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A REVIEW OF THE IMPACTS OF CLIMATE CHANGE ON WATER QUALITY AND HUMAN HEALTH

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ABSTRACT
Climate change has posed a debate to the world lately. It has caused a wide array of effects including ecological influences, agricultural impacts, floods and human health effects. Water scarcity and pollution are also related to climate variations. Intense storms, drought and floods being experienced in the world, which have a potential to influence the water quality, have been reported across the world. Waterborne pathogens are affected by the changing weather patterns and are likely to affect human health. This review was done with an aim to determine the impacts of climate change on water quality and its relations to human health. This review presents a chronology of the potential impacts of climate change on water quality and human health. Bacterial, viral and algal blooms change with variability in climate. Seasonal variations in waterborne pathogens influence human health. *Escherichia coli* O157:H7 is mostly paid attention to at the cost of other potentially harmful pathogens in the same genus (*Escherichia)*. Studies done at different parts of the world were considered, analyzed and presented in a systematic format based on the review objective. Climate change was found to have a strong influence on water quality affecting waterborne pathogens lifecycle, chemical contamination and encouraging algal blooms. There is a need for continuous assessment of water quality for potential climate related waterborne pathogens.
Keywords: Waterborne pathogens, Water quality, Algal bloom, Climate variation

INTRODUCTION
Water is frequently the subject of concern on climatic "extremes," that is, whether there is too much or too little. Climate and hydrology are inextricably related, and this is not by chance. (Michalak, 2016). Water is necessary for ecosystems and societies to function. But it is not just about how much water there is; it is also about how good it is.

Climate changes impact on the hydrological cycle and water quality is intrinsically uncertain. This is because the interaction between climatic conditions and hydrologic components is complicated by a number of competing processes. For instance, increased levels of carbon dioxide in the atmosphere is linked to elevated levels on plant transpiration which further change the seasonality and magnitude of hydrologic components (Luo *et al.*, 2013). Studies have shown that the rate of biomass production is influenced by carbon dioxide concentration, which affects the plant development pattern (Neitsch *et al*.,2011). Additionally, increased carbon dioxide in the atmosphere is expected to increase potential evapotranspiration (PET) and perhaps reduce water flow to rivers, further degrading river water quality due to reduced dilution (Labat *et al.*, 2004; Luo *et al.*, 2013).

Climate-related calamities such as floods and droughts, changes in rainfall patterns, and rise in surface temperature (water-related) have increased recently. Their implications on water quality and, ultimately, human health must be analyzed and managed (Stanford, 2013). Floods account for almost half of all known disasters, whereas high temperatures (heat waves) accounting for roughly 10% (Pollner *et al.*, 2010). Changes in climate and environmental devastation, such as watercourse contamination from polluted agricultural runoff, account for about 25% of all illnesses such as diarrhea, malaria, and respiratory infection(Fang & Chhetri, 2013). In developing countries (Kenya included) these challenges are more prevalent (Ahmed *et al.*, 2016).
Climate change appears to have a variety of effects on waterborne diseases (Rose et al., 2001). Some of the predicted consequences of climate change are; more evident storms, warmer surface temperatures, salinity changes,

changes in pathogen growth, increased animal diseases, and zoonoses (Ashbolt, 2010; Hedican *et al.*, 2009; Nancarrow et al., 2008). Water has a significant influence on agriculture and health as changes in climatic factors such as rainfall, temperature, and humidity being experienced around the globe. Water quality and quantity are degrading with time and as a result, waterborne infections are on the rise. Consequently, the amount and quality of water are significantly impacted (Ahmed *et al*., 2016).

Water pollution is a worldwide issue that is worsening, limiting resources for drinking, domestic usage, food production, and leisure, as well as hurting ecosystems(Michalak, 2016). The Intergovernmental Panel for Climate Change (IPCC) Fourth Assessment Report did not adequately capture the implications of climate change on water quality in great detail, however, this topic is gaining attraction to researchers (Ahmed *et al*., 2016). This paper attempts to review the interconnectedness of climate change, water quality and public health. Comparison is made to other literature material done on other parts of the world and their findings.

METHODOLOGY

A comprehensive literature review was performed between December 2020 and July 2021. "Google Scholar" (in addition to the usual Google search engine) and "Science Direct" were used to find references. To search the references, key words were used including climate change, water quality, agriculture, pollution, public health, waterborne diseases, flooding, landslides, extreme events, water quality, water availability, vector-borne diseases and Kenya. The publication time period considered was between 1980 and early 2020. The literature listed was chosen after a thorough evaluation of articles that were most relevant to Kenya. However, countries having similar environmental boundary circumstances that are pertinent to the review were not overlooked. Other factors such as publication date, outlet type, and author (or institution) did not affect much in the selection of the literature material for the review.

Potential areas Climate Change is Likely to Impact

Climate change is anticipated to have an impact on how water resources are used. These modifications could have an influence on power generation, impacting on water ability in greenhouse gas emission(King, Webber, & technology, 2008). Additionally, ecological service, in providing future water services, will be at stake with the felt climatic changes (Campbell-Lendrum & Corvalán, 2007; Corvalan *et al.*, 2005; Keath, Brown & Technology, 2009). As a result, there is a likelihood for the rise in consumption of it-for-purpose water (Rathjen *et al.*, 2003). For instance, municipal water for drinking purposes may not all be treated since only ten percent is necessary for the use. Instead, recycled wastewater will be utilized for other urban and irrigation purposes. Including, toilet flushing, washing clothes, garden/crop irrigation purposes. This will help to reduce pressure on urban water sources as well as maintain environmental resilience on water resources (Ashbolt, 2010).

Increased cases in diarrheal disease may be seen as a result of climate change in the context of waterborne pathogens. This was evident in Peru during the *El Nino* periods in 2000. Hospital admissions increased by 8% (95 percent CI 7–9%) for every 1°C rise in temperature, with an additional 6225 cases of diarrheal illness recorded (Checkley *et al*., 2000). WHO has kept track reports on suspected climatic changes consequences to waterborne diseases especially diarrhea diseases (Campbell-Lendrum & Woodruff, 2006; McMichael, Campbell-Lendrum, & Kovats, 2004). Similarly, in Fiji diarrhea appeared to increase by three percent (95% CI 1.2-5.0%) for rise in 1°C temperature. Although significant fluctuation in diarrhea rates were observed when rainfall was either high or low(Singh *et al.*, 2001).

Approximately 70 % of water withdrawals from the environment are utilized for agriculture purposes (Assessment, 2008). The greatest global water concern is arguably the need to lower total demand while feeding the planet (Oron *et al.*, 2001). The Israelis have proved the feasibility of employing drip irrigation to provide a solution to the problem using treated municipal wastewaters (Bednarska *et al.*, 2007; Bharti *et al.*, 2003; Fayer, 2004; Hedican *et al.*, 2009; Jay *et al.*, 2007; Rose *et al.*, 2001). However, when crops are watered with untreated water and eaten raw, various disease outbreaks have been reported (Bednarska *et al.*, 2007; Bharti *et al*., 2003; Fayer, 2004; "<PEN_Prototype_Questionnaire_-_version_4-4_-_September_2008.pdf>,"). With zoonotic diseases in surface water, the latter is of particular importance (Ashbolt, 2010).

Waterborne Pathogen Dynamics

There are essential aspects of waterborne and water-based pathogens that should be considered. That is: First, seasonal fluctuations show that pathogens are dynamic in their ability to adapt to changes in their propensity to human wellbeing. Secondly, as approaches for identifying pathogens are developed (mostly molecular based), discoveries are made to pathogens that are difficult to culture or non-culturable which were not known before. As a result, it's safe to claim that many pathogens are still unknown today(Rosario, *et al.*, 2009; Victoria *et al.*, 2009).

Now the question is what might emerge tomorrow as a result of changing environmental conditions.

For instance, consider members of the significant aquatic parasite protozoan genus *Cryptosporidium* as an illustration of the difficulties in characterizing human infections. Most of human infections are believed to originate from: *C. parvum* and *C. hominis* yet there are other species/genotypes: *C. felis*, *C. suis*, *C. meleadridis* just to mention a few. Choosing to target a particular species is a challenge (Ashbolt, 2010). Studies have focused *Escherichia coli* O157:H7 due to numerous water- and food-borne outbreaks. However, concentrating on O157:H7 strains appears to be at the expense of overlooking the far more important non-O157 shiga toxin-producing *E. coli* (Bettelheim, 2007; Lathrop, Edge, & Bareta, 2009).

Climate Change and Water Quality
Extreme climatic conditions have been linked to having an inverse proportional relation with water quality. For instance, high temperature and heavy rainfall contribute significantly to water contamination. Some of the waterborne pathogens associated with heavy rainfall include: *Giardia cysts* and *Cryposporidium oocysts.* They are carried to water bodies from different geographies affecting the water quality (Ahmed *et al*., 2016; Patz & Journal, 2001). The majority of the research included in this review placed a significant qualitative emphasis on the effects of climate change on water quality. The majority of these reviews were based on climate change-related extremes, predicted future climate conditions, and findings from other geographies, but not Kenya. The most prevalent term used to underline the consequences of climate change on water quality is "... is likely..." This indicates the studies' uncertainties and unsatisfactory results. Salinity, chemical contamination (heavy metals such as lead, mercury), pathogenic contamination (viral, bacterial), nutrient cycling, hygienic conditions, and algal blooms are among the effects highlighted in the studies.

Increased salinization of groundwater supplies due to water intrusion was reported in the Mekong Delta River Basin (MDB) (Eastham *et al.*, 2008; Phung *et al.*, 2015). In MDB high salinity levels were thought to be prevalent in delta tributaries and channels due to saltwater intrusion. The salinity levels had considerable changes between dry and rainy season (Neumann *et al.*, 2013; Phung *et al.*, 2015). Furthermore, stream-flow reduction was thought to enhance the salinity of rivers (Phung *et al.,* 2015).

Chemical contamination was identified has been worsening as a result of climate change variability. Heavy metals, herbicides, and toxic algae were among the identified pollutants. These studies noted that, as a result of climate change, pesticide use and pollution are projected to rise. For instance, increased rainfall may result to rise in the application of pesticides which end up in water sources affecting the quality (Barsugli *et al.*, 2012). Flooding in floodplains may improve nutrient cycling between the floodplain and permanent water bodies resulting in higher nutrient concentrations that encourage algal blooms (Lamberts, 2008). As a result, there has been increased pathogens wreaking havoc on ecosystems and human health. However, few research have looked into the link between climate conditions and algal proliferation and its negative health impacts(Phung *et al.*, 2015).

In 2015, Lake Erie (one of US Great Lakes) saw its largest recorded toxic algal bloom. On reaching its climax, the bloom spanned about 200 kilometers across the entire lake (Stumpf & Dupuy, 2016). Similarly, along the west coast of North America, another record-breaking detrimental bloom sprawled from Baja California, Mexico, to Alaska, likely produced by exceptionally warm Pacific Ocean water (Di Liberto, 2015). In both scenarios, highly poisonous Phytoplankton species were dominant (Stumpf & Dupuy, 2016). In 2014, Lake Erie experienced a similar algal bloom. This resulted to 500,000 people living near the Lake to be advised not to drink tap water because it had over two and half level of *hepatotoxins* by the cyanobacterium *Microcystis* which were above the World Health Organization's acceptable limit. The 2015 algal bloom in west coast of North America was mainly algae *Pseudo-nitzschia* and affected fishing activities in the area(Michalak, 2016; Wilson, 2014).

Algal bloom is associated with excess nutrients, ‘dead zones’, and hypoxic, viral, bacterial and chemical contamination. This may result to frequent impairment of ecosystems, as well as human health. The algal bloom in 2015 in USA resulted to losses of up to US$4 billion (Michalak, 2016). A study done in Canada predicted that greater winter discharges as a result of climate change, might result in significant changes in river hydrology and geomorphological processes affecting riparian ecosystems(Boyer *et al*., 2010).

CONCLUSION
It is evident that climate change has and will continue to pose tremendous impacts on agriculture, public health, economy and sustainability on ecosystems across the world. All these sectors affected by climate change are interconnected which worsens the situation.

This review provides the interconnectedness of climate change, water quality, public health and agriculture. Climate change is seen to influence the balance between these sectors. The effects of climate change are trans-boundary in nature. Kenya being a developing country has limited approach to examining the influence of climate change to public health, water quality and agriculture as a country. There is a need for research in this area to understand these relationships. This can aid in developing adaptation and mitigation options for the specific sectors.

REFERENCES

Ahmed, T., Scholz, M., Al-Faraj, F., Niaz, W. J. I. j. o. e. r., & health, p. (2016). Water-related impacts of climate change on agriculture and subsequently on public health: A review for generalists with particular reference to Pakistan. *13*(11), 1051.

Ashbolt, N. J. (2010). Global warming and trans-boundary movement of waterborne microbial pathogens. In *Adaptation and Mitigation Strategies for Climate Change* (pp. 71-82): Springer.

Assessment, M. E. (2008). Living beyond our means: natural assets and human well-being.

Barsugli, J. J., Vogel, J. M., Kaatz, L., Smith, J. B., Waage, M., Anderson, C. J. J. J. o. W. R. P., & Management. (2012). Two faces of uncertainty: Climate science and water utility planning methods. *138*(5), 389-395.

Bednarska, M., Bajer, A., Sinski, E., Girouard, A. S., Tamang, L., & Graczyk, T. K. J. P. r. (2007). Fluorescent in situ hybridization as a tool to retrospectively identify Cryptosporidium parvum and Giardia lamblia in samples from terrestrial mammalian wildlife. *100*(3), 455-460.

Bettelheim, K. A. J. C. r. i. m. (2007). The non-O157 Shiga-toxigenic (verocytotoxigenic) Escherichia coli; under-rated pathogens. *33*(1), 67-87.

Bharti, A. R., Nally, J. E., Ricaldi, J. N., Matthias, M. A., Diaz, M. M., Lovett, M. A., . Gotuzzo, E. J. T. L. i. d. (2003). Leptospirosis: a zoonotic disease of global importance. *3*(12), 757-771.

Boyer, C., Chaumont, D., Chartier, I., & Roy, A. G. J. J. o. h. (2010). Impact of climate change on the hydrology of St. Lawrence tributaries. *384*(1-2), 65-83.

Campbell-Lendrum, D., & Corvalán, C. J. J. o. U. H. (2007). Climate change and developing-country cities: implications for environmental health and equity. *84*(1), 109-117.

Campbell-Lendrum, D., & Woodruff, R. J. E. h. p. (2006). Comparative risk assessment of the burden of disease from climate change. *114*(12), 1935-1941.

Checkley, W., Epstein, L. D., Gilman, R. H., Figueroa, D., Cama, R. I., Patz, J. A., & Black, R. E. J. T. L. (2000). Effects of EI Niño and ambient temperature on hospital admissions for diarrhoeal diseases in Peruvian children. *355*(9202), 442-450.

Corvalan, C., Hales, S., McMichael, A. J., Butler, C., & McMichael, A. (2005). *Ecosystems and human well-being: health synthesis*: World Health Organization.

Di Liberto, T. J. W. w. u. l. l. (2015). This summer's West Coast algal bloom was unusual.

Eastham, J., Mpelasoka, F., Mainuddin, M., Ticehurst, C., Dyce, P., Hodgson, G., . . . Kirby, M. (2008). Mekong river basin water resources assessment: Impacts of climate change. In: Citeseer.

Fang, C., & Chhetri, N. (2013). What have we learned about climate variability and human health? In *Vulnerability of Human Health to Climate* (pp. 79-86): Elsevier Inc.

Fayer, R. J. V. p. (2004). Cryptosporidium: a water-borne zoonotic parasite. *126*(1-2), 37-56.

Hedican, E., Smith, K., Jawahir, S., Scheftel, J., Kruger, K., Birk, R., . . . Report, M. W. (2009). Multistate outbreaks of Salmonella infections associated with live poultry-United States, 2007. *58*(2), 25-29.

Jay, M. T., Cooley, M., Carychao, D., Wiscomb, G. W., Sweitzer, R. A., Crawford-Miksza, L., . . . Millington, A. J. E. i. d. (2007). Escherichia coli O157: H7 in feral swine near spinach fields and cattle, central California coast. *13*(12), 1908.

Keath, N. A., Brown, R. R. J. W. S., & Technology. (2009). Extreme events: being prepared for the pitfalls with progressing sustainable urban water management. *59*(7), 1271-1280.

King, C. W., Webber, M. E. J. E. s., & technology. (2008). The water intensity of the plugged-in automotive economy. *42*(12), 4305-4311.

Labat, D., Goddéris, Y., Probst, J. L., & Guyot, J. L. J. A. i. w. r. (2004). Evidence for global runoff increase related to climate warming. *27*(6), 631-642.

Lamberts, D. J. M. m. o. t. M. (2008). Little impact, much damage: the consequences of Mekong River flow alterations for the Tonle Sap ecosystem. 3-18.

Lathrop, S., Edge, K., & Bareta, J. J. E. i. d. (2009). Shiga Toxin–producing Escherichia coli, New Mexico, USA,2004–2007. *15*(8), 1289.

Luo, Y., Ficklin, D. L., Liu, X., & Zhang, M. J. S. o. t. T. E. (2013). Assessment of climate change impacts on hydrology and water quality with a watershed modeling approach. *450*, 72-82.

McMichael, A., Campbell-Lendrum, D., & Kovats, S. (2004). Comparative Quantification of Health Risks: Global and Regional Burden of Disease due to Selected Major Risk Factors (Geneva: World Health Organization).

Michalak, A. M. J. N. N. (2016). Study role of climate change in extreme threats to water quality. *535*(7612), 349.

Nancarrow, B. E., Leviston, Z., Po, M., Porter, N. B., Tucker, D. I. J. W. S., & Technology. (2008). What drivescommunities' decisions and behaviours in the reuse of wastewater. *57*(4), 485-491.

Neitsch, S. L., Arnold, J. G., Kiniry, J. R., & Williams, J. R. (2011). *Soil and water assessment tool theoreticaldocumentation version 2009*. Retrieved from

Neumann, L., Nguyen, M., Moglia, M., Cook, S., & Lipkin, F. (2013). Urban Water Systems in Can Tho, Vietnam:Understanding the current context for climate change adaptation. In.

Oron, G., Armon, R., Mandelbaum, R., Manor, Y., Campos, C., Gillerman, L., . . . Technology. (2001). Secondarywastewater disposal for crop irrigation with minimal risks. *43*(10), 139-146.

Patz, J. A. J. H., & Journal, E. R. A. A. I. (2001). Public health risk assessment linked to climatic and ecologicalchange. *7*(5), 1317-1327.

<PEN_Prototype_Questionnaire_-_version_4-4_-_September_2008.pdf>.

Phung, D., Huang, C., Rutherford, S., Chu, C., Wang, X., & Nguyen, M. J. A. P. J. o. P. H. (2015). Climate change, water quality, and water-related diseases in the Mekong Delta Basin: A systematic review. *27*(3), 265-276.

Pollner, J., Kryspin-Watson, J., & Nieuwejaar, S. (2010). *Disaster risk management and climate change adaptation in Europe and central Asia*: World Bank Washington, DC.

Rathjen, D., Cullen, P., Ashbolt, N., Cunliffe, D., Langford, J., Listowski, A., . . . Radcliffe, J. J. F. G. o. A., Canberra. (2003). Recycling Water for Our Cities. Report to Prime Minister's Science, Engineering and Innovation Council (PMSEIC), 28th November 2003.

Rosario, K., Nilsson, C., Lim, Y. W., Ruan, Y., & Breitbart, M. J. E. m. (2009). Metagenomic analysis of viruses in reclaimed water. *11*(11), 2806-2820.

Rose, J. B., Epstein, P. R., Lipp, E. K., Sherman, B. H., Bernard, S. M., & Patz, J. A. J. E. h. p. (2001). Climate variability and change in the United States: potential impacts on water-and foodborne diseases caused by microbiologic agents. *109*(suppl 2), 211-221.

Singh, R. B., Hales, S., De Wet, N., Raj, R., Hearnden, M., & Weinstein, P. J. E. h. p. (2001). The influence of climate variation and change on diarrheal disease in the Pacific Islands. *109*(2), 155-159.

Stanford, B. D. (2013). *Water quality impacts of extreme weather-related events*: Water Research Foundation. Stumpf, R., & Dupuy, D. J. B. (2016). Experimental lake erie harmful algal bloom bulletin. *27*.

Victoria, J. G., Kapoor, A., Li, L., Blinkova, O., Slikas, B., Wang, C., Delwart, E. J. J. o. v. (2009). Metagenomic analyses of viruses in stool samples from children with acute flaccid paralysis. *83*(9), 4642-4651.

Wilson, E. J. C. E. N. (2014). Danger from microcystins in Toledo water unclear. *92*(32), 9.