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A Solar Disinfection Water Treatment System for Remote Communities

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Abstract

Worldwide, approximately 780 million people do not have access to safe and clean water for drinking, cooking or washing. Consumption of untreated water exposes humans to a range of contaminants including faecal-borne pathogens and chemical pollutants. As a consequence, it is estimated that 1.5 million people die each year as a result of the consumption of untreated or contaminated water. These deaths are preventable with access to clean and safe water, but capital costs and maintenance requirements for large-scale treatment systems are prohibitive and challenging to implement in remote or distributed communities. Such remote communities typically suffer from faecal contamination of transient water sources, rather than chemical or radiological contaminants. To address this problem a low-cost continuous-feed water treatment facility has been designed and developed. The facility utilises solar (UVA) radiation to treat pathogens. Additionally, the facility is designed such that it can be manufactured in-situ from limited or improvised resources at low capital and maintenance costs. The system is modular so that multiple systems can be used to increase water treatment capacity as required. Testing indicates that 3 modules of the design can treat 34L of water in 4 hours producing a 4-log reduction in E. Coli (from 8×10^5 CFU/ml) with a residence time of less than 30 minutes. This is based on an average solar-based UVA flux ranging from 24 to 36 W/m^2 (time average of 28 W/m^2).

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1. Introduction

1.1. Clean water: A humanitarian crisis

The importance of access to safe drinking water was reflected in target 7B of the UN Millennium Development Goals (MDGs), which sought to halve the percentage of population (from 1990 to 2015) without sustainable access to an improved drinking water source [1]. According to JMP [2], this goal has been achieved. Furthermore, such efforts to improve access have been credited with reducing drinking water related deaths by 31% [3]. Nevertheless safe drinking water is not currently accessible to over 780 million people [4]. Drinking contaminated water has been estimated to contribute to 1.5 million deaths annually, with over 90% of cases being children [4]. Existing water sources are increasingly at risk of contamination, and population growth is driving a greater demand for clean water. Subsequently, there is still a need to improve the quality and quantity of potable water to developing nations, and make these systems affordable and useable to the end user. This is a particular challenge in remote and developing areas where it is often unviable to implement large-scale water decontamination and storage.

1.2. Papua New Guinean communities

Papua New Guinea is one of the most underdeveloped countries in the world. It has a population of approximately 6.9 million people, with 87% living in the rural mountainous regions, making infrastructure transportation a difficult challenge [2]. Although the country is resource-rich, with oil, gas and minerals contributing to the national economy, 37% of the population is in poverty [5] and political instability has resulted in a decrease in living standards since the 1990s [6]. According to the Department of National Planning and Monitoring 2010, only 40% of the population has access to safe water [7]. Statistics from the World Health Organization [3], show that 4,900 people die per year from Water, Sanitation & Hygiene (WASH) related illnesses, which is approximately 10% of the total deaths in PNG. Considering these deaths are preventable, it is evident that appropriate solutions for PNG need to be developed and implemented.

Many villages in PNG use large communal rainwater tanks to collect water in the wet season, which is supplemented with river water in the dry season. Although rainwater is generally pathogen-free and has the lowest capital and ongoing costs out of all the improved water sources [8], the collection and storage of rainwater is not necessarily pathogen-free. Excretion and corpse decomposition of insects, birds, rodents and small mammals on, or above, the catchment area can introduce pathogens into the collected water and storage container [9]. Additionally, fecal pathogens can survive for an extended period during storage within rainwater tanks [10]. Subsequently, a system that can treat communal rainwater without the need for long-term storage of the treated water, is necessary to improve water quality and minimize recontamination.

The average maximum temperature for the capital city of PNG, Port Moresby, is approximately 26^{o}C. The average monthly rainfall ranges from 25 mm to 198 mm, with a total yearly average of 1084 mm [11]. The cloud cover throughout the year is fairly constant with 19% of time overcast, 39% mostly cloudy, 31% partly cloudy and 14% mostly clear. There is an additional 19% of the time with missing data [12]. From a preliminary assessment, there is both sufficient sunshine and rainfall to warrant a solar-based rainwater treatment system in PNG.

1.3. Health concerns from water contamination

In terms of waterborne contaminations, bacteria including Salmonella, Shigella, Escherichia coli and Campylobacter are the major contributors [13]. The ingestion of water contaminated by such bacteria can result in illnesses such as cholera, gastroenteritis and typhoid fever. These illnesses can cause excessive vomiting, severe fever, uncontrollable losses of bodily fluids and eventually death due to extreme dehydration and body organ shutdown. The pathogens that cause these waterborne diseases are the primary concern in humanitarian interventions as they are widespread but easily preventable [14]. Therefore, the current work is focused on the treatment of pathogens in water, rather than physical, chemical or radiological contaminates.