turbidity varied significantly according to geographical area (linked to local geology) but also varied significantly in relation to pump type. The average turbidity of water delivered by rope-pumps was 13 NTU while an average turbidity of 29 NTU was recorded for the water delivered by Nira pumps. One possible explanation for this difference is that the discontinuous reciprocating action of the Nira causes more movement in the well water than the smooth continuous movement of the rope, thus increasing the

**Table 2** | Sanitary inspection scores

| Sanitary inspection scores |                |           |                |
|----------------------------|----------------|-----------|----------------|
| Community                  | District       | Pump type | Sanitary score |
| Atiabisi                   | Bolgatanga     | Rope-pump | 9              |
| Aguridone                  | Bolgatanga     |           | 8              |
| Azimsun                    | Bolgatanga     |           | 8              |
| Aniabisi                   | Bolgatanga     |           | 8              |
| A. Asaka                   | Bolgatanga     |           | 10             |
| Baandaborg                 | Bolgatanga     |           | 9              |
| Natinga                    | Bawku-West     |           | 10             |
| Gandare                    | Bawku-West     |           | 10             |
| Adunia                     | Kasena-Nankana |           | 8              |
| Muslim                     | Kasena-Nankana |           | 7              |
| Total                      |                |           | 87             |
| Sokabisi                   | Bolgatanga     | Handpump  | 7              |
| Atoobisi A.                | Bolgatanga     |           | 9              |
| Asapombisi                 | Bolgatanga     |           | 7              |
| Pel. Nairi                 | Bolgatanga     |           | 10             |
| Gundago                    | Bawku-West     |           | 9              |
| Lanaga                     | Bawku-West     |           | 10             |
| Asason                     | Kasena-Nankana |           | 9              |
| Afania                     | Kasena-Nankana |           | 9              |
| P. Talua                   | Kasena-Nankana |           | 8              |
| P. Aduntra                 | Kasena-Nankana |           | 9              |
| Total                      |                |           | 87             |

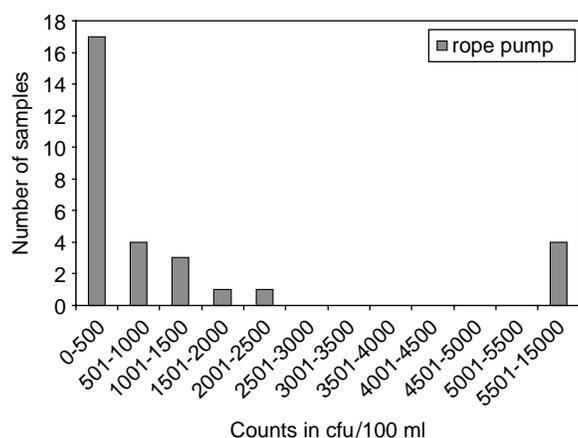
turbidity of the water by the pump stirring up sediments settled at the bottom of the well.

Presumptive counts of thermotolerant coliforms recorded for each pump type are summarised in Figures 3 and 4. The mean count for the rope-pumps



**Figure 3** | Summary of presumptive thermotolerant coliform counts for Nira handpumps.

was. 2015 cfu/100 ml and the mean count for the Nira AF85 was 2474 cfu/100 ml, indicating little difference between the two pumps. In order to test this relationship further the log median value of the counts was used as an outcome measure for each pump type (Howard *et al.* 2003; Gorter *et al.* 1995; Helsel & Hirsch 1992). The distribution of the log median values for each type of pump was tested for normality using the probability plot correlation coefficient (PPCC) test, which indicated that at least one set of data was not distributed following a normal distribution. The comparison between the two sets of data was therefore conducted using a non-parametric test, the Wilcoxon's rank-sum test because of its strength in comparison (Helsel & Hirsch 1992); the null hypothesis being “the presumptive



**Figure 4** | Summary of presumptive thermotolerant coliform counts for rope-pumps.

thermotolerant coliform counts for the rope pumps and for the Nira pumps are similar” and the alternate hypothesis being “the presumptive thermotolerant coliform counts for the rope pump and for the Nira pump are significantly different.”. The test was conducted using the median of the log coliform counts as an outcome measure for each pump type. The p-value obtained by the test was  $p = 0.65$ , which indicates that the null hypothesis should be accepted. This confirmed that there was no significant difference between the two pump types in terms of microbiological water quality.

### Costs

Capital costs and O&M costs for 1036 Nira pumps in the Upper Regions of Ghana had been previously calculated by Nampusuor & Mathisen (2000), over a period of six years from 1996 to 2001 inclusive. The results of that study indicated a capital cost of US\$700 for a Nira pump on a well of 12 metres depth, and average maintenance costs of approximately US\$89 per annum including the replacement of the pump after 15 years without any discount rate.

The capital cost of a Ghanaian rope-pump made by Jenamisa Enterprise is approximately 1,500,000 cedis (US\$168), although there has been no detailed study of maintenance costs in Ghana. One study led by the WSP (2001) in Nicaragua gives maintenance costs of around \$US5 per annum for the rope-pump. However, this does not consider the depreciation of the pump and subsequent replacement cost. If a moderate lifespan of five years is assumed for the rope-pump then US\$40 per annum can be used an indicative value of maintenance costs which incorporates these considerations.

### Technical performance

The pumps assessed in this study were installed on hand-dug wells up to a maximum depth of approximately 12 m and consequently it was not possible to assess them at greater depths. However, the maximum pumping heads recorded for the Nira pump and the rope-pump, as specified by the respective manufacturers, are 12 m and 40 m respectively. These figures are backed-up by

independent assessments (Arlosoroff *et al.* 1987; Brikké 2003). It should be noted that for deeper installations (above 15 m) the rope-pump has to be installed in a drilled borehole rather than a hand-dug well. Nonetheless, this indicates that the rope-pump is significantly more versatile than the Nira as a low-lift domestic water supply pump. This is crucially important in the sub-Saharan Africa context where approximately 40% of the land area is underlain by Precambrian basement rocks, typified by a water-bearing weathered zone of 10–30 m depth, and 220 million rural dwellers live in these areas (MacDonald *et al.* 2002).

Average maximum flow rates for a 10 m delivery head were recorded as 28 l/min for the Nira pump and 41 l/min for the rope-pump. This indicates that the rope-pump has a comparative advantage, since it is able to deliver water at approximately 1.5 times the rate of the Nira.

### CPA results

The six variable factors identified were ranked by a selection of NGOs and communities which allocated a score of 10 to the perceived most important factor. All other factors were

**Table 3** | Importance weightings

| Factor                                  | Scores | Importance weight, $W_i$ |
|---|--------|--------------------------|
| Capital costs                           | 10     | 25.3                     |
| Impact on microbiological water quality | 9      | 22.8                     |
| Maintenance costs                       | 8.5    | 21.5                     |
| Maximum pumping head                    | 7      | 17.7                     |
| Flow rate                               | 4      | 10.1                     |
| Impact on turbidity                     | 1      | 2.6                      |
| Total                                   | 39.5   | 100                      |

then allocated scores according to their perceived importance relative to the most important factor. On the basis of this the average scores were compiled and an importance weight determined for each (see Table 3). This showed that capital cost was the most important factor closely followed by the impact on microbiological water quality. Maintenance costs and maximum pumping head also scored

**Table 4** | Scaled positions for each factor for both pump types

| Factor                                  | Worst plausible value                         | Best plausible value                     | Handpump        |                | Rope pump       |                |
|---|---|--|-----------------|----------------|-----------------|----------------|
|   |   |  | Value           | Score $S_{ij}$ | Value           | Score $S_{ij}$ |
| Capital costs (US\$)                    | \$700 (value of the most expensive hand pump) | \$10 (price of a rope and bucket system) | \$700           | 0              | \$168           | 0.77           |
| Impact on microbiological water quality | 16000 cfu/100 ml                              | 0 cfu/100 ml                             | 2474 cfu/100 ml | 0.85           | 2015 cfu/100 ml | 0.87           |
| Maintenance costs (US\$/annum)          | \$90  | \$1 (price of a rope and bucket system)  | \$89            | 0.01           | \$40            | 0.56           |
| Maximum pumping head                    | 7 m (suction pump)                            | 100 m (deep well piston pump)            | 12 m            | 0.05           | 40 m            | 0.36           |
| Flow rate at 10 m head                  | 15 litres/ min (rope and bucket)*             | 50 litres/min                            | 28 l/min        | 0.37           | 41 l/min        | 0.74           |
| Impact on turbidity                     | 100 NTU                                       | 0 NTU                                    | 29 NTU          | 0.71           | 13 NTU          | 0.87           |

\* Brikké and Bredero 2003.

**Table 5** | Overall evaluation scores

| Factor                                  | Score, $S_{ij}$ |      |                          | Weighted score, $W_i S_{ij}$ |      |
|---|-----------------|------|--------------------------|------------------------------|------|
|   | NIRA            | Rope | Importance weight, $W_i$ | NIRA                         | Rope |
| Capital costs                           | 0               | 0.80 | 25.3                     | 0                            | 19.5 |
| Impact on microbiological water quality | 0.85            | 0.87 | 22.8                     | 19.4                         | 19.8 |
| Maintenance costs                       | 0.01            | 0.96 | 21.5                     | 0.22                         | 12.0 |
| Maximum pumping head                    | 0.05            | 0.36 | 17.7                     | 0.89                         | 6.37 |
| Flow rate                               | 0.37            | 0.74 | 10.1                     | 3.74                         | 7.47 |
| Impact on turbidity                     | 0.71            | 0.87 | 2.6                      | 1.85                         | 2.26 |
| Total, $S_j$                            |                 |      |                          | 26.1                         | 67.4 |

relatively highly, while flow rate and impact on turbidity were deemed less important.

The worst and best plausible values for each assessment factor were then determined based on field evidence and compared to the mean values for each factor for each pump type (see Table 4). Consequently, the scaled positions for each factor for each pump type on a scale from 0 to 100 were determined in relation to the worst and best plausible values.

The final stage of CPA was to determine the weighted scores for each factor for both pump types and to sum these to determine the overall evaluation score for each pump type (see Table 5). This final overall scores obtained were 26.1 for the Nira pump and 67.4 for the rope-pump (on a scale of 0 to 100), giving a rope-pump score of approximately two and a half times that for the Nira pump. The results also indicate that the rope-pump outperforms the Nira pump for all six assessment parameters.

## CONCLUSIONS

The Comparative Performance Analysis approach demonstrates an objective assessment method to compare the performance of two or more pumping technologies in

relation to key assessment criteria. The process adopts a participative approach to prioritising and comparing the importance of different assessment parameters.

The CPA results indicate that the rope-pump demonstrates increased performance for all of the assessment parameters in comparison to a conventional low-lift handpump, the Nira AF85. The rope-pump is significantly cheaper in terms of both capital costs and maintenance costs, and delivers a pumping head considerably higher than that of the Nira pump. Most importantly, perhaps, it has a near identical impact on microbiological water quality despite contrary negative perceptions. It is recognised that the Nira pump is significantly more expensive than other direct action handpumps such as the Tara and Malda pumps, as well as conventional low-lift handpumps such as the Afridev. This may exaggerate the relative advantages of the rope-pump as compared to all conventional handpumps, but this comparison was limited by the need to identify an environment in which rope-pumps and conventional pumps were operating in near identical conditions. Although the difference between the two pump types would probably have been less dramatic if a less expensive conventional pump had been used in the comparison, the overall similarities between the conventional handpumps available indicate that the rope-pump would still have come out top in the CPA by a significant margin.

The financial and technical advantages can be coupled with the fact that the rope-pumps are manufactured locally. Therefore, in terms of economic viability and reliability, benefits for the users, and sustainability, it can be argued that the rope-pump should be actively promoted as a low-lift pump (especially on hand-dug well installations) and, as a first step towards its broader dissemination, accepted as a standardised pump by the Ghanaian Government. Based on the findings of the CPA study in Ghana the case for the rope-pump in Africa would indeed appear to be a strong one.

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