A REVIEW OF LITERATURE ON THE EFFECTIVENESS OF WATER INTERVENTIONS IN THE PREVENTION OF DIARRHEOAL DISEASES IN UNDER-5 CHILDREN IN DEVELOPING COUNTRIES

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Abstract: *The purpose of this article is to evaluate the effects of water intervention on diarrhoea reduction in children living in developing countries.*

This study is a review of the primary studies conducted in developing countries on this subject. Children aged 0-5 years were the target participants. Only through a critical assessment of randomized controlled trials, this study sought to assess whether these interventions have decreased or remained ineffective in controlling diarrhoea rates in participants ' age groups.

The study measures the level of prevalence of diarrhoea before the intervention is introduced compared to the level of diarrhoea after the intervention is introduced. Results from the primary studies were analyzed and compared to previous reviews conducted on this topic in the past.

Conclusively, these interventions reduced the rates of diarrhoea, but several gaps in the different studies ' methodologies still provide room for improved future research.

Key Words*: Water Interventions, Diarrheoal Diseases, Under-5 Children, Developing Countries.*

1. INTRODUCTION:

Diarrhoeal disease is a well known public health issue that is seen across different age groups and countries of the world. This topic is of interest because children are considered to be very vulnerable to diarrhoeal infection and its complications. This is due to the fact that it increases their susceptibility to life-threatening dehydration; water makes up a greater proportion of their bodyweight ((WHO), 2010). Several studies carried out have evaluated the causative factors of diarrhoea infections as well as the effects of the disease on people of all ages and origins. Across the world, Rota virus infections due to poor hygienic practices, salmonella from uncooked meals, Cryptosporidium species from dirty water Group 2009), E.coli, Shigella as well as Campylobacter species WHO (2010) are among the commonest diarrhoea causing organisms which have been identified. On the other hand, lack of access to adequate sanitation or portable water supply has been identified as a major risk factor which can lead to children in developing countries being infected with diarrhoea causing pathogens UK (2010) and their deaths further caused by the effects of exposure to other forms of poor environmental conditions ((WHO), 2010).

The effects of diarrhoea are further compounded with the presence of either co-morbidities such as HIV or environmental influences such as wars and natural disasters; thus, children with compromised immunity due to these factors are considered to be more at risk of contracting the diarrhoeal infections ((WHO), 2010). These effects are more likely to be experienced in the developing nations of the world due to poor infrastructural development and lack of financial capabilities for active management. This may explain the higher rates of deaths due to diarrhoeal diseases recorded in these areas by international health bodies. This was aptly summarized by a WHO Regional committee report which described the average child in a developing country as being at greater risk of diarrhoeal infections and other diseases due to the existence of poverty as well as other social inequities (Asia, 2010).

Thus, for a child living in any developing country, the levels of immunity, type of diarrhoea as well as the state of prevailing sanitary conditions may determine to a great extent the outcome of any occurrence of diarrhoeal disease. These issues have generated the need for to go into research of ways of in preventing this disease in the this disadvantaged parts of world.

Considering the topic of this review, the studies chosen for evaluation were all conducted in countries which were included in the World Bank's official list (2009) of one hundred and forty four developing countries. A total of 53 papers resulted from the initial search and were pooled from two databases; the final papers to be reviewed were narrowed down to six in number by using outlined inclusion and exclusion criteria. All these studies had a total of 1653 children aged between 0-5 years old as participants. Due to the fact that this research will be evaluating an intervention

only randomised control trials were the types of studies included; there was however no specification on the type of water interventions to be included in this review. This author considers that establishing the beneficial effects of an intervention may assist in changing current practices and lead to better management, reduction and outright control of diarrhoea infection.

1.2. OBJECTIVES:

- To carry out a systematic search of the databases and identifying the studies which are in line with the topic of this review
- To carry out a critical appraisal of the final papers chosen to be reviewed; this will be done through the use of a standardized appraisal tool in a systematic format.
- To provide an objective summary of the evidence which shows whether or not water interventions prevent or reduce the rate of occurrence of diarrheal diseases in children living in developing countries.

2. BACKGROUND:

Diarrhoea is a clinical condition described as a symptom of gastrointestinal infection characterised by the passage of three or more loose or liquid stools per day (or more frequent passage than is considered normal for the individual). it could be plain watery (for example in cholera) or passed with blood (in dysentery for example) ((WHO), 2000). There are three different types of diarrhoea known and they are described as acute watery diarrhoea - which may last up to several hours or days (and includes cholera), acute bloody diarrhoea - also called dysentery and persistent diarrhoea – which may lasts up to 14 days or longer; with the persistent or severe type of diarrhoea presenting with complications such as dehydration, malnutrition and deaths ((WHO), 2009). About 2 billion cases and 1.5 million deaths occur annually in children all over the world who are between the ages of zero to five due to diarrhoea with most of these cases known to be very preventable and treatable ((UNICEF) & (WHO), 2009). Currently, diarrhoea is the second leading cause of deaths among children aged under 5 and is causing higher mortality than AIDS, malaria and measles combined ((UNICEF) & (WHO), 2009), this makes it important to explore ways of aiming at better control. Young children have been identified as being among the vulnerable groups with over 68% of the total burden of diarrhoeal disease occurring in them (Bartram, 2003) and this is worsened by an estimated 17% of deaths occurring in children who are less than five years United Nations (2005). Water, poor sanitation and pollution among other factors have been identified as the major risk factors which contribute to the increasing cases of diarrhoea in the developing nations (Aramayo et al, 2009).

In the year 2004, the World Health Organisation (WHO) had a comprehensive estimate of number of deaths due to diarrhoea in children less than 5 years of age in different regions of the world; Africa topped the estimates with 765000 deaths, followed closely the South-East Asian region which had 695000 deaths, the Eastern Mediterranean with about 233000 deaths while the Western Pacific region and the Americas had 10500 deaths and 49000 deaths respectively (Boschi-Pinto et al, 2008). Although these estimates are regional, they however give an insight to the spread of the mortality rates due to diarrhoea around the world.

As a leading cause of child mortality and morbidity in the world, studies have repeatedly shown that diarrhoeal diseases usually result from contaminated food and water sources; this is further compounded by an estimated 1 billion people in the world who lack access to improved water and another 2.5 billion people lacking access to basic sanitation ((WHO), 2009). This amounts to over 94% of cases of diarrhoea resulting from risk factors alone such as such as unsafe drinking water, lack of sanitation as well as poor hygiene (Pruss-Ustun & Corvalan, 2006). These easily identifiable risk factors, morbidity as well as mortality rates caused by diarrhoea infections globally make it imperative that that better efforts at control be made through continuous review of available evidence and information.

2. 1 Importance of this issue

Several facts and studies reflect the public health significance of this topic. The World Health Organisation (WHO) described diarrhoea as a major killer amongst people living in developing countries with about 2.2 million people, most of whom were under 5 years of age dying due to this infection (Clasen & Heller, 2008). This suggests that children aged below 5 living within developing countries are not just more susceptible to diarrhoeal infections but are more likely to also die from it.

A study has described diarrhoea and malnutrition as the two biggest challenges seen in paediatric care in most developing countries and these two alone are responsible for almost 40 per cent of deaths occurring in pre-school children; the same study also suggested that the symbiotic relationship between diarrhoea and malnutrition may lead to more deaths in this age group (Reddy, 1985). Views from both Reddy et al (1985) and the WHO reflect the baseline effects of diarrhoeal diseases in the disadvantaged areas of the world. Prevention and reduction of the rates of these infections includes but are not limited to knowing about its effects only. In 2008, a review by Clasen, F suggested that

the governments of developing nations are sure to benefit better and will save more money, if they invested on the different types of interventions and prevention rather than allow the treatment of the disease itself consume scarce resources. The same study pointed out that challenges that cause and also result from diarrhoeal diseases may under normal circumstances be better managed in nations that are very well developed, however in less developed settings, it may continue to be a challenge due to their poor economic state.

Being second only to pneumonia in causing the deaths of children aged below five globally ((UNICEF) & (WHO), 2009), it is stating the obvious by saying that control of diarrhoea rates will have a great impact on the reduction of rates childhood morbidity and mortality rates globally and more especially in the under-developed nations of the world. Since diarrhoea is a major contributor to morbidity rates, this means that improving child survival can be achieved only if this condition actively managed and prevented. Available literature reflects the past, present and on-going activities that are geared towards the control of diarrhoea. In the past there was a sharp drop in the amount of deaths due to diarrhoea around the 1970s and 1980s following huge international attention it garnered from international and local health agencies but this however was not sustained; its achievement was largely through the introduction of oral Rehydration Therapy (ORT) as well as elaborate educational campaigns which gave information on how to use it ((UNICEF) & (WHO), 2009). The same report shows that there has been very little progress since 2000 with about 39 per cent of children with diarrhoea in developing countries currently receiving the recommended treatment.

An important aspect of diarrhoea is its costs in terms of both human lives and economic terms. There have been several estimates of the cost of providing safe and basic water supply among other needs through the cheapest possible means by both the World Health Organisation (WHO) and the United Nations International Children's educational funds (UNICEF); the aim being to meet the target of the Millennium Development Goals (MDG) estimate of providing good and healthy water supply for all by 2015. An analysis of the cost of these interventions has shown that home based chlorination is the most cost effective followed by the solar disinfection methods and then the ceramic filters which are the most expensive; this ceramic filters however are the most effective of all the methods in the process of water purification (Clasen & Heller, 2008). The attempts at comparing the cost of provision to the effectiveness of the interventions have been an ongoing activity and it shows the significant role provision of safe and affordable water supply play in the control of diarrhoea. It has been shown however that prevention of diarrhoea through the use of water intervention actually reduces disease burden levels in addition to being affordable (Asia, 2010). The WHO recognizes the importance of the control of diarrhoeal disease occurrence by recommending that member States and other partners to promote current policies for the management of diarrhoea in developing countries, conduct research to develop and test new health delivery strategies in this area, develop new health interventions such as the rotavirus immunization and also help to train health workers, especially at community level ((WHO), 2009). These efforts highlight to a great extent the seriousness with which health agencies are aggressively trying to improve child survival rates while reducing or preventing the occurrence of diarrhoeal diseases.

2.2 Current evidence on this topic

In order to achieve excellent prevention, reduction and effective management of diarrhoea cases, it is important then to carry out thorough analysis as well as understand its causes, types and prevailing practices which have encouraged its continued prevalence. With all these information in hand, health agencies bodies and governments can then step-up current approaches and methods of management to ensure the development of measures which will meet up with recent challenges and lead to a more effective control. Several primary researches as well as reviews carried out have evaluated the roles water and sanitation play in the occurrence of diarrhoea.

The World Health Organisation (WHO) has identified infection, malnutrition, water source contamination from sewage as well as food contamination from irrigation etc. as the different sources of diarrhoeal infections ((WHO), 2009). These sources are only able to cause these infections due to the presence of diarrhoeic microorganisms. An important causative organism of diarrhoeal disease especially in regions of poor sanitation in all age groups and across countries is Enterotoxigenic Escherichia coli (ETEC); diarrhoeic bacteria are acquired by the ingestion of contaminated food and water resulting in millions of deaths every day, particularly in children (Okoh & Osode, 2008). Many studies have stated that many of the infectious agents associated with diarrhoeal disease are mostly waterborne and there has been strong evidence for reducing diarrhoea in settings where it is endemic by improving the microbiological quality of drinking water (Clasen et al, 2006)

The different pathways of diarrhoea infections makes it necessary that interventions for the prevention of diarrhoeal disease should not only include enhanced water quality but also steps to improve the proper disposal of human faeces (sanitation), increase the quantity and improve access to water (water supply), and promote hand washing and other hygiene practices within domestic and community settings (hygiene) (Clasen & Heller, 2009, Okoh & Osode, 2008). The control of diarrhoea could take place via active treatment of already present cases, education of the populace on how to manage cases when present as well as education on how to prevent or at least reduce the number of cases. In

a developing country with the challenges of less than adequate infrastructure, poor educational levels, and poor access to health care etc, the best bet will be to emphasis on preventive rather than curative measures. Current recommendations for active methods of management have included Oral rehydration therapy (ORT), zinc tablets, vitamin A supplementation as well as breastfeeding or provision of nutrient rich foods ((WHO), 2009, (WHO), 2010) while the recommendations for prevention include provision of improved drinking water supply, community wide sanitation, hand washing with soap and supply of rota virus and measles vaccines ((WHO), 2009). This is in line with the WHO approved Diarrhoeal Disease Control (CDD) manual which prioritizes the controlling or preventing diarrhoea epidemic as well as recommends reducing transmission of the pathogenic agents through control of water supply and excreta disposal, personal and domestic hygiene, food hygiene, control of zoonotic reservoirs, or fly control ((WHO), 1980) cited by (Feachem et al, 1983)). These preventive recommendations by the World Health Organisation especially breast-feeding, water supply and sanitation improvements have been proposed to be among the first category of interventions (Feachem et al, 1983).

This review is based on the theory that improvement in water supply from either source or domestically, will assist in preventing diarrhoeal infection in children aged between zero and five. A study and meta-analysis carried out by (Fewtrell & Colford, 2005) estimated the rate of the effectiveness of specific interventions, including water supply and water treatment; it showed that multiple interventions, hygiene and water quality were found to significantly reduce the levels of diarrhoeal illness, with the greatest impact being seen for hygiene and household treatment interventions. However, another study by (Clasen et al, 2006) suggests that a variety of conditions and factors which past and present researches may not fully explain affects to a great extent the effectiveness of any chosen water intervention. Information on the causes of death in children who are less than 5 years old due to diarrhoea has not changed so much since the late 1980s however, statistics presented by health bodies should allow settings without good databases to draw a reasonable picture of the burden of under-5 diarrhoea mortality that should ultimately result in planning for the prioritization of interventions and decision-making tailored to the needs of the individual country (Boschi-Pinto et al, 2008). In line with the above recommendations for management and prevention, the uniqueness of the settings where the intervention or prevention method take place are also taken into consideration by the study researchers or health agencies. This is in line with recommendations which have suggested that the choice of specific diarrheal control strategies depends on local factors such as diarrheal aetiologies, the existing infrastructure, and government priorities; in all countries, effective implementation of preventive strategies requires the involvement of a range of sectors (e.g., health, agriculture, water supply, and sanitation) (Huttly. S et al, 1997).

Considering the role water sources play in the health of individuals, this paper will critically appraisal the available literature in order to establish an association between the level of water purity through interventions and the rates of occurrence of diarrhoeal infections in children within 0-5years. This review will adopt the hypothesis that water interventions at both the domestic and source points are effective in the prevention and reduction of the risk of contracting diarrhoea in children living in the developing world. Although there have been several other reviews carried out on the role of water supply in the prevention of diarrhoea, very few have dealt with the age group 0-5 years found in the developing countries of the world. The choice of this topic was based on the gap seen in the reviews of the role of water intervention in diarrhoeal prevention. More attention has been paid to the cost-effectiveness of these interventions, the effectiveness of these interventions in households as well as in all age-groups; this showed a gap in the specificity as regards age bracket and geographical location. It is also worthy to mention that the personal experiences of the author during clinical practice in a country in sub-saharan Africa has to a great extent led to an interest in this topic. Recurrent management of cases of diarrhoea occurring in children all aged less than 5 years old in a tertiary health centre in Nigeria prompted the need for a detailed history from the parents of this children. Their social histories revealed a background that had poor access to portable water supply, poor toilet habits and generally less than ideal sanitary conditions. Reviewing some literature on this topic in addition to all other factors discussed above contributed to the choice of this topic for a secondary research.

3. METHODOLOGY:

The methodology of this review started from the choice and search of a project topic. The topic was chosen based on The author's observations and experiences about the rates of diarrhoea while working as a clinical practitioner in sub-Saharan Africa. The urge for a research into this field was increased when the lack of basic source of good drinking water was found to be the common denominator in most cases of diarrhoea infections identified in the local community where my clinical practice was based. This brought home the thought that there was a possibility that improving water sources could significantly reduce the rates of occurrence of diarrhoea among children living in developing countries. Due to lack of provision of good database for health related information there was a huge difficulty in trying to verify if there had been records of such findings in the past or if there was an on-going evaluation. When an opportunity presented itself for the writing of this research, this topic readily came to mind. There was going to be huge

challenges if this evaluation was to be carried out as a primary research because of time factor, resources as well as not being in the rural sub-Saharan setting where it would have ideally taken place. Based on these, I made the choice of a literature review which will carry out the same evaluation but will be based on the relevant primary studies identified. However, due to the fact that this writer's interest arose from experiences in a paediatric setting, the title of the project was then narrowed down upon as

"Evaluating the role of water intervention in the prevention of diarrhoeal disease among children aged 0-5 years in developing countries".

Thus, before the topic and research question were decided upon, the significance of this topic on both paediatric and public health practices were thoroughly evaluated and considered to be relevant.

The search of the topic started with a search on Google scholar; it was centred mainly on papers which had treated this topic or related topics in the past. Attention was paid to identify both primary and secondary researches carried out on this topic. The search identified lots of studies carried out at different levels (both rural and township settings) on the effect water purification has on reducing rates of diarrhoea. Most of the studies were also discovered not to have narrowed down their choice of the age group as participants. However, the search on Google scholar was not systematic and as such did not totally show all the relevant papers; the papers shown were not totally in tune with the interests of the this writer. Thus, an electronic search of the Cochrane database of reviews was carried out with the aim of identifying previous secondary researches that have been carried out on similar or the same topic. The search on Cochrane showed all available reviews on this topic carried out. However, results from the Cochrane search had different age groups as participants, different intervention methods, various intervention levels – with some at source while some at home and they also differed greatly in methodology, results and conclusions arrived at. The reference lists of the available review articles were looked through and relevant studies which Concerned the reviewed topic were also read through. After this preliminary search conducted, a systematic method of defining the search terms were now chosen and the search carried out in different databases to identify primary studies of interest.

This systematic review will involve a critical appraisal of all studies identified which evaluated the effects water intervention methods have had on the rate of occurrence of diarrhoeal diseases. Different search terms will be used and for the purposes of this study, the term "water intervention" will accommodate any form of purification or modification process of water which may have taken place at source or at home aimed at making the drinkable water safe or safer for consumption with the aim of reduction of disease conditions which could arise from drinking polluted water.

4. RESULTS:

4.1 Diarrhoeal outcomes:

All the studies being reviewed recorded a decrease in diarrhoeal episodes following the introduction of the interventions. The percentage decrease in diarrhoea prevalence ranged between 19% - 64% as shown in the table below. There were different interventions used in these studies and they include Solar Drinking water Disinfection (SODIS), Home chlorination and Biosand Filters (BSF). Relative risks of the intervention groups to control groups recorded by the studies were as follows: Mausezhal et al - unadjusted relative rate (RR) estimate (0.81, 95% CI 0.59–1.12); Stauber et al - unadjusted RR of 0.47 (95% CI, 0.37, 0.59); Semenza et al - RR of 0.33 (0.19 – 0.57). Mahfouz et al however analysed their results based on odds ratio thus – (OR – 1.98, P = 0.047) while Luby et al analysed their results in percentages −70% (−35%, −96%). The study by (Stauber et al, 2009) showed that the decreased diarrhoeal rates were however influenced by seasonal variations in children; their study showed that the rates of decrease in diarrhoea diseases was higher during the wet season but decreased during the dry season. The same study showed the BSF intervention used having more impact by reducing the diarrhoeal infections at higher rates in children aged 2-4 years old.

Other Outcomes: Four studies evaluated water outcome in addition to diarrhoea outcomes. The four papers recorded marked improvement in the quality of water following the use of the Biosand filter, SODIS and two home chlorination interventions. The study by Luby et al also evaluated the rates of visits to the doctor as well as rates of hospitalizations due to diarrhoea and found them to be reduced.

Only two out of the 5 studies took the cost effectiveness of these interventions into consideration. Semenza et al (1998) showed that despite the advantages of clean drinking water, most residents of the area where the study was carried out were quite unwilling to purchase 20L jerry cans of good water at $0.20; these residents were however open to the use of cost free chlorination which was introduced to them in the study. On the other hand, Luby et al (2006) in their study noted that despite the intervention being cost free, there were still fewer persons to follow-up in the intervention group compared to the control group. All the studies were specific about child estimates of the rates of diarrhoeal reductions and this. Luby et al, (Stauber et al, 2009) as well as Mausezhal et al (2009) found their results not to be statistically significant; However, (Semenza et al, 1998) in their study were not specific on the statistical significance of the results while only the paper by (Mahfouz et al, 1995) reported a statistically significant result.

4.2 Study Characteristics

A summary of the major characteristics such as author's names, date of publishing, aim of study/paper, type of study design, main findings as well as strengths and limitations of all the papers to be reviewed is attached and titled table 1.

TABLE 1: STUDY CHARACTERISTICS

S/No	Author/Date	Types of Intervention	Type of Study /Information	Main Findings	Strengths(s)/ Limitations (l)
1.	Mausezhal Et al/ Bolivia /2009	Effect of Sodis in the Prevention of Diarrhoea infections	Randomised controlled trials	19% Reduction in Diarrhoeal rates	s:Good sample size good attempt at randomization l: No blinding recall bias from participants short duration of study
2.	Stauber Et al/ Dominican Republic/ 2009	Effect of Bios and filtration in the prevention of Diarrhoeal infections	Randomised controlled trials	53% Reduction in diarrhoeal rates. Highest reduction seen in children aged 2-4 years old	s: Good attempt at randomisation l: No blinding No placebo used in control groups to assist in verifying if reduction in diarrhoeal rates was purely due to under-reporting.
3.	Luby Et al/ Bolivia/ 2006	Effect of flocculent disinfectant of water and hand washing on prevention of diarrhoea	Randomised controlled trials	64% Reduction in diarrhoeal rates and difference from control following the use of flocculent disinfectant; when merged together with the other intervention, it did not result in any further decline in diarrhoea rates.	s: Good attempt at randomisation l: no blinding over sampling of intervention groups compared to the control groups to get results
4.	Semenza j.c Et al/Uzbekistan/ 1998	The effect of chlorination diarrhoea prevention	Randomized controlled trials	66% Decrease in rates of diarrhoea occurrence	s: Good Randomisation l: Problems with recall ability of participants and no blinding
5.	Mahfouz Et al/ Saudi Arabia/ 1995	Effect of chlorination on diarrhoea prevention	Randomized controlled trials	48% Reduction in diarrhoea occurrence.	s: Good randomisation l: No blinding

From the five independent studies included in this study, the total number of participants included in the studies was 1655 children (males and females) and all were between the ages of 0-5 years of age. The study design of all the studies included is Randomized Controlled Trials (RCT) although most of the studies carried out cross sectional studies to identify baseline characteristics before proceeding with the introduction of any chosen intervention measure. The primary studies were conducted in different rural communities in developing nations of the world namely Bolivia – 2 studies, while Dominican republic, Uzbekistan and Saudi Arabia had one study each conducted in them. These studies were conducted between the years 1995 – 2009.

4.3 Methodological quality of results

Four out of the five studies had a clear definition of the term "diarrhoea"; it was defined according to the World Health Organisation (WHO) guidelines as the passage of three or more loose stools daily or more frequently than is normal for the individual. However the study by (Luby et al, 2006) also included the mothers' description of diarrhoea while (Mahfouz et al, 1995) in their study did not mention any definition of diarrhoea. Only one study used multiple interventions in the form of hand washing as well as water purification using flocculent disinfectant. All the studies

reviewed did not use placebos and in addition to this, deliberate attempts to achieve allocation concealment were not mentioned by any of the studies. Efforts were made by the studies to record pre-study statistics and baseline characteristics in order to provide a good basis for comparison to final study outcomes. The methodological processes of randomisation, allocation concealment, blinding and losses to follow up were carried out by all the papers with all but one paper showing the different methods of randomisation carried out. Blinding was not done in any of these studies and could not be carried out effectively by these studies because the means of intervention were obvious to the participants in the intervention groups.

5. DISCUSSION:

Evidence from the five studies being reviewed shows that that interventions used were very effective primarily in the reduction of diarrhoea infections, in the improvement of bacteriological quality of water, in the reduction of visits to the doctor as well as reduction of hospitalizations due to diarrhoea infections. General findings all point to the effectiveness of the interventions.

The only study which used solar drinking water disinfection (SODIS) by Mausezhal et al (2009) recorded less than 100% compliance with the use of the intervention, reduction in the levels of *Cryptosporidium parvum* seen in the intervention group compared to the control group, the same levels of *salmonella, G. Lamblia* and *shigella* in the two arms of the study. The primary outcome which is diarrhoeal reduction showed a 19% decrease in the intervention arm with an unadjusted relative rate (RR) estimate (0.81, 95% CI 0.59–1.12). With this wide confidence interval, the results suggest there is no statistically significant difference in the number of diarrhoea episodes between the SODIS and control arms of the study. Laboratory findings in the past had shown SODIS as being very effective in the killing of micro-organisms – bacteria and viruses as well as effective in the reduction of the occurrence of diarrhoea. The result of this study was not very similar to the laboratory finding results especially with the killing of micro-organisms completely. However the 19% reduction in diarrhoeal occurrence seen by Mausezhal et al (2009) is similar to the studies carried out by two other SODIS trials which took place in the Maasai cultural settings conducted by Conroy and colleagues which showed a 16% reduction among children <6 y and 5–16 years of age with a 2-wk prevalence of 48.8% in intervention, and 58.1% in control group (Conroy et al, 1999) as well as a 10.3% reduction in the 2-wk diarrhoea prevalence in 5–16 year olds (Conroy et al, 1996). Despite the similarities in the outcomes of the diarrhoea control in these studies, the level of compliance in the study as stated by Conroy et al (1999) was with 100% compliance. This therefore suggests that the study by Mausezhal et all (2009) will probably have yielded better results if compliance with the intervention was adhered to strictly.

The study which used Biosand Filter (BSF) intervention recorded reduced diarrhoeal rates in the intervention arm compared to the control group. Following the introduction of the BSF intervention, households in the intervention group reported 0.47 times the diarrheal disease of control households with an unadjusted RR of 0.47 (95% CI, 0.37, 0.59). The confidence interval here is quite narrow thus making this result more reliable compared to the SODIS results. On age group basis, the following results were obtained: for ages less or equal to 2 years old RR 0.71 (0.50, 0.99) and RR 0.74 (0.51, 1.06) for pre and post BSF use respectively. For ages 2-4 years old, the following statistics were obtained RR 1.29(0.95, 1.76) and RR 0.36 (0.25, 0.52) for pre and post BSF use respectively. These figures show that on the basis of age groups, the BSF intervention was most effective in the ages of 2-4 years old. The study organisers attributed this to the likelihood that children within this age bracket may not be taken care of as much as children aged less than two due to the stoppage of breastfeeding and their introduction on a large scale to regular family meals and drinking water sources etc, however, this author thinks that it creates room for further studies. There were decreased diarrheal incidence rates during the periods of high rainfall as seen in the study and this was irrespective of age groups. This was seen in both BSF and control groups before BSF intervention and only in the control group after BSF intervention, thus, the increased monthly rainfall amounts resulted in decreased rates of diarrheal disease in the control households; as a result, the rainy season had a significant effect on diarrheal disease reduction by the BSF (Stauber et al, 2009). Although it is possible seasonal effects may have affected study results, however the study organisers showed that during the 10 month study period, there was decrease in diarrhoea rates twice during the rainy season – these were before and after the introduction of the BSF as well as higher levels of diarrhoea occurring during the dry season. This effectively removed the probability of the seasonal changes affecting study results. Water quality outcome was also improved with a record of about 83% reduction in E.coli numbers; previous studies however show that the level of reduction of E.coli went as low as 94% and then 99% with time (E. et al, 2006))

The study which evaluated the effect of combining drinking water treatment through flocculent disinfection and hand washing for diarrhoea prevention by Luby et al (2006) also reported a decrease in the rate of diarrhoea across all age groups included in the study. This was similar to the finding by (Chiller et al, 2006) who recorded a significant decrease in prevalence of diarrhoea in children who were less than five years of age. In this review, this was the only study that evaluated the effect of multiple interventions on the participants. The statistics for the less than 5 age group

in the format of intervention versus control groups and the results were as follows: bleach water -44% (2%, -75%); soap and hand washing treatment −55% (−14%, −83%) as well as flocculent disinfectant plus soap−62% (−25%, −89%); all these figures were at 95% confidence interval. These results showed that the flocculent disinfectant water treatment had the highest effect with over 70% decrease in the prevalence of diarrhoea in the intervention group compared to the control arm flocculent disinfectant water treatment −70% (−35%, −96%). The combination of multiple interventions of flocculent disinfection and soap use did not confer additional protection and did not lead to further decrease in the rate of occurrence of diarrhoea. This is similar to the finding of (Fewtrell et al, 2005) which also showed that a combination of water, hygiene and sanitation improvements when combined did not necessarily cause higher rates of decrease in diarrhoeal occurrence compared to when the intervention were used individually. The study by Luby et al (2006) also recorded some secondary outcomes such as rates of hospitalizations as well as number of visits to the doctors; both outcomes were noted to have decreased generally with the use of the interventions.

The study carried out by Semenza et al (1998) recorded decreased prevalence of diarrhoea among the intervention group. However this study compared home chlorination as an intervention to the use of pipe borne water. The home chlorination (intervention arm) versus no home chlorination (control arm) had a RR of 0.33 (0.19 – 0.57) at 95% confidence interval which was low compared to the chlorination (intervention group) versus pipe-borne water (control group) they had a RR of 0.59 (0.29-0.84) at 95% confidence interval for home. However, when the same study compared the non home chlorination group to the piped water group, the RR was highest at 1.5 (1.05-2.13) with a 95% confidence interval. These statistics which were for children aged less than 5 years old. The highest effects were seen in the home chlorination versus non home chlorination group and this decrease was about 66%; this result was close to the 62% decrease recorded in the households generally. Although the study organisers stated that all the 3 groups had the same levels of hygiene and sanitary habits prior to the start of the study, it is however possible that the recorded low rates in the intervention arm may have been due to the emphasis by the study organisers for participants to use the chlorinated water in washing all edible foods in addition to drinking it. The strict adherence to this by the intervention group especially on realising that their water had been treated could have also assisted in reducing the diarrhoeal rates.

The efficacy of chlorination as a form of intervention which reduces water intervention was seen in the study by Mahfouz et al (1995); the study recorded 48% reduction in diarrhoea occurrence. The results showed that in addition to a significant decrease of diarrhoea occurrence there was also marked improvement in the quality of water following the introduction of chlorination. A similar study carried out in developing countries by (Sobsey et al, 2003) showed that the use of chlorination reduced water borne microbes by about 99% and reduced prevalence of diarrhoea by as much as 20-50%. The improvement in rates of diarrhoea recorded by Mahfouz et al (1995) may not be solely attributed to the water intervention especially considering that most of the children lived in households that had very good toilet facilities. Thus factors like hand washing, provision of good sanitation facilities may have contributed to the reduced diarrhoea rates.

On the basis of cost-effectiveness, information from the papers being reviewed shows that although better response was gotten from participants when the interventions were free, it still did not ensure that there will be 100% compliance in its usage. In previous reviews however, chlorination intervention appeared to be cheapest, closely followed by SODIS, ceramic filters and then combined flocculation disinfection (Clasen & Heller, 2008). In 2006, Clasen T, et al stated that the extent at which any intervention is employed will not only be dependent on its effectiveness alone but also on its cost.

5.1 Methodological strengths and weaknesses

Since all the studies included are randomised controlled trials, it is expected that the validity of the results generated will be reliable to a large extent. However, acceptability of these results can only be reached after a critical look at the processes involved in carrying them out. The first step taken by all the studies was carrying out a pre-study evaluation in order to collect baseline statistical information such as the rates of occurrence of diarrhoea etc; this was done by the 5 studies in a clearly described way through the use of cross-sectional interviews. All the studies recorded that there was no difference in the pre-study statistics between the intervention and control groups before the trials were started. This provided a basis for comparison of the final results of the each of the studies after introducing the intervention. Like all primary studies included in this review like any other study has its limitations and challenges. Only four out of the five details described in detail how the process of randomisation was carried out in details. Although the fifth by Mahfouz et al (1995) mentioned picking participants at random, it was however not enough to reduce the possibility of bias. Only one study by Mausezhal et al (2009) carried out the process of randomisation at the community level and it is in line with the recommendation that randomisation be carried out at community level; it is said to give the participants a sense of perceived fairness in the allocation process (Kent Ranson et al, 2006).

A major weakness seen in all the studies was the absence of blinding. Even after the process of randomisation, this was difficult to achieve because the studies attributed this to the challenge of inability to hide the types of

intervention from the users. Blind assessments produce significantly lower and more consistent scores than open assessments and there are available evidence showing that both blinding and randomisation reduce bias to a great extent (Jadad et al, 1996). The studies that used chlorination as a form of intervention found out that it was difficult masking the chlorine smell from the participants. The same thing was seen in the cases of participants introduced to the use of filters, they realised that they were in the intervention group following the introduction of the filters. The study which employed the use of SODIS has even bigger challenges because the special bottles which were given to the parents of these children for water filtration automatically sensitizes them into knowing that they have are among the ones receiving the special treatment. Looking at this critically, it is possible that the presence of these interventions may have had an influence on the information given by the participants and may also have affected the reports given by the observers. The knowledge of being in the intervention group and the likelihood of receiving more attention from the observers is very likely to tilt the results of the study in favour of participants in the intervention group. Participants who are in the control group with time will realise which group they fall into and as such may not take as much precautionary measures about their sanitation habits like those in the intervention arm. This shows that in some studies blinding may not be possible because exposure can be discovered (Day & Altman, 2000); this is seen in the studies being reviewed. These factors cannot be overlooked when evaluating these results.

Only one paper was able to state that the participants had no idea about the group which they were going to be placed in during the duration of the study. All the other papers were quite unclear about this point. Accounting for lost to follow-up was adequately done in all the papers with over 90% of all participants completing the studies.

The absence of the use of a placebo in these randomised controlled trials is a highly significant finding. Due to the lack of placebos, it will be a huge task trying to know if the reduced diarrhoea rates were actually due to under reporting or if there was a genuine decrease. Stauber et al (2009) suggested that the "placebo (Hawthorne) effect resulting from study participants under-reporting illness is a limitation of the study design". Prior to this present study, so many other previous studies which had evaluated the effects of water interventions such as solar disinfection, chlorine disinfection etc in developing countries did not also use placebos (Fewtrell & Colford, 2005, Clasen et al, 2006).

A potential limitation to this methodology carried out is that there are some articles which may not have been reached using the search terms and inclusion criteria outlined above. This is worsened by the fact that the choice of these criteria was made by only one individual. This challenge is considered to be significant especially as some of these unreached studies could make a difference in the analysis, discussions and conclusions of this systematic review. Another major limitation here is that unlike in systematic reviews of Cochrane standards where multiple authors are involved, this research is being carried out by one person. Thus, there is the absence of independent review of methods of searches carried out, relevance of studies found, methodology employed as well as some other minor but equally significant part of a standard review process. This absence of a group of researchers as well as inability to identify some other papers will give room for better improvement in subsequent systematic reviews which may be carried out in this area of interest.

5.2 Implications for Future Research

The role safe water occupies in the provision of good health has been seen from the several papers and studies carried out Concerning it and its place in prevention of diseases. Fewtrell et al (2005), Fewtrell et al (2006) as well as Clasen et al (2006) are among the several studies that have been carried out which evaluated the effect of water interventions on diarrhoea control. This shows that the study has been on-going and will likely be continued due to the importance of this topic.

Although this review used fewer studies than past reviews which have been carried out; but they seem to have similar outcomes and limitations with very few differences. The methodological weaknesses of blinding, absence of placebos among other things give room for more studies to be carried out. These newer studies while trying to see the effects of the interventions in diarrhoea reduction should employ the use of standard randomisation procedures which will be clearly described, adequate allocation concealment methods, and use of placebos as well as put much effort that they can into the blinding procedures.

At least 2 of the studies evaluated in this review showed the effects the seasons had on diarrhoea rates and the maximum number of months the studies lasted was 10months. Future papers can reduce the bias of results due to the weather by carrying out their studies over a long period of time in order to accommodate the weather changes and give room for an unbiased observation of the children who are the participants.

Results from future studies will be reliable when efforts have been made to carry out the studies in the right settings and previously recorded limitations are reduced to the barest minimum. For further research, it is important to note that a lot lies on not just the results showing the effects of these interventions on diarrhoea rates but also the

methodological quality of the process which was used in the study as well as other further look into other added health benefits of these interventions in children.

Reliable results can assist in providing more knowledge for healthcare planners, it can lead to a change in health policy and also show ways in which on-going healthcare programs can be improved upon and modified to be of benefit to children ages less than 5 years old in the developing nations of the world.

6. CONCLUSIONS:

All the reviews conclude that water interventions improve the incidence of diarrhoea in children under the age of 5, and these results are consistent with Fewtrell et al (2004) findings. Evidence suggests that the methods used to enhance the microbiological value of drinking water are not only efficient in children under 5 years of age, but also beneficial in all other ages and populations (Clasen et al, 2006) Given the various methodological weaknesses in these research, it will not be appropriate to completely accept the results.

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