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Identifying barriers to the sustainable implementation of the Ceramic Water Purifier for rural Sierra Leone

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Abstract With improved water sources failing to meet World Health Organisation standards due to a lack of user education and supply chain networks not in place the need to develop a market for point of use (POU) water treatment systems is in urgently required in Sierra Leone to achieve safe water for the 73% residing in rural areas of who lack access to even improved water supplies. Through well water analysis and surveys of 5 villages in the surrounding area, this paper assesses the market potential of the Ceramic Water Purifier (CWP) as a low cost, low energy POU water treatment solution. From these results this paper develops a preliminary market map, based on a methodology developed by Practical Action, for the establishment of a CWP enterprise in Bonthe district of Sierra Leone. Potential barriers to implementation have been identified and show that providing capital cost subsidies, integrating POU technology into government policy and offering training to users and producers through government and NGO resources, a CWP enterprise has the potential to effectively reduce mortality as a result of diarrhoea and empower local communities.

Keywords Ceramic Water Purifier; Community Integration; Education; Market Mapping; Point-of-Use; Sierra Leone

INTRODUCTION

Of the 884 million people still lacking access to improved water sources nearly 40% of these live in Sub-Saharan Africa (WHO, 2010). With many countries in this area unable to sustain their growing populations throughout dry seasons due to lack of natural water supplies and with biomass in the form of firewood being their primary energy source. This creates a demand for low cost safe water treatment with minimum energy requirements and low environmental impact.

Point of Use Water Technologies: A potential solution to safe drinking water? Point of use (POU) water treatment solutions are essential tools for providing immediate access to safe drinking water, and have the potential to be an initial step towards long term economic growth for rural communities in many areas of the developing world. Access to safe water will allow children access to education as opposed to performing tasks such as water and firewood collection and will minimise the health risks associated with contaminated water sources and indoor air pollution from open fires. Additionally, it has been reported that diarrhoeal diseases was reduced by 25%, 32% and 35% using increasing water quantity, improved sanitation and POU household water treatment (HWT) systems, respectively (Montgomery and Elimelech, 2009).

Appropriateness of the Ceramic Water Purifiers. The ceramic water purifier (CWP) is one of several household water treatment (HWT) devices developed and implemented by various aid and donor organisations (REF). Whilst the aim in many areas is to allow the infrastructure to support a centralised or small scale water treatment system, this is not currently in place (REF). CWPs compared to other POU water treatment devices are a low cost low energy HWT solution. They require no ongoing operational cost and no further utilities, and they are shown to achieve the second highest reduction in diarrhoea (Hansen, 2010). The downside of

the CWPs is their ability to foul easily, and clay being a brittle substance, if not handled with care they can easily fracture and break (Lantagne *et al.*, 2006). Despite this, replacement of the filter alone is \$4-6, which requires a relative low capital. Under laboratory conditions a >99% pathogen removal with the CWP has been previously achieved (Hansen, 2010), however field tests conducted by Potters for Peace in Nicaragua showed a significant reduction to <50% removal (Lantagne, 2001). Reasons for such a decrease in the field tests were suggested to be due to recontamination through dust accumulation in the spigot, use of dirty receptacles and a lack of general household cleanliness (Lantagne, 2001). Factories surveys also indicated a variation in practices suggesting a lack of producer understanding (Hansen, 2010). Investigation as to the suitability of CWP for rural Sierra Leone with an alternative TiO₂ coating has been investigated for their technical viability (Hansen, 2010). Further to this, this paper is a study to assess the appropriateness of the CWP for rural Sierra Leone, with consideration to implementation barriers such as user and producer educational and training needs.

Participatory Market Mapping. In Cambodia where CWPs are an established HWT solution, the social enterprise, Hydrologic, has been using social marketing principles from the private sector to brand the Tunsai water purifier (Hydrologic, 2011a). This demonstrates that effective social marketing can help to reach the poor with intermediate technologies. Participatory Market Mapping is a new tool which has been developed by Practical Action which assesses markets to enable the poor sustainable access to technologies. Research by Albu and Griffiths (2005) has shown that participatory market mapping is a method that can be used to strengthen supply chain networks, allow policy makers to connect with users and producers and also place demand on the enabling environment to act to provide the means to set up the required services. Several tools and methodologies are being developed on this subject. Mostly these are being used to enhance and improve existing markets; however preliminary market maps can help to identify potential barriers to implementation and thus, the appropriateness of the technology for a given area (Practical Action, 2010).

Case Study: Sierra Leone. Sierra Leone, located on the West coast of Africa and bordering Guinea to the North and East and Liberia to the South, has some of the most abundant water resources in West Africa. Yet water scarcity and lack of even basic sanitation are prevalent throughout the country. Following a 11 year civil war much of Sierra Leone's infrastructure has been destroyed, and many previously existing water supply and sanitation facilities left to ruin due to destruction or a lack of maintenance and repair (UNICEF, 2005). Currently only 26% of the rural population have access to improved drinking water sources and a meagre 6% access to improved sanitation facilities (UNICEF, 2010).

In 2003 coverage of water supply was as low as 15% in the Bone district, second only to Khalaun in the North (UNDP, 2009a). Investigations into water quality in the Moriba town area, Bonthe district, showed that the levels of *E. Coli*, Total Coli forms and *Salmonella Vibrio* (cfu/100ml) present in both, supplied and hand dug wells failed to meet the World Health Organisation drinking water standards (Hansen 2010). Where Non Governmental Organisations (NGO) have provided "improved" water sources, namely sealed pumps, many of these pumps are broken. Due to a lack of understanding or lack of tools to fix them this results in communities resorting to hand dug wells or simply accessing the wells by rope and buckets which are dirty and cause cross contamination of water sources. Water policy and government objectives to address safe water needs in Sierra Leone. In the Government of Sierra Leone's (GOSL), water and sanitation policy for Sierra Leone identifies contributing factors to depleting water supply to be as a result of deforestation, inadequate storage of

water, inability to use water conservation techniques such as rainwater harvesting. In urban areas this is compounded by loss in transmission and distribution systems and demographic shifts result in a failure to meet rising demand of the capital of the country, Freetown (UN-ECA, 2007).

Included in the challenges which need to be met is the need to manage water resources and to use appropriate water storage techniques; To use technologies which take account of capital, operation and maintenance costs; to involve communities in determining the price of water services and to train local professionals to be able to address water and sanitation needs. Watsan committees and boards are to be put in place and exercise management and responsibility for services in villages and small towns. In order to prevent NGO and donor dependency, the national water policy states that NGOs should intervene through district councils (DC's), who will be responsible for creating an enabling environment for communities to manage and maintain their own water treatment supplies (UN-ECA, 2007). Further to this, it has been identified that in rural areas there is a need to ensure communities actively participate in the planning, construction, ownership, operation and maintenance of water supply; that minimum service levels for domestic water supply are established; to promote private sector participation to assist in providing goods and services relating to water supply needs; to establish collaboration amongst stakeholders and to develop effective monitoring and evaluation of services (UNDP, 2009a). In addition to the scientific and technical demands for provision of safe drinking water, these policy objectives for Sierra Leone's drinking water targets clearly highlight the need for market development; consideration of community participation; user education and stakeholder engagement at all levels. However failure to address the fact that too often ground water sources are contaminated and dirty receptacles are used which renders even improved water sources unsafe to drink.

AIMS AND OBJECTIVES

This aim of this paper is to determine the appropriateness of CWP's for rural Sierra Leone through three objectives:

- Addressing the need for intermediate education and community participation to ensure a sustainable design.
- Identifying barriers due to lack of supply chain networks and available skills and resources.
- Addressing ways to improve the market structure to enable POU water treatment systems to be accessed by rural areas in Sierra Leone.

METHODS

A small sample of 21 participants from 5 of the villages where wells had been sampled in July 2009 were questioned regarding water quality in March 2010. Of those surveyed, 71% were female and 29% male. The average number of school years was 12.3 and 6.9 for male and female, respectively, amounting to an overall average of 8.5 years. The age distribution of participants was 9.5% <20, 9.5% 20-30, 28.6% 30-40 and 52.4% >40 years. The average sized household was 10 inhabitants. All participants were asked a series of questions to identify user awareness of water treatment issues, current methods of practice and to identify a suitable point of use water treatment method for the area.

RESULTS AND DISCUSSION

Survey's were conducted in the same villages as sampling took place. The survey results were from a small population sample, so results cannot be assumed to be definitive for the wider population, but help to give insight into the reasons behind poor water quality in the area investigated.

Hygiene Practices

When asked 95% of participants stated that they do not treat their drinking water, yet alarmingly 100% of participants surveyed identified water treatment as one of their top three health concerns for their family. Dirty containers (100%) and dirty hands (95%) were understood to be contributing factors to poor water quality (Figure 1) and 62% of participants report washing their containers daily (Figure 2). Water storage containers were described as buckets, bowl pans, jerri cans or drums. This shows the effectiveness of hygiene training in the area however survey results concerning water treatment method identified somewhat different levels of understanding.

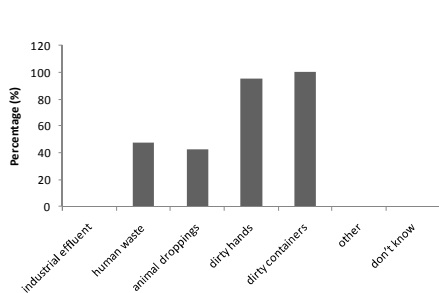


Figure 1 Main reasons identified for the contamination of water sources

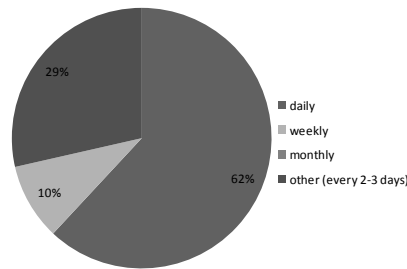


Figure 2 Percentage of participants who clean their water storage container at identified frequencies

Water treatment awareness

All the participants asked access their water through a well with a pump, and yet 95% of those asked failed to know how to fix it should it break and would opt to contact an organisation who may no longer be in operation or contactable due to limited communication infrastructure before attempting to fix the device themselves (Fig. 3). Too often there are examples of technologies which have been installed, but for when these devices fail, there are no maintenance or supply chain networks in place to provide services to fix the device (Byars *et al.*, 2009).

Interestingly the only participant who stated they felt confident to fix a broken well was a 20-30 year old woman who had received 9 years of education. This exemplifies that access to education empowers women. As women are responsible for many of the household tasks such as water collection, the education and training of women is fundamental to achieving poverty reduction. However, [Figure 4](#) shows that participants failed to be aware of viable water treatment methods other than Chlorine, which only 5% used, and they had little understanding of the mechanisms behind the treatment methods proposed. Whilst Chlorine is an internationally marketed product, studies show that many point-of-use (POU) systems lack effective marketing strategies, often have poor product design standards and availability of spare parts is often an issue (Heireli, 2008). This could explain why other HWT technologies

have failed to be recognised by survey participants (Figure 4Fig-4), thus exemplifying a marketing failure.



Figure 3 The percentage of the 100% of participants who use a well with a pump who would attempt to fix it should it break

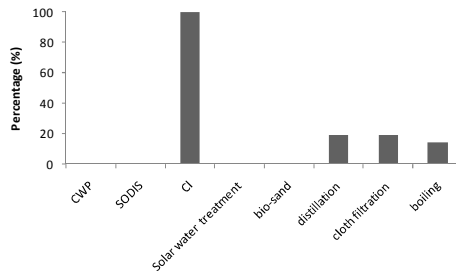


Figure 4 Percentage of participants aware of each of the different POU treatment methods available

User demands

When participants were asked what they would be willing to pay for a water treatment system the figure stated was <10,000 Leones (equivalent \$2.33). This provides an insight of the market demand for a low cost water treatment device. 100% of participants felt that NGO's were responsible for providing water services (Figure 5Fig-5), only 5% also stated that themselves and their family had some level of responsibility as well. This behaviour is also identified in national water policy, where lack of community participation is identified as a real barrier to the implementation of sustainable water treatment systems. An overall dependency on donor agencies and NGO's has meant that many expect the NGOs who installed the device to provide, maintain and replace it (UN-ECA, 2007). In the long term as NGO support reduces, there needs to be mechanisms in place which empowers locals to take on responsibility for service provision to ensure long term use.

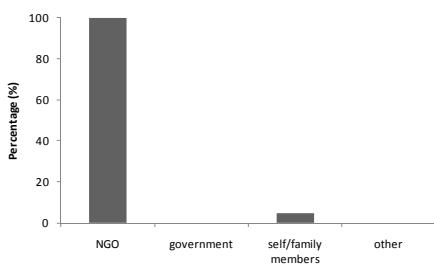


Figure 5 Percentage of participants who identified authorities responsible for providing water treatment services they felt should be responsible for providing safe drinking water.

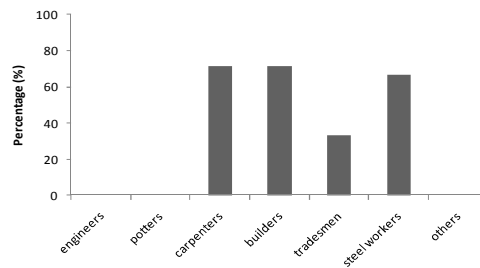


Figure 6 Percentage of participants who identified the presence of each listed local skill

Figure 7

~~When asked to identify which skills and traders were available in the local vicinity no one identified potters, a useful skill for the production of the CWP, however steelworkers, builders and carpenters were identified, so production of the machinery necessary to produce~~

~~CWP's could be available (Fig. 6). Using the automated presses means less skill in pottery is required however whilst personal contacts did suggest that there are potters in Sierra Leone this is not a predominate trade as for example in Guatemala where the CWP originates from. Identifying a region where an entrepreneur who has skills in pottery would be key to facilitate the set up of a factory. The materials required for production of both the Biosand filter and CWP: clay, sand, wood were identified as available resources. For previously investigated CWPs with a TiO₂ coating (Hansen 2010) rutile was also a known and readily available resource.~~

Fig. 7 shows that those with a good understanding of water treatment mechanisms have undergone between 8 to 15 years of education. Participants with no years of education were partially or completely lacking understanding. Those with over 15 years of education also seemed to have little understanding of mechanisms. This could either highlight that number of years of education may mean a very fragmented education and not therefore that an individual has achieved a high level of secondary or further education, or that these are people who are having to repeat years and struggling to grasp some of the concepts being taught. A barrier to understanding scientific principles in many developing countries being a result of didactic teaching methods due to limited resources resulting in a little opportunity for practical application (Byars *et al*, 2009).

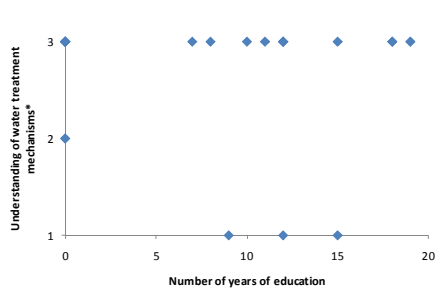


Figure 7 Participant years of education against understanding of water treatment mechanisms, (*1=good understanding, 2=partial understanding, 3=lacks understanding)

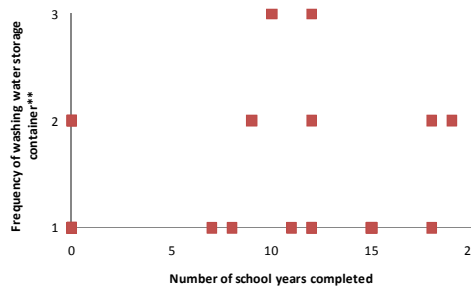


Figure 8 Number of school years against frequency of washing water storage container (**1=daily, 2=bi-daily, 3=weekly)

Figure 8 also shows a slight correlation between education and hygiene practices. Those with the greatest number of years of education wash daily or bi-daily. However for those achieving an average number of years of education (8-12 years) there is varied practice.

Mapping the Market

A lack of user awareness of HWT products is evidenced by the results of the surveys showing that currently no market for POU water treatment devices exists. With no easy infrastructure to transport equipment unless a market structure is created, even if a project is implemented the likelihood is it will lack sustainability and an ability to achieve the outset agenda. In order to produce a preliminary map results from the surveys carried out and an existing study of current government policy documents surrounding water treatment in rural areas have been put together and a preliminary map formed.

Market Actors. As this is in the outset to be for small scale distribution within the locality, there are few market actors involved. This will help to reduce problems encountered in other market chains where imports and exports and large scale production add complexities to distribution and supply chain networks. There are however still barriers to implementation which need to be addressed and a full understanding and appreciation of market actors involved needs to be taken into account before set up. Household demand for water treatment is evident from the survey results shown, however currently pottery is not a widespread trade in the area, and surveys of the wider district would therefore be required to determine whether the skills set required to establish a filter factory existed.

Traders. Results identified an abundance of tradesmen in the area. Though training and awareness from supporting services would be required to ensure those buying the appliance are properly trained in how to use and maintain their device to avoid replication of survey results where appliances have been left in disrepair or fail to operate effectively which, in the case of water treatment devices is have devastating consequences to the health of the user.

Enabling Environment. The enabling environment consists of structures and institutions which influence the market chain environment such as government policies and legal frameworks. They are beyond the control of immediate actors in the supply chain but unless addressed they impact the effectiveness of the market (Albu *et al.* 2005).

Availability of Resources. Clay and Rutile were identified as locally available resources by those questioned. Current designs use a colloidal silver coating and experiments to determine the effectiveness of TiO₂ as a viable resource concluded that some amount of silver doping is required in order to activate TiO₂ in the visible light range (Hansen 2010), therefore consideration as to appropriate chemical coatings for the CWP needs to be considered to ensure it is available and if required to be imported that policies are in place to prevent high import taxes in order to keep capital costs at a minimum.

Financial Policy. To support the uptake and set up of social enterprises will help enable the market for CWPs. Barriers such as high capital cost prevent the poorest from accessing water treatment. By negotiating with policy makers to ensure distribution cost are kept to a minimum and government subsidise POU water treatment enterprises this will enable the market set up. The private sector can also assist by reducing tariff and nontariff barriers to commercially available HWT devices (Clasen, 2009).

Import taxes. On specific products such as colloidal silver high import taxes may be required. This will increase capital costs and affect marketability of the product. Corruption can also increase cost of importation due to bribes demanded to avoid heavy taxation costs (Encyclopedia of the Nations, 2011). Policies to prevent high import taxes for products relating to water treatment needs will enable ease of cash flow through the market chain. Government policies can help to enforce *trading standards* as set by Potters for Peace such that filters need to meet optimum flow rates and coating solutions need to be made up to the specified concentration and ultimately that product meet WHO drinking water standards. A lack of standards for HWT has been a contentious issue between public and private sectors and leads to a perception that HWT devices are not in fact effective (Clasen, 2009). This therefore highlights the need to involve stakeholders at all levels to ensure standards are met.

Quality Assurance. Full quality control needs to be in place to monitor POU water treatment in order to ensure effectiveness (Clasen, 2009). This is recommended to combine government resources to enable the initiative alongside NGO support.

Consumer trends. An understanding of local markets and demand is essential. Markets are not simply cost driven but the need to understand cultural and sociological barriers to uptake of water treatment devices is essential. Participants expected NGOs to provide water treatment devices, a move toward a community approach and user awareness will require a mindset change. Awareness of chlorine is evident (Figure 4) but uptake is extremely low. Understanding why this is will help in establishing alternative POU markets.

Supporting service. The supporting services help to facilitate market growth and sustainability by providing training, coordination and technical assistance (Albu et al. 2005)

Producer Coordination. NGO's who specialise in water treatment can help to train users, retailers and producers to ensure that devices are used and maintained correctly. Support from the government through local district councils to ensure water is safe and meets WHO standards will help to maintain good reputation for CWP and enable the market to grow and develop. Training for maintenance and enhancing production can be provided by specialists such as NGOs where required. Ultimately if the incentive and initiation comes from the government as opposed to NGO's as stated in GOSL water policy framework, there will be less dependency on aid and donor support and help empower local villagers. Supporting services can facilitate and identify *supply chain networks* and skills availability to help meet growing demands. Facilitation of networks with tradesmen in local towns and assisting in the promotion of the CWP to villages is essential to growing the market. Where high capital cost is a major barrier to the viability and success of a water treatment device, financial service can assist by offering micro loans or subsidies (Shukla, 2011). Participants stated they were able to pay \$2-3. The ceramic water purifier requires no operational costs and simply a onetime capital cost which is lower than that of biosand filters and its sister device the ceramic candle filter, however this is still higher than the stipulated amount. Should receptacles break, supply chain networks need to be in place but the filter itself is only \$4-5 to replace every 3-6 years compared to the capital cost including storage devices which amounts to \$12-15.

Market information. Support to facilitate participatory market mapping of potential distribution networks is essential to sustainable implementation. Involving key stakeholders at all level of the market chain will ensure communication and awareness and from earlier participatory approaches has proved to effectively highlight barriers and raise awareness of stakeholders.

Upgrading standards. To ensure greater quality and effectiveness private partnerships may help to enhance the product design and partnerships. Hydrologic, a social enterprise in Cambodia have already started to improve factory production (Hydrologic, 2011b). Greater research from academic institutions and investment by private and multinational corporations can help to drive markets, reduce capital costs and ensure product quality and international standardisation of CWPs and other HWT device.

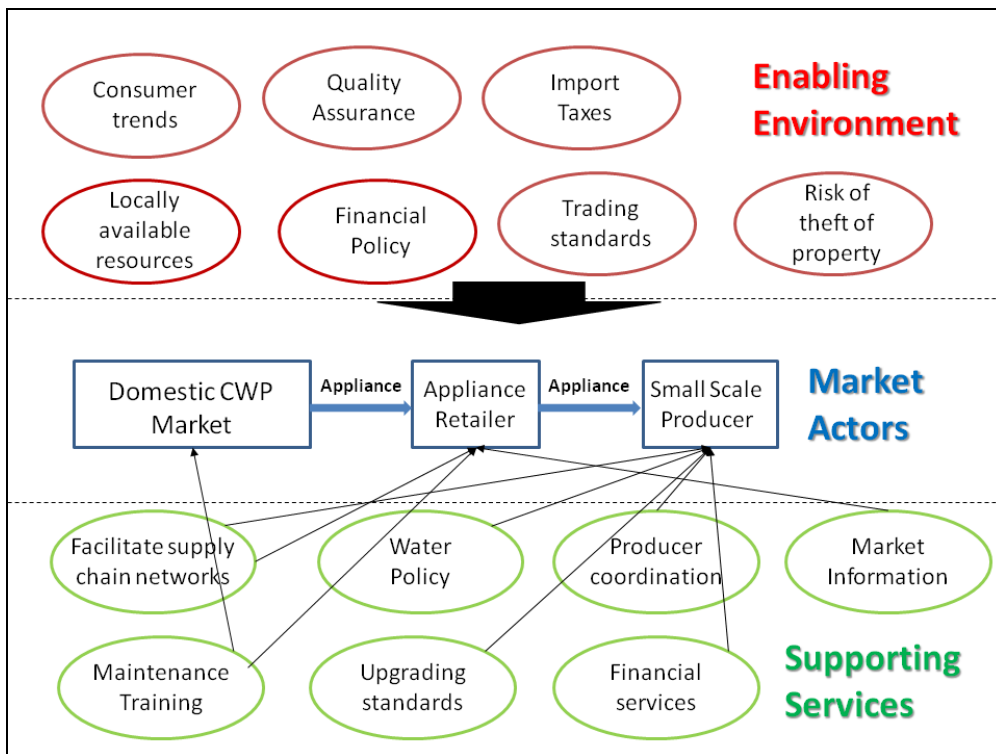


Figure 9 Market Map for Household Water Treatment Devices (adapted from (Practical Action 2010))

Fig. 9 shows a preliminary market for ceramic water purifiers. It shows that the training needs can be identified by piecing together a delivery model, supply chains, market barriers and user education. This can be beneficial to effectively and sustainably scale up the production and distribution of the technology and allow participants from across the sector, from entrepreneurs to key policy makers, to engage and understand the demands and constraints on service provision. This market map can be used to identify key stakeholders in the market chain for the enterprise establishment of CWPs in the Bonthe district of Sierra Leone.

CONCLUSIONS

Providing alternative more sustainably produced water treatment solutions can help to reduce the impacts on biomass resources, engage community participation and increase the quality of water and thus the health of the user, all of which are identified as specific policy objectives by GOSL (UNDP, 2009a). The need for a detailed market mapping study which involves all participants in the value chain is required. In order to form a sustainable market, barriers capital needs to flow to the producer efficiently. As has been shown by Practical Actions work on aloe markets and analysis of household energy supply systems, engagement at all stakeholder levels is required in order to effectively improve supply chain networks and meet user demands. The driver is to identify the key sector roles which are needed to make distribution and up scaling of CWP's and other water treatment technologies a success. By

offering maintenance and training to users through government and NGO resources, POU systems have the potential to empower local people. This enables the community level economy to grow; enables individuals to understand the importance of the technology and helps to provide a sustainable supply chain and technical appreciation of the technology for community level maintenance.

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