Rope pump vs. Nira AF85, a Ghanaian case study.

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Abstract:

The present study compared the rope pump with an already standardised hand pump, the Nira AF85. A comparative analysis based on microbiological water quality, costs and technical performance was conducted during a field work in Upper East Region, Ghana. The data were gathered through interviews, sanitary inspections and water analysis using the membrane filtration technique looking for presumptive counts of thermotolerant coliforms as an acceptable alternative to E. Coli. The analysis of the data showed that the two types of pumps had a similar impact on microbiological water quality. The other parameters of the comparison showed a net advantage of the rope pump over the Nira AF85 in terms of costs and technical performance. These results led to a recommendation for the acceptance of the rope pump as a standardized hand pump in Ghana.

Key words:

Ghana - Hand pump – rope pump – standardization - Sustainability – water quality

INTRODUCTION

Rural water supply

Many rural areas in the sub-Saharan region rely mainly on groundwater for their water supply especially during the dry season. Despite the works and research made during the International Drinking Water Supply and Sanitation Decade (IDWSSD, 1980-1990) (Reynolds 1992), there are still more than one billion people lacking access to clean water supply; hence by 2015, due to increasing population an additional 1.6 billion people will need access to improved water supply (Brikké and Bredero 2003). In rural areas handpumps are the preferred option to provide them with good quality water.

During the last thirty years, learning from different project's failures and successes, the Water and Sanitation sector has been focusing on the sustainability of the facilities implemented. The evolution towards cheaper, more reliable ways of providing people with safe drinking water has taken place at the management level as well as at the technical level. In the rural water supply sector, the lack of fund and of skilled workers resulted in the failure of many centralised governmental systems of maintenance of the facilities. This in turn led people towards unsafe sources of water, thus causing major threats and catastrophes in terms of public health.

In order to limit the expenses and the logistical burden by aiming for realistic maintenance solutions, the projects evolved towards what has been called the Village Level Operation and Maintenance (VLOM) system, now more often called 'Community Management' or 'Demand Responsive Approaches' (Parry Jones et al 2001). The principle of these approaches is to involve the communities, as much as possible, in the management of their water supply, hoping that a sense of ownership on an affordable water supply scheme, using an understandable and accessible technology, would cost less and last longer.

With regard to rural water supply the major technical advance tends to make hand pumps more readily available and easier to maintain. But even the Demand Responsive Approaches coupled with the technological progress encountered many failures. The communities still need outside support for some major repairs and for the provision of the spare parts.

Thus the standardisation of the pump and the privatisation of the spare parts supply network are now the goals for the actors of the water sector. In this context, locally made pumps are of particular interest as soon as their manufacture is affordable to the locals. This however implies a centralised system of quality control to guarantee the respect of certain norms and the standardisation of the spare parts.

Any water supply device should at least protect the water source from microbiological contamination. In fact, very few studies have tried to assess the impact of hand pumps on water quality. It is assumed that they protect the groundwater, based on the logical assumption that the more they isolate the source from contamination at the point of abstraction, the less pollution will enter the well. Thus the rope pump principle, in which the rope goes in and out of the well is often considered as not entirely satisfactory in terms of protection of the water source (Gorter et al 1995) compared to other pumps like the Nira AF85 which are more tightly closed.

The emergence of the rope pump

The rope and washer pump is not a new technology. The principle was already known and used two thousand years ago in China. The technique is easy to understand, to adapt and to manufacture with locally available material such as wood, bamboo and tyres. The functioning principle is a continuous rope, with pistons attached to it, pulled through a pipe the bottom of which is in the water. Each piston traps some water and lifts it up.

This pump was already mentioned by Arlosoroff (1987:189) as a pump meeting the VLOM criteria and providing a particularly high discharge rate, but operating only at low heads (up to 6 metres).

A Major evolution took place in Nicaragua in 1984, when a small Nicaraguan workshop called HUTECNIC, created a rubber washer made by injecting moulds (Alberts et al 1993). This innovation allows a dramatic increase in the operating head of the pump, up to 40 metres for the standard depth. Some adaptation of the design with narrow pipes and double crank allows a depth of 60 metres to be reached. There is even mention of depths of up to 80 metres (Alberts 2004:22). This major evolution transformed this pump mainly used for irrigation into a hand pump suitable for lifting even deep groundwater. Despite this evolution of the washers that need to be made by equipped workshops, the technology remained cheap: around US$150 for a complete pump, as opposed to the US$700 of a Nira AF85 a widely used strong handpump.

As a result, the pump spread quickly in Nicaragua which adopted it as a standardised pump in 1996. Actually, more than 30 000 rope pumps are in use in Nicaragua and provide water to 25% of the population (Alberts 2004).

<u>The rope pump in Ghana</u>

One of the first workshops to build hand pumps in Nicaragua, Bombas de Mecate and its technology transfer division, supported by the Swiss Agency for Development and Cooperation and the WSP handpump programme made a first attempt of technology transfer from Nicaragua to Ghana in 1999-2000 (BOMBAS 2004). The programme trained workers of two workshops in Tema and Tamale formerly selected by Ghanaian government under the expertise of Bombas de Mecate. This led to the implementation of 100 pumps by 2000 (BOMBAS 2000).

This programme presented some weaknesses that need to be mentioned. The pumps were not grouped: some isolated pumps were 100 kilometres from the nearest other rope pumps, limiting the creation of a rope pump culture among the communities and the mechanics (BOMBAS 2001). The other problems were relating to the poor manufacture of some parts. The steel used for the handle was of poor quality leading to frequent breakdown. The rope was also of poor quality and the manufacture of the guide box was badly done on some pumps leading to an early wearing of the rope and frequent breakdowns (BOMBAS 2001).

Nevertheless, this programme was not the only one to occur in Ghana. The present study is centred on the Upper East Region where none of these workshop implemented rope pumps.

The workshop making the rope pump in Bolgatanga, Upper East Region, Ghana. Jenamise Enterprise, is opened in February 2001 on a personal initiative of Jan Mons a Dutch specialist of the rope pump working for the “Programma Uitzending Managers” (PUM) a Dutch group of experts. Since its foundation, this workshop privately owned by Edwin Annan and Jan Mons and financially sustained by the Victory Foundation a Dutch organisation, has already installed 120 rope pumps. Six workers make the pumps and install them. The workshop is also responsible for the repairs.

The first pumps were installed in town with some of them under the responsibility of the Community Water and Sanitation Agency (CWSA) which is still testing them (Babisma 2004).

The main promoter of the rope pump in the Upper East Region is Rural Aid. This local NGO founded in 1986, aims to provide Water supply and Sanitation to the rural areas in the Upper East Region. The financing is mainly from Water Aid Ghana, the Ghanaian branch of the English Charity. Rural Aid is engaged in many projects all over the region and was notably fitting hand dug wells with Nira pumps model AF85. This programme involves the communities in the setting up and the maintenance of the facilities through Water and Sanitation committees. Rural Aid is in relation with the water and sanitation committees through some trained literate people: the Zonal Based Facilitator (ZBF).

The programme of Rural Aid was to dug and improve wells as a first step, then to equip the improved wells with handpumps. The communities were asked for a financial participation of around 150 000 cedis (around $15) and a substantial contribution in kind, notably the digging of the well. The pumps installed were mainly Nira AF85, each of which costs around $700 (Nampuosor and Mathisen 2000). So far, 2000 wells have been dug but by the end of 2003, 1200 wells were still not equipped with handpumps. The money has been collected from the communities but Rural Aid was not able to afford the price of the Nira. The NGO decided to go for rope pumps which were sold for $150 by the Jenamise enterprise. To implement the rope pumps the NGO hired Isaac Chege, a VSO specialist of the rope pump.

Rural Aid is thus now implementing the two types of pumps. The rope pumps form the majority of the new installations, financed by Water Aid. Rural Aid is still implementing the Nira pump because of a contract with UNICEF renewed in July 2004.

The present study took place in this context and intended to compare the rope pumps and the Nira pumps in terms of their respective influences on microbiological quality but also in terms of costs and technical performance.

METHODS

The field trip, organised within the scope of a MSc work at the Water, Engineering and Development Centre (WEDC), took place between June 29th 2004 and August 1st, 2004. The aim of the field work was to gather three sets of data concerning the two types of pumps.

The first set consisted of the physical and bacteriological data involved in the comparison of their respective influences on microbiological water quality.

To support and help the interpretation of these data, sanitary inspections were prepared and conducted for each pump.

Other pieces of information were also collected for a broader sustainability comparison, including costs, maintenance networks and social aspects.

Water analysis

The preparation of the field work, through literature review and correspondence, led to the choice of the parameters to be measured. Turbidity, pH, colour and temperature were checked on site and registered for each sample. The presumptive counts of thermotolerant coliform, chosen as an acceptable alternative to *E. coli* (Dufour et al 2003) because of the allotted time and money, have been obtained by using the membrane filtration technique. The samples were cooled and filtered within 4 to 6 hours of sampling in a hotel room in Bolgatanga using an Oxfam-Delagua Kit. After a 4 hours recuperation period they were incubated for 18 hours in the incubator of the Oxfam Delagua kit at 44° Celsius.

Twenty pumps, ten Nira and ten Rope pumps, from different areas of the Upper East Region were selected in accord with Rural Aid staff. Three samples were taken for each pump. The samples were taken weekly during three weeks from July 9th to July 29th 2004.

Sanitary inspections

Sanitary inspection forms were set up on site after visiting pumps of both models, and adapted to their specific settings. One sanitary inspection form was prepared for each type of pump. They have been modified, to suit the local habits, following the advice of Rural Aid staff, especially concerning the drawings accompanying the questions. One sanitary inspection was conducted for each sample taken.

Interviews

The gathering of information about the sustainability of the pumps mainly occurred through directed and informal interviews of key stakeholders in the water and sanitation sector of the Upper East Region, Ghana: among them the employees of the workshop producing the rope pump; Raphael Nampusuor, consultant working for the Canadian international Development Agency (CIDA) in Ghana; Enoch Babisma, engineer working for the Community Water and Sanitation Agency (CWSA) in Bolgatanga, Ghana; and Wiljo Fleurkens, founder of United Cross Culture, a Ghanaian NGO who funded some of the first rope pumps in Bolgatanga district.

Interviews were prepared and conducted in each community. The questions aimed to collect information about the construction of the well, the acceptance of the pumps by the community, the uses of water, the maintenance system and the costs.

Analysis

The data thus collected were analysed and compared with existing information. In order to weight the influence of external parameters on the results, correlations were statistically analysed using the presumptive count of the thermotolerant coliforms counts as the dependent variable. The independent variables considered were: type of pump, location (district, zone), physical parameters of the water (temperature, pH, colour, turbidity), depth of the well, time period since the last rain, age of the pump, time period since the last cleaning of the well and number of users.

Further statistical analysis were then conducted to compare the respective influences of the rope pumps and the Nira AF85 on microbiological water quality. In order to test the actual differences between the two sets of data it was decided to conduct a Wilcoxon's rank-sum test, and as a first step the distributions of log median value of the thermotolerant coliform counts for the Nira Pumps and for the Rope pumps had to be tested for normality using the Probability Plots Correlation Coefficient test.

RESULTS AND DISCUSSION

The wells

All the wells chosen within the scope of the present study were hand dug shallow wells. After siting by Rural Aid, the wells were dug by the communities themselves during the dry season. The depths of the wells vary from 6.1 metres to 12.1 metres with no significant variation between the two types of pumps. The aquifer is a layer of weathered fractured sandstone. After digging, the wells were lined by casing from bottom to top by the Rural Aid technicians.

The pumps

The Nira pumps were significantly older than the rope pumps. The oldest rope pumps were installed in March 2003 and the newest Nira was installed in November 2002. The information concerning the repairs occurring on the pumps was gathered during interviews with the communities and the answers, notably concerning the time, are often approximated. However, the main repair mentioned by the community was the cleaning of the foot valve for the Nira pumps.

The rope pumps need oil to ease the operation of the handle but only six major repairs were mentioned. Among these repairs, mainly due to a bad manufacture, the replacement of the rope was required on two pumps. This happened twice in Asulgum Asaka, Bolgatanga district and once in the Muslim community in Kasena-Nankana. This is probably due to a bad manufacture of the guiding box at the bottom of the riser pipe. Some cement might have been left around the bottle guiding the rope which led to an early wear of the rope. It is worth noting that the community of Aniabisi, Bolgatanga district, whose pump was installed on the same day as the neighbouring one of Asulgum Asaka, has never had to change the rope since the installation in March 2003.

Costs

The results of the interviews with the communities were not consistent enough to compute realistic maintenance costs. However, capital costs and operation and maintenance costs for 1036 Nira pumps in the Upper Regions of Ghana have been calculated by Nampusuor and Mathisen (2000:21), over a period of six years from 1996 to 2000 inclusive. The results of that study give a capital cost of US$ 700 for a Nira on a 12 metres well with maintenance costs of around US$ 89 per annum including the replacement of the pump after 15 years without any discount rate.

On the other hand the capital cost of a Ghanaian rope pump made by Jenamise Enterprise is around 1 500 000 cedis (US$ 168) but there is no actual study about the maintenance costs. One study led by the WSP (2001) in Nicaragua gives maintenance costs of around $US 5 per annum for the rope pump.

Consumption and uses of water

The number of users per pump was estimated by the communities and often given in numbers of households. However it has been possible to make estimates from this information. The number of users varies from 125 to 300 with an average number of 196 and no significant differences between the two types of pumps. An estimation of the water consumption has also been possible and the results give an estimated average of 35 litres per person per day once again with no significant differences between the two types of pumps.

Neither were there many differences in the perception of the pumps. The Nira and the rope pump were perceived as an advance by the communities compared to the river or the rope and bucket they were using before. One frequent complaint is that the wells often dry out at the end of the dry season; this does not really depend on the pump but was one of the most frequent answers when the community were asked if they were satisfied with their pump. The main demand was for the construction of more wells.

Sanitary inspections

The two sanitary inspection forms contain fourteen questions each. Sanitary inspections were conducted for each sample, but their utilisation was sometimes problematic and some questions arose.

The major finding of the sanitary inspections was that their use is not straight forward. Two main difficulties were encountered. The first one was concerning the evaluation of the state of a well. Answers to questions such as: What size of cracks should be considered at risk? What amount of water on the well head cover should be considered to be a risk? will always be estimated ones and depend partly on the subjectivity and experience of the person conducting the inspection.

The second related difficulty was in answering questions concerning drainage, as the actual presence of stagnant water might not be related to the level of contamination registered at that time. Conversely water might have contaminated the supply but no trace of it was visible at the time of inspection. It is therefore difficult to accurately relate a sanitary inspection with the results of the microbiological water analysis for the same sample.

However, the scores of the sanitary inspections varied from 7 to 11 on 14. But the sanitary risk scores of the present study seem to be poorly related with the presumptive thermotolerant coliform counts.

<u>Water analysis</u>

Physical parameters

No major differences were encountered between the two types of pumps concerning the measured physical parameters. One however is worth mentioning. The turbidity varied according to the districts, from 5 NTU on average in Bolgatanga district, to around 20 NTU in Kasena-Nankana district and more than 70 NTU in Bawku-West district. The turbidity also showed variation according to the pumps: an average turbidity of 13 NTU has been calculated for the rope pumps compared to an average turbidity of 29 NTU for the Nira pumps. This difference is noted for the three districts.

One of the explanations for these differences between the two types of pumps is that the Nira causes more movement in the water of the well than the rope pump, thus increasing the turbidity of the water by the pump stirring up the particles settled at the bottom of the well. The continuous movement of the rope is less likely to perturb the particles in the well.

Presumptive counts of thermotolerant coliforms.

One sample per pump was taken weekly during three weeks on ten Nira AF85 and ten rope pumps, a total of sixty samples were analysed using the membrane filtration technique and incubated for 18 hours at 44° Celsius using an Oxfam Delagua kit.

Each daily set of samples was accompanied by a blank bottle used as a control sample and filtered with the samples of the day as recommended by Bartram and Ballance (1996).

Six samples had to be discarded because the blank bottle gave a result Too Numerous To Count (TNTC). The counts varies from 1 to 15000 colony forming unit (cfu) per 100ml, 15000 being a value attributed to the counts that were TNTC as this was above the highest value directly recorded.

The mean count for the rope pumps was 2015 cfu/100ml and 2474 cfu/100ml for the Nira AF85. This result seems to indicate an advantage for the rope pump in terms of water quality.

Table 1 Thermotolerant coliform counts means in cfu/100 ml and standard deviation by community and by type of pump

community wells	type of pump	district	sample 1	sample 2	sample 3	mean	st. dev.	Mean by type of pump (without discarded)
Asapombisi	Nira	Bolga	100	200	0	100	100	2474
Atoobisi Asogrobisi	Nira	Bolga	15000	0	10	5337	9235	
Pelungu Nairi	Nira	Bolga	570	985	15000	5852	8791	
Sokabisi	Nira	Bolga	3600	1200	0	1600	1833	
Afania	Nira	K.N.	8300	2450	395	3715	4102	
Asason	Nira	K.N.	14200	0	0	4733	8198	
Yitonia Aduntra	Nira	K.N.	1100	4750	120	1990	2440	
Yitonia Piose	Nira	K.N.	3900	4400	570	2957	2082	
Gundago	Nira	B.W.	1200	200	60	487	622	
Lanaga	Nira	B.W.	11000	1750	455	4402	5751	
Aguridone	Rope	Bolga	15000	100	245	5448	9138	2015
Aniabisi	Rope	Bolga	585	0	1025	537	514	
Asulgum Asaka	Rope	Bolga	1100	405	490	665	379	
Atiabisi Yikene	Rope	Bolga	15000	0	20	5340	9232	
Azinsum	Rope	Bolga	82	120	70	91	26	
Baandaborg	Rope	Bolga	475	985	0	487	493	
Adunia	Rope	K.N.	800	1150	110	687	529	
Muslim	Rope	K.N.	15000	14350	605	10318	8452	
Gandare	Rope	B.W.	2250	0	1680	1310	1170	
Natinga	Rope	B.W.	400	0	155	185	202	

Blank bottle contaminated (TNTC)

The difference observed on the two sets of samples analysed in the present study might however not be true for the entire population of Nira and rope pumps in Upper East Region.

In order to confirm the trend observed in the above table a further statistical analysis is needed. The log median value of the counts was used as an outcome measure for each pump as currently applied in the water resources field (Howard et al 2003), (Gorter et al 1995), (Helsel and 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. The test was conducted as outlined in Helsel and Hirsch (1992:113). The result of the test showed 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 and Hirsch 1992:118); the null hypothesis being "The presumptive 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 outcome measure for each individual pump.

For the null hypothesis to be accepted the result of the test should give a p-value greater than $p = 0.05$ (Shier 2004).

In the present case, the p-value given by the test was $p = 0.65$; indicating that there was no evidence for a difference between the pumps.

The final result of the statistical analysis is that there is no difference between the two types of pumps in term of microbiological water quality. The comparison needs therefore to include other parameters.

Overall comparison

It is possible to conduct a ranking comparison between the two types of pumps including several parameters of importance discussed in the present study. The ranks are computed as follow :

Rank1 is the rank given to the type of pump with the best value for a given parameter.

Rank 1 = 1

Rank2 is the rank given to the type of pump with the worst value for the same parameter.

$$rank2 = 1 + \frac{|X - Y|}{Z}$$

Where:

X = the value of the parameter for the rope pumps

Y = the value of the same parameter for the Nira AF85

Z = the highest value of the two

The ranks are then summed and the results for the two types of pumps can be compared on this basis. The values given for each parameter are presented and discussed in other parts of the present study and are based on a roughly equal number of users for the two types of pumps. The following parameters are included in the comparison:

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

Table 2 presents the results of this ranking comparison. There are two columns for each type of pump, the column on the left gives the value of the parameter for the type of pump, the column on the right gives the rank attributed to it for this parameter. The rows are filled with the different parameters and indicate where the information can be found in the present study.

The present ranking comparison gives a score of 6 to the Ghanaian rope pump against a score of 9.4 for the Nira AF85. The rope pump is performing better for each parameter included in this ranking comparison.

Table 2: Ranking comparison between Nira AF85 and rope pumps

Parameters of the comparison	Ghanaian rope pump		Nira pump AF85	
	Data	Rank	Data	Rank
Impact on microbiological water quality Section 6.3.2 and 7.2 Similarity of the two types of pumps (Wilcoxon's rank-sum test)	Mean presumptive thermotolerant coliform count = 2015 cfu/100ml	1	Mean presumptive thermotolerant coliform count 2474 cfu/100ml	1.2
Impact on turbidity Section 6.3.1.2	Mean turbidity = 13 NTU	1	Mean turbidity = 29 NTU	1.5
Capital costs Section 4.2.3.2 and 6.1.2.3	Around 150 US$	1	Around 700 US$	1.8
Maintenance costs Section 4.2.3.2 and 6.1.2.3	Around 5 US$/year	1	Around 89 US$/year	1.9
Flow rate Section 4.2.3.2	Up to 41 litres/min for a 10 metres head	1	Up to 28 litres/min for a 10 metres head	1.3
Maximum pumping head of the standard model Section 4.2.3.2	40 metres	1	12 metres	1.7
Totals		**6**		**9.4**

CONCLUSION

The analysis of the results shows that there are no significant differences between the two types of pumps in terms of their impact on microbiological water quality. The comparison has to be done on other parameters to decide which pump to implement.

The comparison of the other parameters shows that the rope pump outperforms the Nira AF85 in all of them.

The rope pump is cheaper than the Nira AF85 in capital cost and also in maintenance costs.

The pumping head is dramatically higher for the rope pump than for the Nira along with the flow rate.

These financial and technical advantages are hence coupled with the fact that the rope pumps are manufactured locally.

Therefore, thinking in terms of standardization, economical reliability, benefit for the users and sustainability, the rope pump should be actively promoted and, as a first step towards its broader dissemination, accepted as a standardised pump by the Ghanaian government.

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