IMPERIAL COLLEGE LONDON, DEPARTMENT OF ELECTRICAL & ELECTRONIC ENGINEERING

Project Dwiri

A feasibility report into the use of a pico-hydrokinetic water sanitization system in rural Ghana

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1: Introduction

The Republic of Ghana is a developing country located in West Africa. It has a total population of 24.3 million, with the Akans as the major ethnic group. Ghana has been facing a slew of difficulties since its independence from the United Kingdom in 1957. Extreme poverty, the prevalence of HIV, lack of sanitation, clean water and food are among its most pressing problems. [1]

<u>The dire need for clean water in Ghana</u>

A research conducted by the WaterAid suggests that 3.4 million people in Ghana still lack access to clean water. In the capital of Ghana, Accra, only 25% of the residents receive continuous water supply, whereas 30% of the population only have access for twelve hours a day, five days a week. Furthermore, 10% of rural residents live with virtually no access to clean water. More than half of the rural population still obtain most of their water through natural resources, such as rain, river water and groundwater dug from wells, bore-holes and underground streams [2]. A study conducted by WaterAid suggests that 3.4 million people in Ghana still lack access to an improved water source, especially in the rural region.

<u>Aim of Project Dwiri</u>

Through preliminary research, our group discovered that Ghana possesses a significant amount of fresh water bodies, with a large amount of land area accessible to the Volta River Basin, one such water body. [3] Volta branches out to many smaller rivers and streams which are connected to rural villages in south and central Ghana. [3] This unique geography provides us with hydro-electrical resources and a large amount of fresh water to be sanitized using a suitable purification mechanism.

Our group proposes to alleviate the lack of clean drinking water in Ghana by providing a **portable, pico-hydrokinetic water sanitization system** which can readily service local, rural villages. The primary reason why such hydrokinetic systems remain untapped is that this technology is not available in many countries, especially developing countries like Ghana. Even if they are available, only a handful of people know how to construct and install complete design schemes. Our group hopes to eliminate the technical difficulty of installing such a system by **providing a ready-made and compact design which can be easily maintained by rural villagers with minimal technical knowledge.** We have three broad objectives for implementing our project:

1. To secure the basic human right to access of clean water

We believe that everyone has the rights to access safe drinking water and the main aim of our project is to reduce the mortality rate from drinking contaminated water. According to World Health Organization, an average human being requires around 2 litres of drinking water a day. A typical rural village in Ghana [5] would contain approximately 50 households or 250 people. Assuming that each household consists of five people, as such a village like this would require 500 litres of water to completely meet their daily needs. Therefore, our group proposes to supply at least 500 litres of water a day with our system.

2. To empower women and children

Many women and children are forced to go through the daily routine of looking for clean, drinking water for their families. They spend most of their day looking for water sources and transporting the water back to their homes. By eliminating this daily chore, our project aims to free up time for women to go to work and children to receive proper basic education in schools.

3. To provide the technology with minimal upkeep and cost

One of the crippling reasons as to why rural villages have less or no access clean water is that they do not possess the technology to sanitize water cheaply. Common solutions such as bore hole drilling and large scale water filtration plants are not feasible in the rural setting as they require high technical expertise for installation and are often hard to maintain without knowledge in this area. These installations tend to be expensive and require a high maintenance cost. Our design aims to completely eliminate the need for technical skills for maintenance by providing a cheap and ready-made design where the components can be replaced by villagers for new parts or cleaned.

2: Geographical Analysis

Background on geography

The southern coastline of Ghana is a sandy shore backed by plains and scrubs, where most urban developments can be found. A tropical rain forest belt, populated by heavily forested hills with many streams and rivers, extends northward from the coastline. Further north, the land is savannah-like, mostly covered by low bush and grassy plains. Most rural villages in need of clean water are situated within the northern and central region. The weather in Ghana is tropical, with varying wet and dry seasons. During the wet season, people from the rural villages are able to harvest some water through rain collection mechanisms and wells which are filled by rainfall. During the dry season, it is difficult to obtain water readily. There is little rainfall and the small rivers and streams often run dry. Villagers are often forced to use water from pot holes dug in the ground for their daily needs or drink untreated river water.[6] This water is often contaminated with parasites and bacteria which are the cause of many waterborne diseases such as Cholera, Hepatitis A and E and Typhoid fever. These waterborne diarrheal diseases account for 20% of all deaths for children under five in Ghana. [4]

Densu River System

Our group has targeted the Densu River, to implement our system. The Densu River is a 116 km long river in Ghana, starting from the Atewa Range and ending at the wetlands close to the Atlantic. [5] It flows through an economically important agricultural region, where most rural villages are situated for farming activities. There are around 200 settlements around the river system, with a total of around 600,000 people (average 3,000 per settlement) living in this area. [5] The Weija hydro-electrical dam is situated downstream on this river, which gives strong evidence that the river flow rate is sufficient to generate large amounts of electricity. Densu River also provides half of Accra's drinking water, giving a good indication that the river water is appropriate for sanitization.

Figure 1: Section of Densu River[7]

Figure 2: Model Village[8]

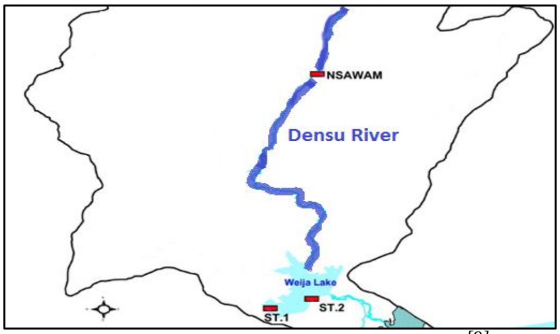

Figure 3: Span of Densu River[9]

The figures above show the span of the Densu River across Ghana, a segment of the Densu River and a portion of the Densu region with a rural village situated approximately 200 metres away from the river. Our group would be using this village (Figure 2) as a basic model for our estimations. The water needs of any larger or smaller villages can be estimated and scaled and provided accordingly.

River Properties [10]

Properties	
Wet season river flow rate (June to September)	$2.2\ m^3/s - 5.7\ m^3/s$ Average: $3.95\ m^3/s$
Dry season river flow rate (November to February)	$0\ m^3/s - 0.74\ m^3/s$ Average: $0.37\ m^3/s$
River sediments	Sand, silt, clay, gravel
Micro-organisms in river	Plant, algae, bacteria and viruses
Inorganic chemicals in the river	Fertilizers and insecticides from farming Chemicals from industrial activities Some metals e.g. Mercury, Iron, Manganese[11]

Table 1: Important Properties of the Densu River

3: Technical Analysis

Overview of our technical design

1. **Pico-hydrokinetic electrical generation unit**
   This unit provides the electricity for running the whole system. It will also consist of a generator, a battery and a regulation circuit to store excess electrical energy produced. [12]

2. **Pressured water pump**
   A water pump will be used to circulate water throughout the whole system. It is also used to generate pressure at the water sanitization unit in order to push the untreated water through the reverse osmosis membrane.

3. **Water sanitization unit**
   The water sanitization unit will consist of three stages. The first stage removes all large particles using a conventional filter. The second stage operates by using Reverse Osmosis. This process removes smaller particles, viruses and bacteria from the water. A water pump will provide the necessary pressure for reverse osmosis to occur. The last stage is a UV light sanitization system, where unfiltered bacteria and viruses are destroyed by altering their DNA.

4. **Data Collection Module (Prototype)**
   Our water sanitization system will contain a data collection module and a microprocessor which could send live data to a server to record the amount of sanitized water generated and used by local villages. The module also tracks whether the filters require replacement.

Pico hydro-electrical power

Pico-hydro is a term used for hydroelectric power generation of under 5 kW. [12] This technology has already been successfully adopted by rural and developing communities in Vietnam and Kenya to power small scale electrical grids. A low-head, hydrokinetic system is ideal for us to achieve our objectives. [12] The system has to be cheap, portable, power efficient and has to be easily maintained by the rural villagers as well. Our group proposes the use of a “Run of Stream” system which utilizes the natural downward flow of rivers to power pico-hydrokinetic turbines. The vertical axis of our turbine and low head enables our system to work in shallow rivers and during the dry season, where the water level of the Densu system decreases significantly.

Power Calculation

Although pico-hydrokinetic systems give only a small amount of electricity, this amount is already feasible to power our sanitization mechanisms and data collection module. The excess energy can be stored in high capacity batteries for alternative use. Installation of such a system is cheap and has very little detrimental environmental impacts.Our project is aiming for a 200 W, 12 V A/C generator which would more than sufficiently operate a 150W water pump, a 15W ultraviolet sanitizer and data collection module which runs on less than 5W.

Parameters	Equations to consider	Estimated Calculations
Hydraulic Power:	We first estimate the amount of kinetic energy (in Joules) generated by the flowing river: $$Hydraulic\ Power = \frac{1}{2}\rho A v^3$$ *ρ = density of water in kg/m^3* *v = linear speed of the river-flow* *A = area of the turbine blades in m^2*	Assuming the radius of the turbine blades to be 0.20m and an estimate of an average of 2 m/s river flow: $$Hydraulic\ Power = \frac{1}{2} \times 1000 \times \pi \times (0.20)^2 \times 2^3$$ $$\approx 503\ W$$

Efficiency:	To simply our calculations, our group used the following assumptions: 1. 70% of hydro energy is converted into the mechanical energy of the turbine. 2. 60% of mechanical energy is converted into the electrical energy of the system. 3. Losses in the circuit are deemed to be negligible provided the amount of power generated is large enough.	We obtain the efficiency of our system by multiplying the two efficiencies together. $Efficiency\ (\eta) = 0.7 \times 0.6 = 0.42$
Useful Electrical Power:	To calculate the electrical power (in Watts) generated by this system, we use the following equation: $Electrical\ Power = Hydraulic\ Power\ \times\ \eta$ *Hydraulic Power = Watts* *η = Efficiency of system*	Finally we obtained our useful electrical power by substituting the calculated values into the equation. $Electrical\ Power$ $= 503\ \times\ 0.42$ $\approx 211\ W$
Angular Velocity of Turbine	The angular velocity of the turbine can be calculated by converting the linear speed of the water to the angular speed of the turbine: $Revolutions\ Per\ Minute\ (RPM) = \frac{Flow}{R\ \times 0.10472}$ *Flow = Water flow in m/second* *R = Radius of Turbine in m*	Using the radius of our turbine as 0.20m: $Revolutions\ Per\ Minute\ (RPM)$ $= \frac{2}{0.20\ \times 0.10472}$ ≈ 95.5

Table 2: Simplified calculations for turbine and generator

Generator

A suitable generator is chosen such that it will generate 12V A/C voltage and 200W of power when connected to a turbine rotating at 95.6 RPM under load.

Pressured Water Pump

The pump is essential crucial in providing water pressure for our filtration process. Based on datasheets from various manufacturers, there are a variety of water pumps which satisfy our requirements: 1) Operates at 150W or less 2) Operates at 12 V_{RMS} 3) Generates at least 40 PSI of water pressure for the Reverse Osmosis process. Our group researched into one possible pump which is suitable for our design:

TP-35S TOPSFLO Water Pressure Pump (Changsha TOPSFLO Micro Pump Technology Co. Ltd)[13]			
Characteristics	**Values**	**Characteristics**	**Values**
1) Operating Voltage	12V	**2) Pump Rate**	5.0 litres/minute
3) Maximum Current	6 A	**4) PSI (Pressure/Square Inch)**	60
5) Operating Power	40 W	**6) Weight**	2.79 kg

Table 3: Characteristics of a typical water pump

Water Sanitization Unit

We present a three step purification system which aims to eliminate the unwanted constituents of the Densu River.

Stage 1: Sedimentation
Aim: To block large particles above 5mm in diameter from reaching the second stage of filtration and to prevent substances such as organic chemicals and chlorine from degrading the reverse osmosis membrane.
Removes: Clay, silt, sand, gravel, mud, large organic matter, organic chemicals and chlorine.
We have to make sure to only pump the water near the river surface to avoid the presence of large particles near the riverbed. The pumped water will go through an additional activated carbon filter which removes any residual sediment, organic chemicals and chlorine. Removal of these substances prevents the second stage membrane from rapid degradation and preserves the lifespan of this system. This initial filtration system is designed to be compact and modular in order to be easily removed from the main unit and cleaned. Our group's data collection module would have an opacity sensor which senses and indicates whether the filter needs to be replaced. This stage of the filter is designed to be easily replaced or cleaned without any prior technical knowledge.

Stage 2 : Reverse Osmosis (RO) Filtration

Aim: To ensure we use the most suitable and efficient water sanitization unit, we researched into various filtration technologies and compared their advantages and disadvantages.

Removes: Most small particles which are between 0.1 nm to 5000 nm in diameter, viruses and bacteria.

Reverse Osmosis is a traditional membrane-technology filtration method which removes unwanted molecules and ions from solutions by applying external pressure to the liquid onto the membrane surface. The pressure overcomes the normal flow process where the solvent usually moves from an area of low concentration to high concentration. The effectiveness of the RO membrane is dependent on solute concentration, pressure, and water flux rate. [14]

Disadvantages of such system are that it requires high pressure (approximately 40psi), and therefore a substantial amount of electrical power. Membranes which are capable of filtering out very small particles can also be expensive. Also, reverse osmosis only recovers small proportion of the purified water (3% - 15%). [15] But our group design circumvents these problems by providing an electrical source and a high water flow rate using a pump. The membrane assembly is the most critical part to the filtering system. It consists of a pressure vessel with a membrane that allows untreated water to run through. The most common RO membrane materials used in industrial water treatment are cellulose acetate and polyamide composite. Our group have decided to use spiral wound membranes structures as it maximise flow while minimises the system size. In the spiral wound configuration, a flat membrane and spacers are wound around the core tube to produce flow channels for permeate and feed-water. With the back of the membrane completely sealed to the edges of permeate spacer, feed-water will be forced through feed channel spacer and clean water will be forced into the permeate channel and flows in a spiral direction and collected in the core tube.

The reverse osmosis process utilizes a semi-permeable membrane to remove and reject a wide variety of impurities. (* These are conservative estimates)[16]

Aluminium	97-98%	Nickel	97-99%	Ferro cyanide	98-99%
Ammonium	85-95%	Nitrate	93-96%	Fluoride	94-96%
Arsenic	94-96%	Phosphate	99+%	Iron	98-99%
Bacteria	99+%	Polyphosphate	98-99%	Lead	96-98%
Bicarbonate	95-96%	Potassium	92%	Magnesium	96-98%
Bromide	93-96%	Pyrogen	99+%	Manganese	96-98%
Cadmium	96-98%	Radioactivity	95-98%	Mercury	96-98%
Calcium	96-98%	Radium	97%	% TDS	95-99%
Chloride	94-95%	Selenium	97%	Sulphite	96-98%
Chromate	90-98%	Silica	85-90%	Zinc	98-99%
Chromium	96-98%	Silicate	95-97%	* Virus	99+%
Copper	97-99%	Silver	95-97%	* Insecticides	97%
Cyanide	90-95%	Sodium	92-98%	* Detergents	97%
Ferro cyanide	98-99%	Sulphate	99+%	* Herbicides	97%

Table 4: Percentage of substances removed by Reverse Osmosis

As the table above shows, most of the unwanted substances present in the river will be removed at this stage.

Stage 3: Disinfection

Aim: To completely eliminate the presence of micro-organisms in the water

Removes: Bacteria, viruses and microscopic fungi

Ultraviolet Germicidal Irradiation(UV) [17]

Ultraviolet (UV) light with wavelength ranging from 220nm to 250nm is an effective disinfection method.
UV light kills bacteria and viruses (up to 99.9% of the microorganisms) and is also able to damage their DNA and RNA, preventing them from reproducing.[17] One of the main advantages of this system is that UV does not produce any other chemical by-products in the water. It is cheap and operates well under low power conditions. It is also unresponsive to temperature and pH variations. We also have to minimize errors of scattered lighting. The treated water has to be transported in a contamination free environment to avoid any possibility of recontamination.

Water Generation Calculation

Using the pumping rate of the "Topsflo" water pump as described above, we obtain a flow of 5 litres/minute at 60 PSI.[13] Typical Reverse Osmosis membranes have about 12% efficiency when converting waste water to treated water. By running the water through the Reverse Osmosis system, we get:

$$Water\ Generated\ Per\ Minute = 5\ \times 0.12 \approx 0.75$$
$$Water\ Generated\ Per\ Day = 0.75 \times 60\ \times 24 \approx 720$$

Based on these estimates, our group predicts our design can generate approximately 700 litres of clean water a day.

Data Collection Module (Prototype)

Each water sanitization unit is equipped with a data collection module which can transmit and receive data. **Our group has created a hardware prototype with a web-based interface for this design, which will be demonstrated during the presentation.** Each unit is individually addressable and a network of these units is arranged in a tree network mesh topology. This topology ensures that the most optimal route is undertaken when transmitting data and this reduces the amount of power needed for data transmission. The module contains six analogue channels which can be fed with water level and voltage detectors, opacity and temperature sensors. These data can be pushed onto a web server and displayed in an interactive website.

Advantages of the data collection module:

1. Enables an on device notification system for the villagers to inform them about the amount of sanitized water produced. This will inform the villagers how much water they can procure from our system so that there will be enough water for the whole village.

2. This module also allows the group to wirelessly calibrate our sensors, turbine settings and UV lamp intensity from anywhere around the world. This makes the process of maintaining and reviewing our water sanitization effective and mobile.

3. By collecting data from different water sanitization systems, our group can map out different "hot-spots" for generating water and optimize the placement of our units. This also enables the group to monitor the water consumption of various areas and plan out strategic placements of our units in order to maximize the water sanitization coverage across the region in the future.

Design layout

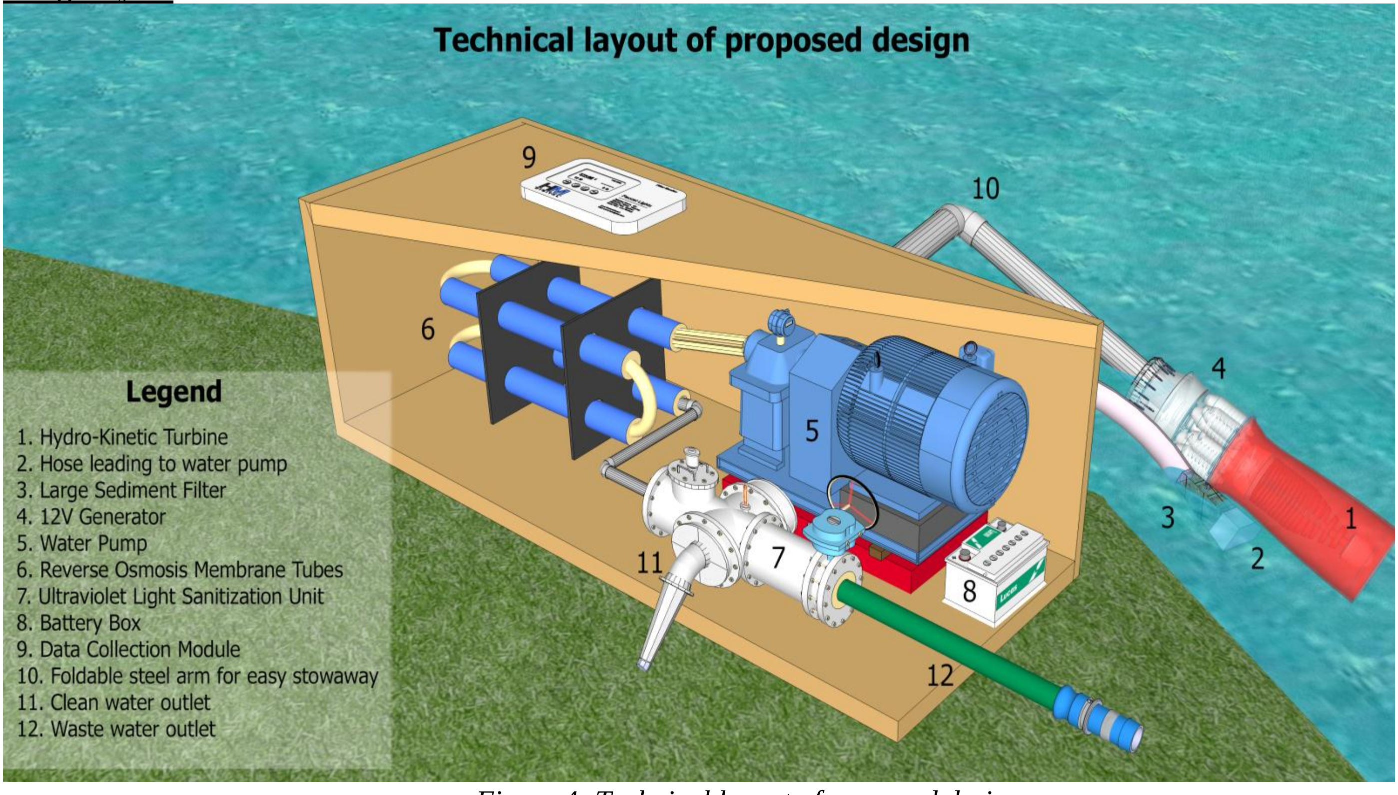

Figure 4: Technical layout of proposed design

The above figure shows the layout of our final proposed design. A waterproof box will contain the main sanitization mechanism, water pump. The hydro-kinetic turbine and power generator is attached to the box via a foldable steel arm which can be adjusted to fit the water level in the river. Kinetic energy from the running river is captured by the hydro-kinetic turbine and turned into useful electrical energy in the generator. The battery box stores the electricity produced and also contains a circuit which regulates the power and voltage. The water pump and ultraviolet lamps are powered by this battery box. Once activated, the water pump will force untreated river water at high pressure through the reverse osmosis membrane tubes. Clean water which flows from the tube are additionally sanitized by the ultraviolet lamp to remove any unfiltered viruses or bacteria. Not all of the water is successfully forced through the membrane, and the remaining waste water is expelled through a pipe back into the river.

4: Implementation

We plan to roll out the project in 4 phases within a year. Phase 1 begins with initial testing and building of a more robust prototype. In Phase 2, our group plans to test the system on local river sites to obtain data for design optimization. Phase 3 will involve more rigorous tests along the Densu River and in Phase 4, we hope to finally implement our project and see the results of our water purification system. The test-to-final implementation process is estimated to cost £2000 including travel for one group members.

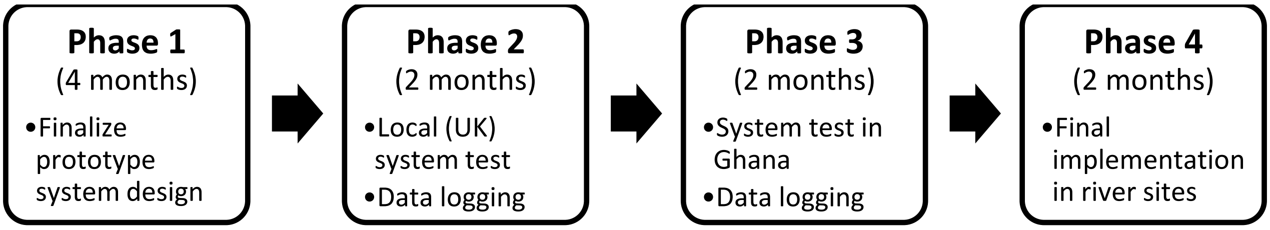

Figure 5: Implementation flow chart

5: Cost Benefit Analysis

Our system has various advantages as compared to the existing water purifying mechanisms. Most water purification technologies used are primitive and out dated. They rely on either gravity-aided filtration or solar disinfection which have unreliable efficiencies. They also do not provide long term solutions for the shortage of drinking water in Ghana.

<u>Current Water Aid Efforts</u>

In 2011, the rural water coverage in Ghana is estimated to be around 63%. [18]. However, only a small part of this is harnessed and converted into accessible water for the rural areas. The estimated water sanitation coverage is only about 16% across rural regions.

1. <u>WaterAid Ghana</u>
   WaterAid is the primary organization in charge of improving water supply coverage in Ghana. The organization provides expertise to local villagers on how to install wells in rural regions. WaterAid Ghana also provides the materials for building the pumps in the well [19]. Villagers form a committee to decide the location of the well and the village representatives organise the work. WaterAid volunteers sometimes help to dig the wells while their engineers help to install hand pumps in the well.

2. <u>University Charity Organisations</u>:
   On top of WaterAid's efforts, many charity organizations also distribute rainwater collection systems or filters for rural villagers to filter untreated water. Many student-led charity organisations travel to Ghana in summer to help build rainwater collection and storage systems for villagers, passing on the technical knowledge and resources to the locals. One such organisation is the Water Brigades at Imperial College London.

3. <u>Government Aid</u>:
   The government of Ghana is also trying to harness clean water from wastewater by treating it. Several biological treatment plants have been built to support this effort. Nonetheless, this has proven difficult as only about 10% of wastewater is collected and only 25% of the 46 treatment plants abide by the regulations and inventories provided.

Why our method over the current methods?

Component	Price
Turbine	£15.00
Generator	£29.95
Water Pump	£32.81
RO Filter	£6.56x4 = £26.24
Large Sediment Filters	£0.27x3 = £0.54
Pipes	£0.33x3 = £0.98
Battery box and regulator circuit	£19.98
Data Collection Module	£5
Outer Shell Materials	£13.12
Estimated Total	≈£143.62

Table 5: Price estimation table for our design

Our group estimates the cost of such a system to be around £150 pounds. This device fulfils the drinking needs of 250 rural villagers. A good cost-benefit yardstick for our design is the WaterAid wells. Medium-sized water well projects cost £3000 [22] pounds to build and they can service up to 500 people. This translates to roughly £6 per person compared to our design which translates to only £0.60 per person. Financially, our solution triumphs over this method, especially in Ghana where tightened aid budgets mean less funding on well construction projects. Moreover, our design provides water which is purified to a high standard, whereas the WaterAid wells lack a proper sanitization mechanism. Moreover, hand dug wells created by WaterAid have varying dimensions from 5 meters up to 20 meters deep, the excavation has to be carried out under supervision and after careful analysis of local geology.[19] Therefore their capacity will also be limited by the construction. Safety concerns of wells could also be problematic; wells and pumps that are dug during the dry seasons also have to be carefully maintained during wet seasons to prevent collapse. This will further require money and effort to ensure its operation.

Other methods presented by WaterAid such as gravity schemes [20] and rainwater harvesting [21] are less reliable as they are highly dependent on geographical locations and the weather. Rainwater collection is cheap and easily implemented but the water supply is unreliable and subject to seasonal changes. As for gravity-based filtration systems, there are simply not enough filters to go around for every household to purify untreated water. They also only provide minimal amounts of drinking water. Pot holes and bore holes may provide a more permanent fixture but they are not guaranteed to provide clean drinking water, as there is only a concrete slab to prevent contamination. This is an ineffective way to prevent contamination as bacteria and viruses could easily penetrate from the soil.

Project Dwiri is reliable in obtaining large amounts of water from a constant supply of river Densu, while the supplied water is safely sanitized to industrial standards. The system is made portable such that it could be implemented in multiple locations according to the need for water. In addition, the technology used in our design is sustainable and environmental friendly. Most importantly, the components can last for months before filters need to be cleaned or replaced, at little cost with no technical knowledge needed.

6: Conclusion

Project Dwiri boldly aims to provide a long lasting solution water purification system for the rural villagers in Ghana. Through an intensive feasibility study, we realised that more can be done for better rural water coverage in the northern and central regions in Ghana. The past few months of work have resulted in a myriad of ideas coalescing into a final design which hopes to mitigate the shortfalls of the current water aid programmes. Our rigorous research into the geographic and technical aspects has proved the system to be viable for implementation. We analysed initial design requirements and specifications, and carefully balanced the cost of our components with efficiency of water generation. Our design also utilized readily available water purification technologies to ensure an industrial standard water filtration process. As a result, we are proud to produce a final design which is low-cost, self-sustaining, environmentally friendly and efficient in clean water generation. We strongly believe that with more effort and funding, our system can definitely achieve the three goals that Project Dwiri embarked with.

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Appendix:

Transcript of face-to-face interview with Water Brigades (Imperial)

Interviewees: Matthew Keating, Water Brigade Secretary

Date: 8 December 2012

What they did:

They spent 10 days in Ghana building rain collection facilities for a few households. The method used is they built gutters along the roofs of the houses and channel the water into storage tanks. The walls of the tanks are basically made of wire mesh with concrete. Everything was made with local materials.

Why they choose the location:

There were a few places they considered such as Samaria, where most people are centred on the coast which is where they work. There are no rivers nearby and they get their water mostly from the ground water. Since they located along the coast, it is possible to produce hydroelectricity from waves. The people there have enough electricity, but what they lacked was clean water. This situation is similar to that in Ghana, but the reason they chose Ghana is that they felt it is where they could have the biggest impact.

Problems the people faced:

The communities they helped are located along the coast line as they mainly do fishing. As such, they usually dig wells to obtain ground water as sea water is too salty. The main problem is contamination from faeces that are mostly from livestock. These faeces contaminate the ground water.
Another problem is that most communities are isolated. They are not located near any cities or anywhere useful.

Suggestions:

They did suggest a method of filtration using this device called a LifeStraw which removes particles and even bacteria. They also suggested that we get the community involved so that the community would value the project more and have more interest in it. The community would then put in effort to self-develop. They also suggested the possibility of using the rain collecting technology and use the flow of the water to power the turbine instead.

Transcript of email interview with Dr. J.M. Kusimi

Interviewee: Dr J.M Kusimi, Department of Geography and Resource Development, University of Ghana
Date: 27th February 2013

"Hello Daniels,
This is the response to your questions based on information available. Much information could be sought for later if the project will actually be implemented.
1. a) Akrabu = Distance is 9.3 km and population is 2,080.
   b) Kukua = Distance is 5.3km, and no available data on the population

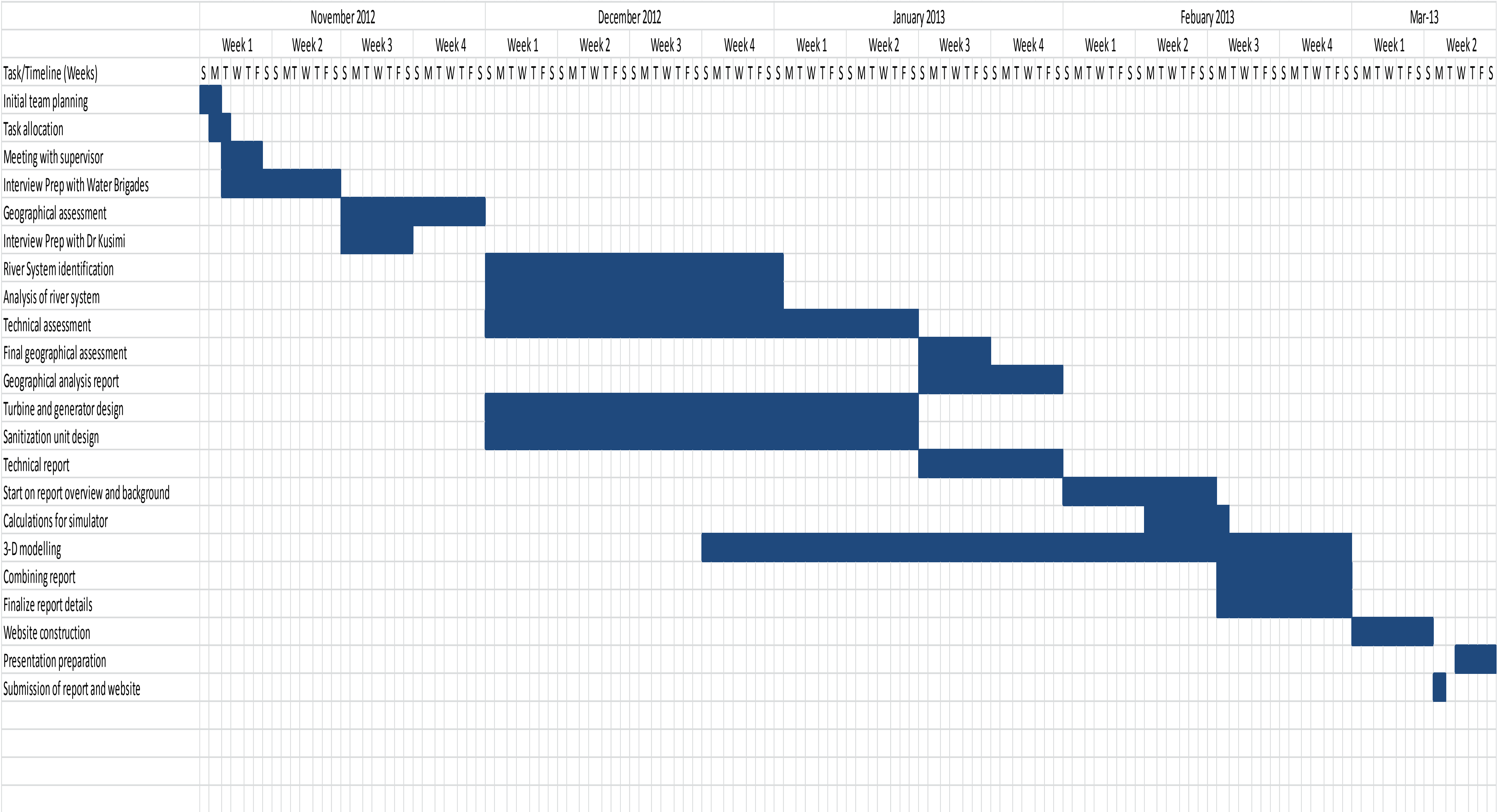
2. During high flows the river has more energy to carry its sediments resulting in less deposition. However during harmattan, flows are low because it is in the dry season which has occasional storms or not at all, consequently, there will be low sediment transport in the river.

3. Fertilisers and other chemicals (insecticides) used in vegetable farming along the river are washed into the river and these pollute the river.

4. Other towns along the river at Ashalaja, Nsawam, Koforidua, Adoagyiri, Mangoase, Akwadum, Ahoatumpon etc

5. I did not undertake flow measurements, but I could work on that for you later on if the project will be operational.

Best regards."



Gantt Char for management

Task allocation table

Introduction	
Ivan & Chien Lee	What is the purpose of our project?
	• Overview and background • Why Ghana? • What kind of problems does Ghana face? • Why clean water is a pressing issue? • Death /sickness rates caused by drinking unclean water
	Comments about current aid efforts
	• What are the factors that contribute to the severe lack of water in these parts of the country? • What is WaterAid (UN) doing about these sanitized water shortages? • Why are the current methods not working as effectively as they should be? • Include current Imperial-run projects • How can our method mitigate the current problems?
Body	
Wellington	Research
	• Alternative methods of purifying water • Alternative methods of electricity generation • Why we chose our method? • Critical analysis
John	Geographical Feasibility

	• Identify core sites which the system can be implemented
	  o Densu
	  o Akurabu
	  o Weijia
	• Investigate the feasibility of electrical generation at different locations
	• Investigate the river flow rate and feasibility to generate electricity
	• Investigate the amount of harmful substance in the river which need to be filtered
	• Investigate any extenuating circumstances which may contribute to the quality of the water (E.g., upstream farming, industrial activities which may discharge chemicals into the water)

Jia Sheng	Technical Feasibility

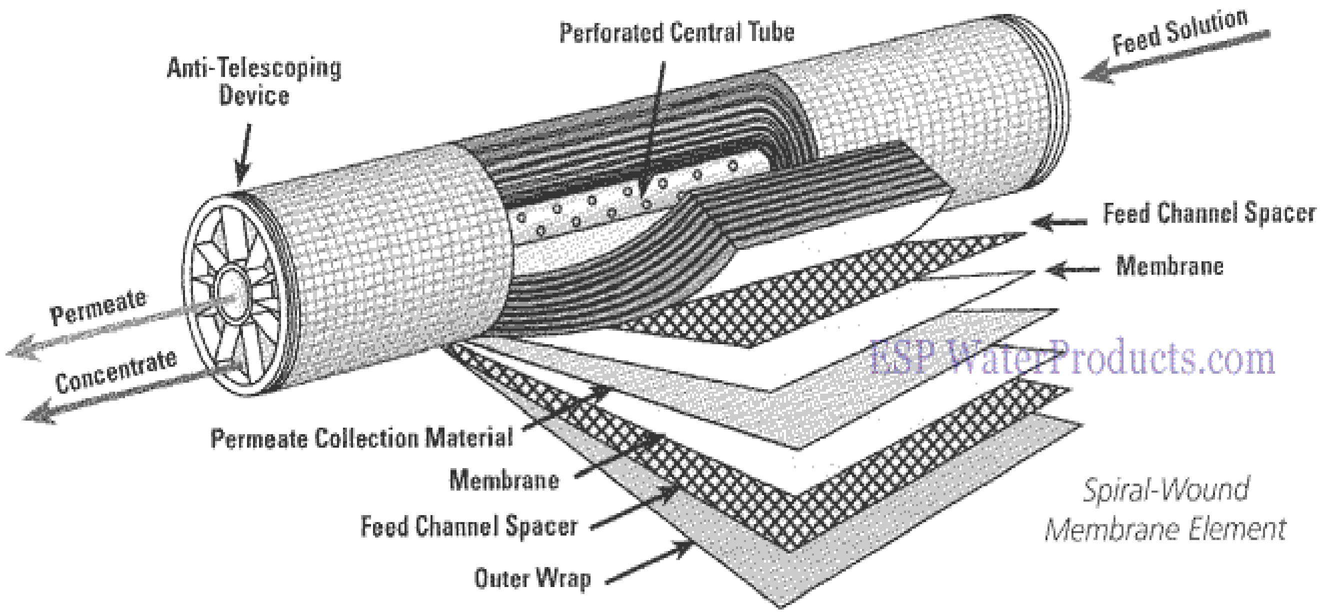
	• Purification of water
	  o Removal of large particles (5mm)
	  o Removal of bacteria, viruses
	  o Disinfection of water
	    ▪ Reverse Osmosis
	    ▪ Boiling
	    ▪ UV Light
	    ▪ Electrolysis
	    ▪ Chemicals
	• Generation of electricity
	  o Horizontal Axis turbines which are capable of funnelling water into both generator and collection for sanitization
	  o The amount of electricity generation can be simulated
	  o Investigate whether the amount of electrical energy generated is enough to power our proposed sanitization mechanisms

Jian Yuan & Ivan & Steven	Cost and Benefit analysis

	• Cost/benefit analysis of our project versus existing projects
	• Cost versus benefits to the local community
	    o Economic benefit
	    o Health Benefits
	    o Social Benefits
	    o Environmental Benefits
	• Measure against the population of villages and investigate whether the amount of water produced a day is sufficient
	• Break-even period
	• Why our project is cost efficient and should be implemented?

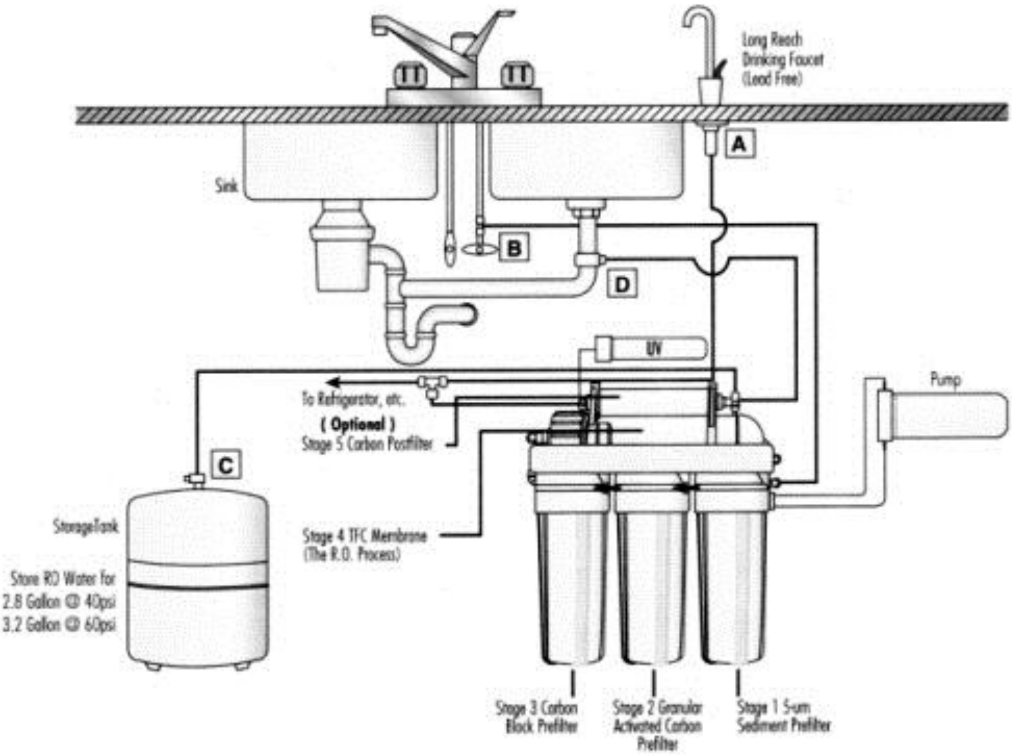
Conclusion	
Wellington & Steven	Introduction to our prototype
	General conclusion
Appendix	
	Email Interviews
	Face-to-face Interviews records
	References
	Management Chart

Detailed Diagram of Reverse Osmosis



Source: www.espwaterproducts.com

Example: Process of household Reverse Osmosis



Source: http://www.a1waterservices.co.uk/images/reverse-osmosis-system-diagram_medium.jpg