A STUDY OF SOCIOECONOMIC DIFFERENCE IN REMOTE AREAS BASED ON THE USE OF POLLUTED WATER

Rizwan Lateef Khan[1], Prof. Devendra Kumar Sharma[2]

Research Scholar in Faculty of Engineering & Technology, Bundelkhand University; ABES Engineering college Ghaziabad

Email- rizkhn@live.com[1]; dksharma.dev61@gmail.com[2]

ABSTRACT

Water is an important resource necessary for a variety of human activities, including drinking, cooking, and enjoyment. While developed nations have made significant progress in providing adequate quality water and sanitation devoid of virus contaminations to a significant percentage of residences, many developing nations continue to lag, resulting in numerous cases of death among the vulnerable due to the ingestion of water contaminated with viruses and other waterborne pathogens. This analysis evaluated the socioeconomic disparities associated with the use of virus-contaminated water and other waterborne diseases in distant places. Poverty, style of living, access to health care facilities, age, gender, and level of education are the socioeconomic variables attributable to the many waterborne illnesses caused by the usage of virus-contaminated water in many locations. Therefore, certain mitigation techniques to combat the viral contamination of water sources are given, along with a discussion of the future scope and suggestions for addressing the fundamental concerns relating to socioeconomic disparity in emerging countries.

Keywords: *Drinking water, Inequality,Remote Areas, Socioeconomic.*

I. INTRODUCTION

Water is regarded as the epicenter of human activities as it is required for drinking, irrigation of crops, recreational activities and industrial use. Protecting this essential natural resource against any contaminants is critical to forestalling its potential avenue for outbreaks of diseases. Unfortunately, water quality and sanitation remain elusive, with conspicuous occurrences in the developing countries [1]. Available data indicate that more than 30% of the developing and less developed countries have no access to quality drinking water sources [2]. Consequently, leading to an upsurge in the use of any available water resources including reclamation and reuse of treated wastewater for domestic activities and irrigation purpose, considering the rapid population growth, climate change, and increased water demand [3]. An estimate of 663 million people is reportedly consuming untreated water obtained from different sources including groundwater and surface water [4]. While the current treatment procedures have achieved excellent results in treating physical, chemical and selected microbiological contaminants [5], the removal of human enteric viruses in the wastewater remains unsatisfactory, with less attention giving to virus contaminations in water sources and their health impact [6]. Moreover, there is no regulatory standard procedures for the treatment of virus-contaminated water and wastewater at the moment [7]. The ability of some of the viruses to travel a much greater distance than bacteria in the soil and eventually to groundwater source due to their sizes and their persistence for a more considerable period making their removal difficult and high risk of waterborne gastroenteritis virus infections [8]. A recent global review of groundwater-related enteric disease outbreaks identified 649 events within the published literature from 1948 to 2015 with an alarming increase in groundwater-related Acute Gastrointestinal Infections [9].

The impact of using unsafe water on public health is of great universal concern with the frequent detection of pathogens in various water bodies. The ingestion of contaminated water, which is most often caused by poor sanitation and hygiene often results in various waterborne diseases [10]. In 2012, 1.8 billion people which is almost 25% of the world population were estimated to consume contaminated water containing viruses, protozoa, and bacteria [11], that have led to various kind of diseases in human especially gastroenteritis [12]. One of the significant reoccurring waterborne diseases is diarrhea with 1.7 billion reported cases annually [13], resulting in the death of 525,000 children below the age of 5 years annually [14]. UNICEF (2012) documented that about 90% of diarrhea death globally is a result of poor hygiene, inadequate sanitation and unsafe water. The general knowledge is that microbes are the primary organisms leading to the spread of diarrhea. Some of the contracted viruses through drinking water and their impact on human health is often neglected [15]. Based on the guidelines on drinking water, WHO classified water transmitted virus-related pathogens as exhibiting an average and to a great health significance on human health, and these viruses include enteroviruses, adenovirus, rotavirus, norovirus and other caliciviruses, astrovirus, hepatitis A, polioviruses and coxsackieviruses [16]. Besides, other viruses like cytomegalovirus and polyomaviruses can also be proliferated via water [17], as well as coronaviruses and influenza that have been alluded to spread through potable water with inconclusive evidence [18]. Unfortunately, some of the viruses may result in acute illnesses such as hepatitis (hepatitis A and E viruses), cancer (polyomavirus), meningitis, encephalitis, and myocarditis (enteroviruses) [19].

In the present context of rural economy, it does not seem possible to supply protected water to all Villages in our country. The cost of piped water supply increases rapidly as the population density decreases and hence in Villages where population density is less the per capita cost of piped water supply is higher than that in urban areas. In an interesting study Chaudhary and Bhattacharya (1979) observed that the towns with a population density greater than 30 persons per acre can be served by piped water supply economically while those with a lower density should depend on spot wells.

The water quality standards recommended World Health Organization are generally adopted for piped water supplies in India with modifications (Manual on water supply and Treatment, 1976). However, these need not be followed in rural areas. The primary objective of a rural water supply scheme should be safety against transmission of waterborne diseases physical and chemical quality of water can be secondary one. Higher values of certain Impurities like hardness and dissolved solids and turbidity (which affects the aesthetics) than those permissible may be allowed since local population can tolerate such quality by long usage.

Consequently, the most important treatment that water should receive is disinfection so as to prevent transmission of diseases like typhoid, dysentery, cholera, jaundice and dracontiasis (guinea worm disease). The devices (Chlorinators, iodination facilities and ozonators) used for dosing the disinfectant in public water supply schemes are quite costly, require lot of skilled supervision and maintenance and hence cannot be used in all isolated rural areas.

Therefore, a great need exists to develop a simple and cheap device with self-regulatory release of disinfectant.

In an attempt to provide an outline of the status quo of socioeconomic disparities on the basis of virus-contaminated water use in developing nations, the paper is structured as follows. Firstly, there is a review of the water pollution status in developing countries. Also, virus associated with water pollution and their human health impacts are expatiated. More importantly, this paper assessed the socioeconomic inequality factors relating to virus-contaminated water usage in developing countries. Further, some possible mitigation strategies were proffered based on the existing literature that can be adopted for the developing countries, especially those characterized by low level social and economic development. Finally, this review concludes with future research needs to curb the viral contamination in water in developing countries and put forward recommended policies.

II. STATUS OF WATER POLLUTION IN DEVELOPING COUNTRIES

Water quality indicators of an area are usually defined based on physical, chemical and biological parameters and the choice of which is dependent on water use. The physicochemical properties of water have been reported to influence the development of biological life in water, thereby affecting water quality [20]. Thresholds are allocated to each indicator, and when such permissible limits are exceeded, there is a high risk of threat to human health [21]. Recent studies on analyses of river water pollution in Ethiopia considered some physicochemical water quality parameters (pH, dissolved oxygen, biochemical oxygen demand, total nitrogen, total phosphorus, and electrical conductivity) and bio-indicators (macroinvertebrate and diatom indices) by obtaining water samples from agriculture, forest, and urban landscapes within the Nile, Omo-Gibe, Tekeze and Awash River basins [22]. Water policy frameworks and interviews were also employed to ascertain the effectiveness of the study. The study concluded that there was a significant water quality deterioration in the study areas in all the four basins. It was concluded that the river water pollution poses a great challenge to human health and immediate solutions should be proffered to prevent future health deterioration. A good look at available literature centered on water pollution in the South Asian region, predominantly in Bangladesh, Nepal, and India, showed that high pollution loads discharged in rivers as a result of industrial wastes, population growth, pesticides, fertilizers, domestic sewage, domestic effluent and urban activities had offered more severe and adverse effects on the health of inhabitants. Karn and Harada (2001) performed regression analysis on their study data to evaluate annual pollution trends in average biochemical oxygen demand (BOD) and dissolved oxygen (DO) at Bagmati, Yamuna and Buriganga rivers and discovered that the BOD increase rate in Bagmati was highest and most rapid than the others. Average annual BOD was found to be at least five times higher than standards in the rivers of Dhaka and Delhi and as much as 15 times higher in the Bagmati if the standards for Nepal were on the same scale as those in India and Bangladesh.

Table 1: Detection of viruses in water environment

Virus type	Water Matrix	Concentration in genome (copies/L)	Country	Reference
Rotavirus	Wastewater treatment plant (influent and effluent)	10^3 to 10^5	South Africa	Osuolale and Okoh (2017)
Adenovirus,	Treated wastewater	4.6×10^4 to 1.2×10^6	Brazil	Schlindwein et al. (2010)
Pepper mild mottle	Municipal pond	1.0×10^3 to 1.0×10^6	Bolivia	Symonds et al. (2014)
Hepatitis E	Wastewater treatment plant (influent and effluent)	6.1×10^2 to 5.8×10^5	Italy	Di Profio et al. (2019)
SARS-CoV-2	Sewage	Low of detection to 5.6×10^4	Italy	La Rosa et al. (2021)
SARS-CoV-2	River	2.1×10^3 to 3.2×10^4	Ecuador	Guerrero-Latorre et al. (2020)
SARS-CoV-2	Wastewater (treated and untreated)	10^5 to $10^{6.5}$	France	Wurtzer et al. (2020)
SARS-CoV-2	Untreated wastewater	2.6×10^3 to 2.2×10^6	The Netherlands	Medema et al. (2020)
SARS-CoV-2	Wastewater (treated and untreated)	3.1×10^3 to 7.5×10^3	USA	Sherchan et al. (2020)
SARS-CoV-2	Untreated wastewater	1.9×10^1 to 1.2×10^2	Australia	Ahmed et al. (2020)
SARS-CoV-2	Wastewater (Untreated and Secondary treated wastewater)	1.4×10^5 to 3.4×10^5	Spain	Randazzo et al. (2020)
SARS-CoV-2	Secondary treated wastewater (before chlorination)	2.4×10^3	Japan	Haramoto et al. (2020)

As a continent, Africa is endowed with substantial water resources, including a huge interconnected river water network (Fig. 1), which are often serve as a reservoir for domestic, industrial, and agricultural wastes, thereby leading to significant economic scarcity of the water resources in the region. Some studies have assessed and confirmed the viral contamination of river systems in selected countries in Africa. Marie and Lin (2017) evaluated the presence of viral causing waterborne in the Umhlangane River of South Africa, which serves as the main drinking water catchment as well as reservoir for domestic, industrial and agricultural wastes. Some infectious viral groups, including human adenovirus, polyomavirus and hepatitis A and C virus were identified, which may pose a significant health risk to the many populations using the water from the River source for various domestic and agricultural uses. Also, the section of Nile River up to

ISSN- 2394-5125 VOL 4, ISSUE 06, 2017

300 km south of Egypt was reported to contain enteroviruses and (coxsackieviruses) with a frequency of 60% [23], which indicates potential health risk for the rural communities who majorly use the River water for domestic consumption and recreational purposes. Likewise, Virus-like particles were reported in the Umgeni River water samples in South Africa, indicating potential health risk implications for human consumption [24]. Similarly, the high prevalence of Human astrovirus was identified from both Rivers Mboone and Mbagathi in Kenya [25]. Further, the enteric viruses like adenoviruses and enteroviruses were also confirmed from the water samples taken from the Lake Victoria in Kenya [26]. Although some of the tested samples only confirmed the genetic materials of the viruses with no possible viability, the reported viral infections associated with drinking water supplies cannot be entirely ignored [26].

Developing countries, mainly in Africa, are currently faced with adoption, implementation and valuation of water for ecosystem conservation and water quality management practices are still in the juvenile stage. This situation has strengthened the consumption of untreated water and enhanced untreated water discharged into rivers. Similar reported cases have been documented in Ethiopia, and findings have been concluded that gross pollution of many rivers is a consequential result of rapidly increasing urban populations and intense industrial and agricultural activities [27]. The ultimate goal of drinking water supply as declared by water resources engineers in developing countries is to provide good water quality, not only on the verge of leaving the treatment plant but at the customer's tap and point of discharge. However, most researches have failed to assess water pollution in the course of distribution. According to Prest et al. (2016), treated drinking water enters a distribution system containing physical particles, microbial loads (cells) and nutrient loads (organic and inorganic nutrients). When treated water moves through contaminated distribution lines and it's retained with an extensive 'water age', especially at the dead-end nodes, available physicochemical and microbiological contaminants can result in the deterioration of the quality of water that reaches customer's tap compared to the original water produced at the treatment plant [28].

Viruses associated with water pollution

Viruses are intracellular organisms with a genome within a protein capsid and are possibly the most lethal pathogens amongst those discovered in wastewater [29]. According to Flint et al. (2004), viruses are classified as single-stranded DNA (ssDNA), single-stranded RNA (ssRNA), double-stranded DNA (dsDNA), and double-stranded RNA (dsRNA), depending on their genome kind. Bosch et al. (2008) reported that over 100 known kinds of viruses are defecated in human feces. In contrast, about 200 high diversity of human viral pathogens are found in the environment [30]. They are also raised in samples affected by pollution with more species discovered [31]. Moreover, human viral pathogens such as bacteriophages might have a severe impact on the natural watercourses that receive treated effluent containing these viruses which are specifically resistant to wastewater treatment and difficult to detect in environmental media despite the recent advances in water and wastewater treatment technologies [32].

Water has been recognized as a common medium for the proliferation of viruses which may allow their continued existence [33]. Surface water resources like oceans, rivers, lakes, estuary, groundwater, marine water are concerned with viral pollution [34]. This is because the sewage treated effluents are not efficiently removed, containing certain amounts of viruses that are subsequently discharged into the water environment [35]. The receiving water bodies further convey these viruses downstream, where it is utilized for various purposes like irrigation of crops, recreational activities, and other anthropogenic uses. This clearly explained how humans are exposed to fecally contaminated water via different exposure routes like direct ingestion of water during recreation, improperly treated drinking water and feeding on contaminated food products. Some viruses such as coxsackieviruses, echoviruses, adenoviruses, noroviruses, and hepatitis A viruses are portrayed as recreationally related waterborne microorganisms [36].

ISSN- 2394-5125 VOL 4, ISSUE 06, 2017

Pathogenic germs such as protozoa and bacteria are also transmitted via the water route and stayed in the gastrointestinal tract of their host (humans and animals) and subsequently released into the environment via feces from where surface and ground waters are polluted. It may also be released into the host's environment through urine and respiratory secretions. The most common human enteric viruses include enterovirus, Hepatitis A virus, Adenoviruses, Torovirus, Hepatitis E virus, Bocaviruses and coronaviruses, which may be released into water supplies, recreational waters and crops through sewage, runoffs, solid waste landfills and septic tanks [37]. Instances are prevalent with swimming pool water where outbreaks of norovirus, hepatitis A virus and adenoviruses were recorded.

III. SOCIOECONOMIC INEQUALITY DUE TO VIRUS-ASSOCIATED WATER POLLUTION

One of the 21st century's challenges is the continuous gap in educational and socioeconomic inequalities that have ravaged different countries around the world and consequently rendered the world economic growth and development at high risk [38]. Generally, it has been established that there exists a wide margin of inequalities between the rich and the poor; an average rich man's income is 57 times the poorest. Socioeconomic inequality has distinctively shown the varied level of access to basic social amenities within most developing nations' homes, including essential facilities such as access to potable water and sanitation [39]. Part of the United Nations sustainable development goals (SDG) (Goal 6) stressed on the need to provide adequate and sustainable water and environmental sanitation for all. However, adequate water supply, proper sanitation and improved hygiene are devoid of a particular location and time – it is a primary need for human survival. These are mostly not adequately provided, especially in developing nations [40].

The lack of access to potable water, proper sanitation and proper waste management conspicuously exists in many parts of the developing nations. For instance, Nigeria recorded a decline in access to potable water from 32% to 7% from 1990 to 2015, while 90% of rural dwellers in Niger republic practices open defecation and 51% do not have access to potable water. Similarly, lower-income households in Haiti have high susceptibility factors of 2.4 in contracting enteric diseases than high-income household children; 41% of water supply sources in Bangladesh is contaminated with E. coli and 56% of the top 20% in India has access to treated water compared to 6% of the bottom 20% [41]. Developing nations have been ravaged with high death rates due to the use of contaminated water from complications from enteric diseases, with a larger percentage of these populations from rural dwellers. The socioeconomic imbalance of water supply and sanitation have rendered the low-income earners to wait for options provided by the government, which sometimes are irregular. In contrast, the high-income earners sought after personal provisions, such as borehole and premium sanitation services. Improved access to water and sanitation services will increase people's hygiene, increase work productivity, reduce susceptibility to diseases and malnourishment [42].

A. Poverty

The poor are more susceptible to waterborne diseases than the welloff[43]. This is because they lack adequate supplies of safe water and proper methods of disposing of their wastes. The lack of quality water and sanitation creates ideal conditions under which viral pathogens thrive. Further, the lack of good quality and reliable water sources may drive the poor to extract water from unsafe alternative sources, thereby exposing them to waterborne viral diseases and putting their health at risk. Several studies have established linkages between poverty and virus-associated water pollution. El Zanfaly (2015) reported a clear link between poverty and water pollution, implying an association between poverty and dirtiness, and dirtiness with microbial polluted water.

B. Standard of Living

A decent standard of living entails that people are able to comfortably provide health or medical facilities for the well-being of their families. Thus, the prevalence of waterborne diseases could be used as an index for measuring the level of development in a given country. Studies have shown that waterborne diseases vary widely due to a country's standard of living. Polimeni et al. (2016) reported varying degree of macro-level socioeconomic factors such as the standard of living; the unbalanced split of rural/urban population; regional inequality; the level of trade (imports of goods and services) and access to health care with an increased risk for viral waterborne illnesses and death. Also, Yongsi and Ntetu (2008) and Pande et al. (2008), whose study areas were developing countries (Cameroun and Benin Republic, respectively), reported that households with the low standard of living recorded a higher prevalence of waterborne illnesses and vice versa; implying that waterborne illnesses could be inhibited or encouraged by household's standard of living. Kunasol et al. (1998), whose study was conducted in Southeast Asia, also documented that exposure to waterborne viral pathogens decreased with an improvement in living standards. Similar results were also reported by [44].

C. Level of Education

Several findings show a clear inverse correlation between the level of education of a people and the rate of viral waterborne illnesses. The more people know about waterborne viral diseases, the greater the tendency to manage the diseases, and hence the lower the disease occurrence. Nearly one-third of the global population lives in developing South Asia, where waterborne diseases are high, especially in rural areas due to the inadequate awareness about these diseases [45]. Arora et al. (2013) also reported that an increase in the household level of education would decrease viral waterborne disease prevalence. Martins et al. (2015) also confirmed these reports in their study on environmental sanitation and mortality associated with waterborne diseases in Brazilian children, concluding that the most significant health hazards related to water pollution were found in the rural communities characterized by a high concentration of low-income population with limited education. Furthermore, similar studies conducted in Algeria and Bangladesh by [46][47], respectively, also reported a lower seroprevalence rate within households with a higher educational level, further confirming the significance of educational level to the degree of waterborne disease prevalence.

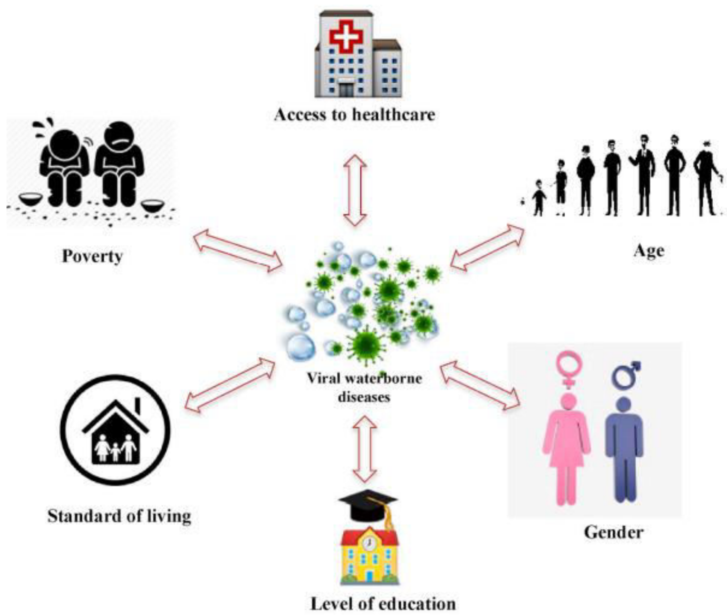

Fig. 1. Socioeconomic factors influencing the occurrence of viral waterborne diseases.

D. Access to Healthcare

The risk of infection with waterborne viral diseases can be influenced by the level of access to healthcare, reflecting a factor of households' socioeconomic status. The tendency to easily access healthcare facilities can decrease susceptibility to waterborne viral disease complications by providing early detection and required medication to curb morbidity [48]. As reported by Polimeni et al. (2016), the level of access to healthcare would influence the risk level of waterborne viral infections. Households with low access to health facilities were at a greater risk of waterborne illnesses than households with high access, implying a negative correlation between access to healthcare and waterborne diseases. Saback et al. (2001) also gave an account of similar findings in their study on waterborne viral infections and socioeconomic status in a developing country. They observed that exposure to waterborne infections among residents decreased with an improvement in the country's healthcare status. Similarly, WHO (2009) and Hughes et al. (2014) reported that poor access to healthcare facilities was a measure of the high waterborne disease burden in developing countries of Africa and Asia [49].

IV. CONCLUSION

In this review, socioeconomic inequality based on virus contaminated water usage in developing countries was assessed and discussed. Possible mitigation strategies were proffered based on the existing literature that can be adopted for the developing countries, especially those characterized by low level social and economic development. As discussed in the review, the socioeconomic factors attributed to the various waterborne diseases due to the use of virus contaminated water in many developing countries are poverty, the standard of living, access to health care facilities, age, gender, and level of education. Some mitigation strategies to address the viral contamination of water sources are therefore proposed, while future scope and recommendations on tackling the essential issues related to socioeconomic inequality in developing nations are highlighted.

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