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IMPACTS OF TEMPERATURE VARIABILITY ON SALMONELLA TYPHI INFECTION IN NGOKETUNJIA DIVISIO, CAMEROON (1980-2021).

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ABSTRACT : Climatic elements have significant effects on human health. This study investigated the relationship between temperature variability and the prevalence of *salmonella typhi* infection in Ngoketunjia Division. This mixed-method research combined quantitative and qualitative techniques to collect and analyze primary data through field observations, interviews, focused group discussions, and secondary data from publications obtained from libraries, government ministries, and NGOs. 325 questionnaires were distributed among the 13 villages that makes the area. Using linear regression analysis to process climate and health records, bacteriological analyses of sampled potable water sources established the association of patterns of temperature variability with the incidence of typhoid fever. Analysis of climatic data revealed a general increase in the temperature record of the region, with 6 outstanding positive and 4 outstanding negative anomalies observed over the study period from 1980 to 2021, marked by the frequent occurrence of several hydro-meteorological extreme events such as droughts, dry spells, and storms. The Student t-test statistical analysis technique verified and validated that an increase in the rate of *S. typhi* infection was recorded between the years 1980 and 2021. The regression analysis generated a linear model ($y=0.034x+28.159$; $R^2 = 0.8529$) with a P-value 0.002 establishing that temperature variability trend significantly and positively correlated with the trend of occurrence of typhoid fever (the number of *salmonella typhi* seropositive cases) in Ngoketunjia Division. This rejected the null hypothesis and confirmed the alternative, which stated that "temperature variability influences the prevalence of typhoid fever in the Ngoketunia Division". It was further established that the perception of households on the association between temperature variability and the prevalence of typhoid infection in Ngoketunjia Division corroborate the above results. By concluding that temperature variability exacerbated the transmission of *S. typhi*, the research emphasizes the need for public health interventions tailored to mitigate the impacts of temperature variability on disease prevalence in the vulnerable population of Ngoketunjia Division. The research recommends that surveillance and monitoring systems, water, sanitation, and hygiene (WASH), public awareness campaigns, collaboration with environmental agencies, climate adaptation strategies, research and capacity building should be promoted.

KEYWORDS: *Temperature Variability, Prevalence, Salmonella Typhi, Infection, Ngoketunjia Division*

I. INTRODUCTION

Temperature variability is a critical environmental factor influencing the epidemiology of certain infectious diseases (Chop, 2023). In regions where climatic conditions significantly fluctuate, pathogens can strive and more efficiently spread. One of such pathogens, *salmonella typhi* which is the causative agent of typhoid fever poses significant public health challenge especially in inadequate resource settings. The Ngoketunjia Division of Cameroon characterised by its unique climatic pattern and varying temperature ranges serves as an important case study for understanding the interplay between environmental factors and the prevalence of *Salmonella typhi* infections.

Research has shown that temperature affects the survival and virulence of *S. typhi* with warmer conditions often facilitating its proliferations (Kirk *et al.*, 2015). In Cameroon where temperature can fluctuate due to seasonal changes, understanding how these variations correlate with typhoid fever outbreaks is essential for implementing effective public health interventions (Baker *et al.*, 2017). Previous studies have highlighted a relationship between climate variability and the incidence and prevalence of infectious diseases, suggesting that temperature extremes may exacerbate the risk of outbreaks (Mastrorillo *et al.,* 2016). Temperature variability influence the distribution, survival and the severity of typhoid fever. The growth and survival of *S. typhi* highly depends on temperature (Xue *et al* 2022). Higher temperatures generally promote faster replication of the bacteria meanwhile very low temperature on the other reduce replication. At room temperature growth and replication of *salmonella typhi* is increased. Investigations have shown that for every 2^0c increase in temperature above 18^0c in temperature, typhoid fever cases rise by 6% (Hill *et al* 2022). Typhoid fever and other climate related diseases always show an increasing trend with higher incidence in the dry season which is generally warmer. Temperature influence the strength of our immune system increasing vulnerability to S.Typhi infection. This has becomes very severe among vulnerable groups such as children, farmers and people with weakened immune systems.

Given the rising incidence and prevalence of typhoid fever in Cameroon and the potential role of climate change in altering temperature patterns, this study therefore aims to explore the relationship between temperature variability and the prevalence of *salmonella typhi* infection in the Ngoketunjia Division of Cameroon. By analysing local temperature data alongside infection rates, this research seeks to provide insights that could inform public health strategies and improve disease management in the region and beyond. Our investigation was guided by three objectives:

- **I.** To analyse the patterns and trends of temperature variability the Ngoketunjia Division of Cameroon from 1980 to 2021.
- **II.** To examine the evolution of typhoid seropositive cases recorded in Ngoketunjia Division from 1980-2021.
- **III.** To show the association of temperature variability with the evolution of typhoid seropositive cases in Ngoketuinjia Division of Cameroon from 1980-2021.

II. BIOPHYSICAL BACKGROUND OF NGOKETUNJIA DIVISION

Ngoketunjia Division is located between latitude 5°81′ and 6°17′ N of the equator and longitude 10° 30′ E to10° 67′ E of the Greenwich Meridian (Figure 1).

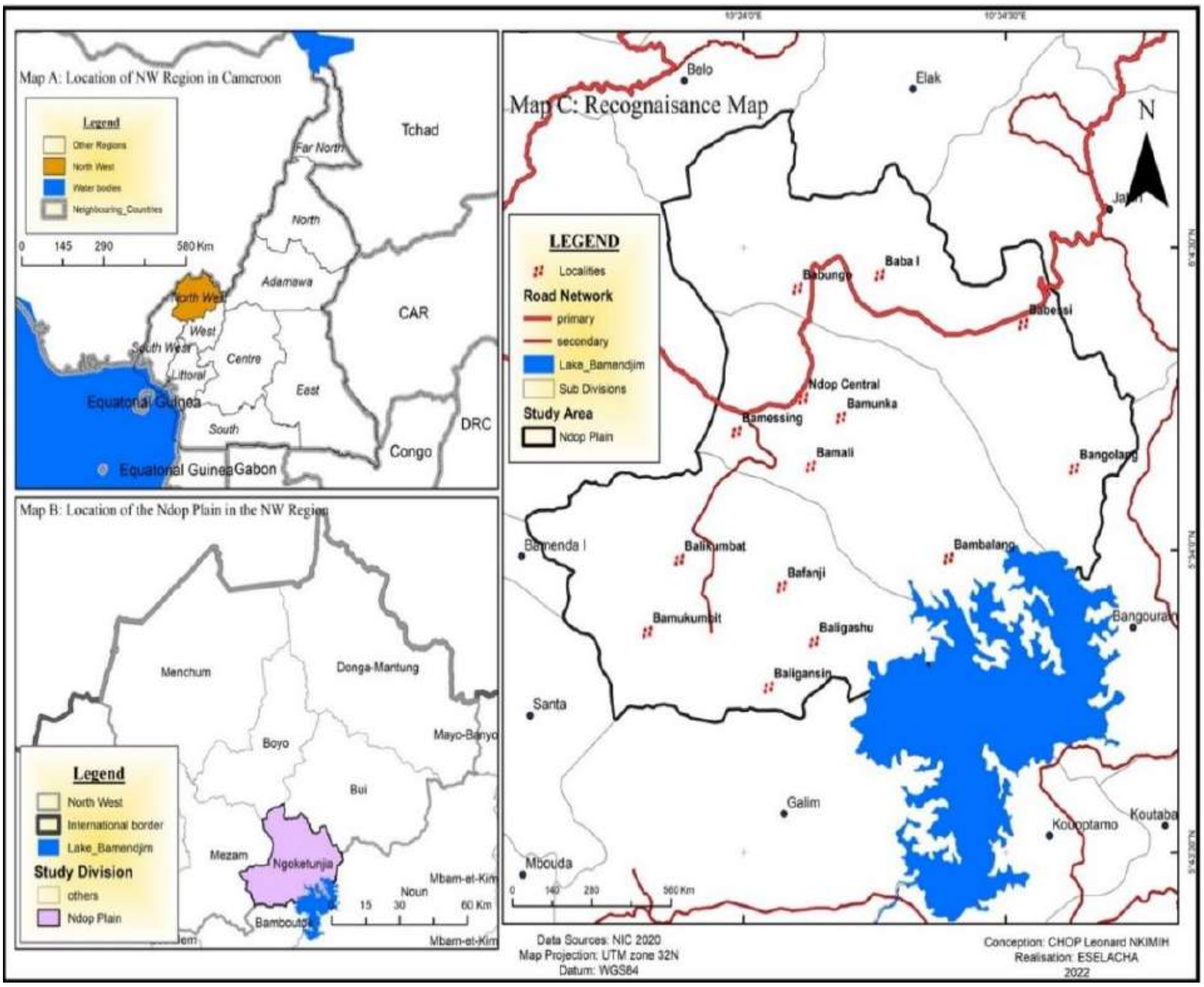

Figure 1: Location of the Study Area
Source: Fieldwork 2015/ CAMGIS ltd retouched

Ngoketunjia Division is found in the North West Region of Cameroon precisely in the eastern part of the region constituting part of the Western Highlands of Cameroon. It is bordered in the west by the Mezam Division, south by Bamboutos and Noun Divisions, East by Bui Division and to the North by Boyo Division. Ngoketunjia Division is divided into three Sub administrative units called Sub Divisions which include: Ndop Central Sub-Division, Balikumbat Sub Division and Babessi Sub-Division with a total of 13 autonomous villages. This area is found between High Lava Plateau and the Bamoum plateau. It has a flat landscape and forms a part of the Cameroon Volcanic Line that stretches from Fernando Po through Mount Cameroon to the Mandara Mountains in the northern part of the country. Ngoketunjia has an average altitude of 1150 m above sea level with an extensive low altitude Ndop Plain (Chop, 2022). This plain is limited by few hills like the Bamessing-Sabga, the Babungo hills that extend to Belo Sub-Division in Boyo, Bamunkumbit–Baligansin hill that extends right up to Santa Sub-Division in the Mezam Division and Bamboutos in the West (Nkwemoh, 1999). The distribution of temperature, wind, precipitation and humidity of the area is highly influenced by the relief characteristics of the zone. The climatic characteristics of the Ngoketunjia Division like the North West Region of Cameroon shows two distinct seasons, the wet and the dry seasons. The rainy season begins in the month of March and ends between the second half of October and early November while the dry season runs from early November to March (Chop, 2017). This area has a dense hydrographic network with permanent water courses like the river Noun which is the largest in the area and its tributaries (river Monkie, Sefou, Meyem, Mbeye, Tembou, Monoun, and Melongo). The soil is much more hydromorphic and clayey and carries much more of hydrophytic vegetation with patches of gallery forest and grasses. All these renders the breeding and proliferation of *salmonella typhi* easier and so increasing infection rate.

III. MATERIALS AND METHOD

Data were collected from secondary sources which included text books, dissertations, theses, journals, newspapers, magazines, reports, periodicals, articles and all materials drawn from the internet. These research documents were obtained from, ministerial departments (MINSANTE, MINADER, MINRESI, and MINT) and Corporations (National Institute of Statistics, newspapers production centres), libraries (library of the Faculty of Arts Letters and Social Sciences, Master's library of the University of Yaounde 1), internet sources (ASK, Google, bring, Wikipedia). Research from the above cited sources resulted to the acquisition of diverse information including the map of North West Region and Ngoketunjia Division adapted from the topographical sheets, Bafoussam NB-32, Nkambe NB-32-XVII at a scale of 1;200000. These documents were consulted and useful data (qualitative and quantitative) obtained, assembled and kept in hard copies and computerised files for further exploitation. Primary data were gathered through experiments, administration of questionnaires, interviews and focus group discussions.

Experimental procedure through bacteriological analysis of water sources were conducted for *salmonella typhi.* This made use of the culture media preparation technique and Gram Stain Reaction method. pH measurement was conducted using the **whatman pH paper**. **Catalase test** was used to differentiate staphylococcus species which are catalase producing from streptococcus species which are non-catalase producing. **Coagulase test** helped to differentiate Staphaureus which produces the enzyme coagulase (coagulates plasma) from other staph species which do not produce coagulase. **Oxidase test was** used to assist in the identification of Pseudomonas, Neisseria, Vibrio, Brucella, and Pasteurella species, all of which produce the enzyme cytochrome oxidase meanwhile **Indole test** helped in the identification of enterobacteria. Most strains of *E.coli, P. vulgaris, P. rettgeri, M. morganii,* and Providencia species break down the amino acid tryptophan with the release of indole. The samples were serially diluted before inoculation so as to help us calculate the amount of bacteria per plate.

Generally water samples were collected from various portable water sources in the area (spring, stream, wells, borehold and pipe borne water) in both the dry season and rainy season. 15 water samples were collected from different points, three of each water source in the rainy season. It was repeated in the dry season to make a total of 30 water samples. These samples were collected in sterile containers, labelled, and incubated at 35-37^{0}c for 24 hours allowing Salmonella to multiply to increase the possibility of detection. Selective plating was done, colony identified and confirmation test made. Antibiotic sensitivity testing was done to confirm or deny the presence of *S.Typhi.* This was concluded by reporting where report finding are documents were done including colony counts or bacterial load counts

A total of 350 questionnaires were intended for households and 325 were actually responded. To easily assess sampled households' responses each questionnaire had 45 questions systematically structured under four main headings; **personal identification, perception of temperature variability, perception of the evolution of typhoid fever, association between temperature and typhoid fever**. Questionnaires contained both opened and closed questions with each question coded to ease analyses.

Interviews were conducted with the District Medical Officers and Chiefs of Integrated Health Centres of Public Health and certain health workers using interview guides. Three (3) Focus Group Discussions were effectively carried out in 03 villages.

Data gathered were processed using both descriptive and inferential statistical methods. Descriptive statistical analysis was employed on the operational variables and response variables to establish averages, running mean and variations (standard deviation and coefficient of variation). These techniques of data analysis helped in calculating inter-annual, mean daily and monthly averages which were therefore used in indicating trend. Inferential statistical techniques used included regression line analysis that established the correlation between the two variables. Regressive lines were fitted in the trend so as to determine general trends. The equation of each trend line is given as;

Y=MX+C

Where Y=Value of data (eg rainfall in mm), M=the gradient

X=the years under consideration, C=the intercept on y axis when x=0

Increasing or decreasing trends were easily indicated by the positive or negative gradient of regression lines. The coefficient of determination was used in some cases to assess the degree of relationship between changes in the operational variables and response variables. Any value closer to 1 showed a strong relationship and any value closer to 0 showed a weak relationship. Regression imputation technique was used to replace missing data in some. Here existing data were used to predict missing values effectively while in some cases like temperature data forecasting was done using historical values.

Data analyses were aided by cartographic techniques in the production of maps such as Adobe illustrator, QGIS and ArcGIS. Furthermore SPSS and Micro software were used in counting questionnaires, generating frequency tables and realizing charts. The data analysed are presented in the form of graphs, charts, histograms and tables and maps**.**

IV. RESULTS

4.1 Observed variability of mean daily temperature trends

Numeric data on daily temperature were obtained by summing the maximum and minimum temperatures and dividing by two. To illustrate variations in daily temperatures we selected 4 different months within different years across four decades. Two of the months were selected in the rainy season (July and October) and two in the dry season (December and February). Selecting across various decades helped to elucidate facts on variation in daily temperature records across the period under study with reference to Highest Daily Temperature record (HDT) and Lowest Daily Temperature record (LDT), (figures 2 a, b,c and d)

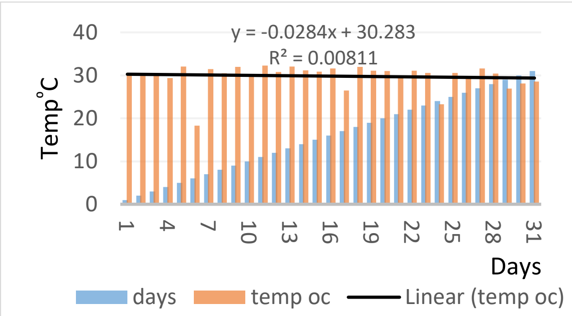

Figure 2a: Daily temp for December 1985

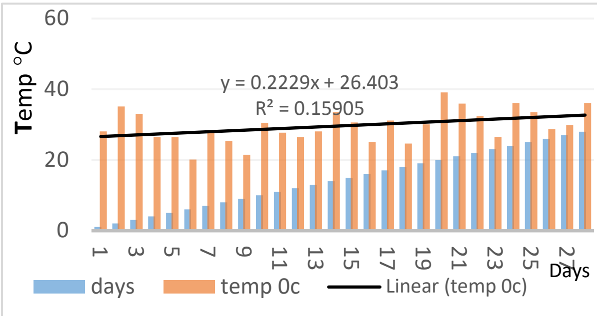

Figure 2b: Daily Temp for February 2000

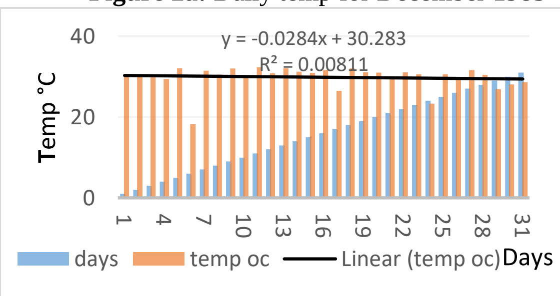

Figure 2c: Daily Temp for July 2010

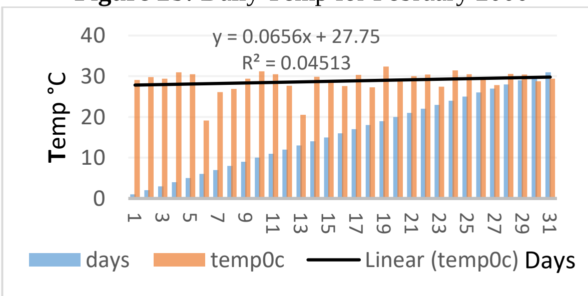

Figure 2d: Daily temperature for October 2020

Figure 2: Observed variation in mean daily temperature trends
Source: Bamendjin dam weather station, UNVDA

Daily temperature has varied substantially over the years. Some months as December and February witnessed higher temperatures than others. In December 1985, the HDT was registered on the 21st (37.3 °C) while the LDT was recorded on the 13th (25.8 °C). On February 2020, the HDT was registered on the 20th (39.1°C). The LDT was recorded on the 6th, 20.1°C. On July 2010 the HDT was recorded on the 11th, 32.3°C while the LDT recorded was 18.3°C on the 6th. In October 2020, the HDT was registered on the 19th, 32.4°C and the LDT was 19.1°C on the 16th. Daily temperature varied according to days and seasons. Among the four months under study, the LDT temperature was recorded on the 6th of July 2010 meanwhile the HDT was registered on the 20th of February 2000.

4.2 Observed mean monthly temperature trend from 1980-2021

To ensure a proper understanding of the level of significance of temperature variability in the Ngoketunjia Division, we were able to summarize average monthly temperature over the study period (1980-2021). Average monthly temperature was obtained by adding the monthly temperature for each of the months to cover the 42 years' period under study. The sum was inserted in a table and the result presented in figure 3.

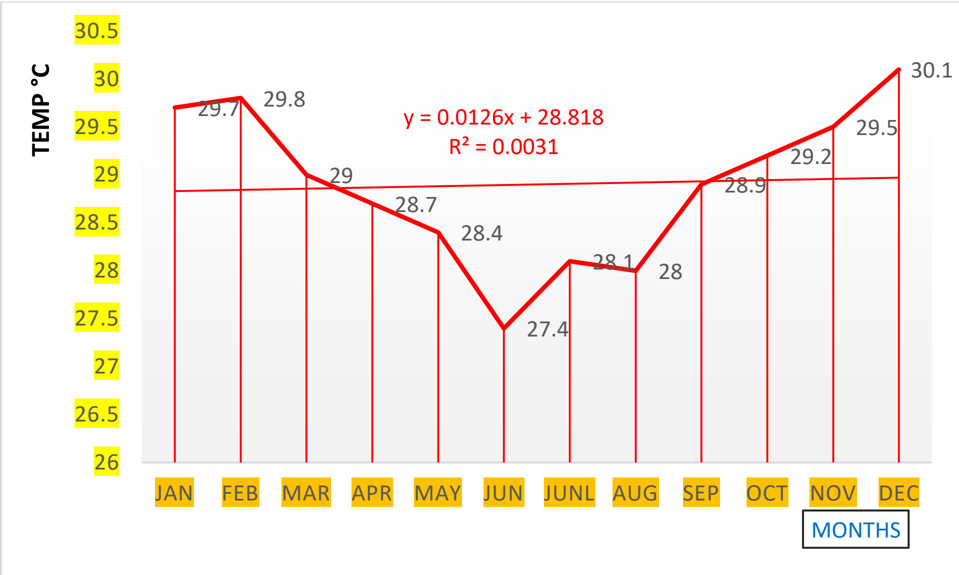

Figure 3: Observed Mean Monthly Temperature trend from 1980-2021
Source: Bamendjin dam weather station, UNVDA

There was a steady variation in mean monthly temperature though with a slight but significant increase as indicated by the trend line and the equation of trend line ($y = 0.0126x + 28.818$, $R^2 = 0.00309$). Taking a close look at the pattern of mean monthly temperature one will quickly notice a constant fluctuation. December, January and February registered the highest mean monthly temperature values (30.1°C, 29.7 °C and 29.8°C respectively). These very high temperatures mean a high frequency in the occurrence of heat waves as well as high evapotranspiration which is the main factors behind soil moisture deficit. Such deficits are detrimental to portable water availability both for domestic usage and for the sanitary need.

In the same manner, there were months with meaningful reduction in temperature throughout the period. These months generally experienced abrupt fall in average temperature leading to high vulnerability to the occurrence of cold waves. June, July and August registered the least average monthly temperatures. June had an average monthly temperature of 27.4 °C, July recorded 28.2 °C while August 28 °C. Though these temperature values are not too low for the continuation of human activities, a high range would mean a lot to human health. This is so because a sudden fall or rise in temperature can provoke either heat waves or cold waves which exercise great influence on human health.

4.3 Observed Annual Mean Temperature Trends

Mean annual temperature data was calculated from the daily temperature records from Bamendjin weather station and the UNVDA weather station record. A simulation was done in order to reduce the error margin in some cases and the result which was presented in a tabular form was later converted into figure 4. A trend line was inserted and the equation of trend line attached to initiate a clear view of the variability trend.

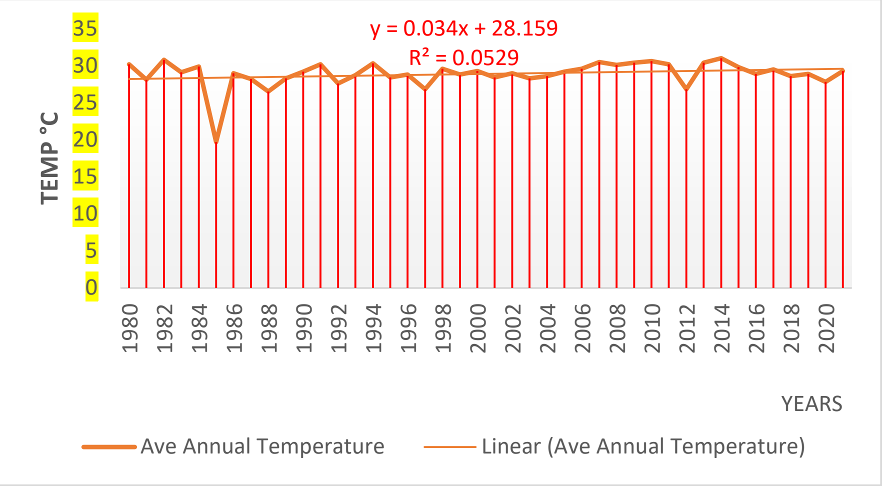

Figure 4: Observed Mean Annual Temperature trend
Source: Bamendjin dam weather station, UNVDA

Temperature has increased substantially over the study period as indicated by the trend line and the equation of trend line ($y = 0.034x + 28.159$, $R^2 = 0.05295$). This increase is marked by constant variation across the years. Some years recorded very high average annual temperature meanwhile some recorded a significant fall in average annual temperature. Among those with exceptional high temperature easily identified years are 1980 (30.2 ˚C), 1982(30.8 ˚C), 1994(30.3 ˚C), 2007(30.5 ˚C), 2010 (30.6 ˚C) and 2014 (31˚C). These high temperatures signify increase aridity which has great impacts on water supply and availability. Contrary to the above there were years with drastic temperature reduction records. These are years which witnessed a severe drop in their average annual temperatures. Some of these years include 1985(19.7 ˚C), 1988(26.5 ˚C), 1997(26.8 ˚C) and 2012 (26.8 ˚C). The year 1985 was the coldest year and such low temperature signifies a high frequency in the occurrence of cold wave which is very detrimental to human health as well as some crop production.

4.4 Variability in the onset and termination of the dry season

Seasonal variability was highly manifested in the onset and termination of the dry season. Information obtained during our investigation permitted us to make an inventory of the onset and termination of the dry season over the period under investigation. Summarised data pertaining to this information are presented in 1.

Table 1: Variation in the Onset and termination of the dry season

Years	Onset	Termination	years	Onset	Termination
1980	25-Nov	26-Mar	2001	3-Dec	11-Apr
1981	28-Nov	1-Apr	2002	29-Nov	24-Mar
1982	21-Nov	20-Mar	2003	21-Nov	6-Mar
1983	15-Nov	19-Mar	2004	8-Nov	24-Mar
1984	28-Dec	5-Apr	2005	4-Nov	21-Apr
1985	29-Nov	2-Apr	2006	9-Nov	27-Mar
1986	20-Nov	23-Mar	2007	6-Nov	14-Mar
1987	17-Nov	13-Apr	2008	28-Nov	15-Mar
1988	17-Nov	24-Apr	2009	11-Nov	25-Mar
1989	25-Nov	11-Mar	2010	18-Nov	27-Mar
1990	23-Nov	13-Apr	2011	27-Nov	21-Apr
1991	02-Dec	29-Mar	2012	24-Nov	11-Apr
1992	21-Nov	28-Mar	2013	5-Nov	15-Mar
1993	10-Dec	29-Mar	2014	10-Nov	10-Apr
1994	4-Dec	26-Mar	2015	7-Nov	9-Apr
1995	22-Nov	30-Mar	2016	17-Nov	14-Apr
1996	2-Dec	4-Apr	2017	2-Dec	31-Mar
1997	12-Nov	2-Apr	2018	3-Nov	27-Mar
1998	26-Nov	18-Mar	2019	18-Nov	29-Mar
1999	4-Nov	27-Mar	2020	21-Nov	19-Apr
2000	13-Nov	30-Mar	2021	23-Nov	15-Apr

Source: Bamendjin Weather Station, UNVDA

Under normal conditions, the people of the Ndop plain observe the dry season from late November to late March. But over the past decades there has been a constant variability in this tendency. Generally, there has been a steady variability in the onset and termination of annual dry season over the period under investigation. We observed years in which the dry season started earlier than expected and years in which the dry season began late. In the same manner we recorded years in which the dry ended late and those in which it ended earlier. In the years 2004, 2005, 2006 and 2007, the dry began earlier than expected (8th, 4th, 9th and 6th November respectively). Such early starts increase the trends of malaria and causes water stress that provokes salmonella infection. Again in 1980, 1984 and 1988, the dry season started as late as in the month of December (25th, 28th and 18th December respectively). With respect to the termination of the dry season, we observed early termination in the year 1989 (11th March).

4.5 Temperature Anomalies

The temperature data obtained were used to calculate anomalies in the Ndop plain. This was realised by subtracting mean annual temperatures calculated for the 42 years' period (28.9 $^{\circ}$C) from the average annual temperature of each of the years within the period under study and the result obtained was presented in Figure 5.

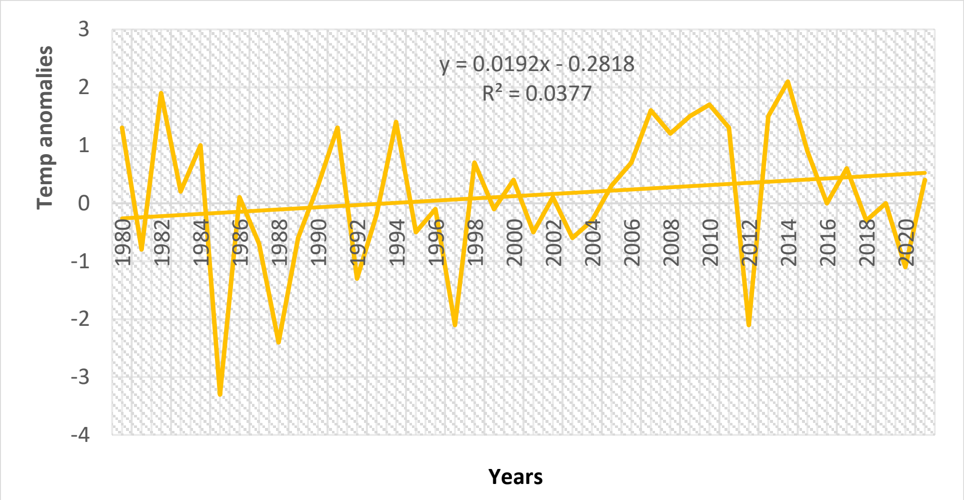

Figure 5: Temperature Anomalies
Source: Bamendjin Dam Weather Station, UNVDA

Anomalies were calculated to show years in which annual temperature exceeded the average of the sum of average annual temperature on the one hand and years in which average annual temperature was inferior to the average of the sum of annual average on the other hand. In a general manner it is noticed that annual temperature was hardly on the average. In most of the years, average annual temperature was either above or below the average signifying either deficit or surplus rainfall. The years 1994, 2007, 2008, 2009, 2010 and 2014, (1.4°C, 1.6°C, 1.2°C, 1.5°C, 1.7°C and 2.1°C respectively). The year 2014 recorded the greatest amount of average annual temperature anomaly (2.1°C). These years represent years with deficient soil moisture and recurrence of extreme hydro-climatological events which render human health more vulnerable to several infections such as typhoid and malaria. Such high temperatures indicate a greater possibility of droughts occurrence, heat waves and pollution of water courses.

Years that recorded average temperature below the average of 28.8°C included 1985, 1988, and 2011 (-3.3°C, -2.4°C, and -2.5°C respectively). Such drastic fall in average annual temperature create a situation of cold waves which is not a favourable condition for ensuring good health. Such a situation may be accompanied by intense rainfall which provokes pollution of water sources causing scarcity for domestic usage. This exposes the population to untreated water sources which is a major host of *salmonella typhi*. Inadequate water resources equally reduce the sanitary conditions of households in the Ndop plain, creating poor sanitary conditions which is one of the major means through which *salmonella* is distributed from one carrier to another.

4.6 Seasonal Variation of Typhoid Infection in the Ndop Area.

The total number of typhoid infections in the rainy season and dry season was obtained by summing up total monthly infections for dry season months (December, January, February and March) and total monthly infections for rainy season months (April, May, June, July, August, September, October and November). The grand total for each season was obtained for the years 1982, 1992, 2002, 2012 and 2021 (Figure 6).

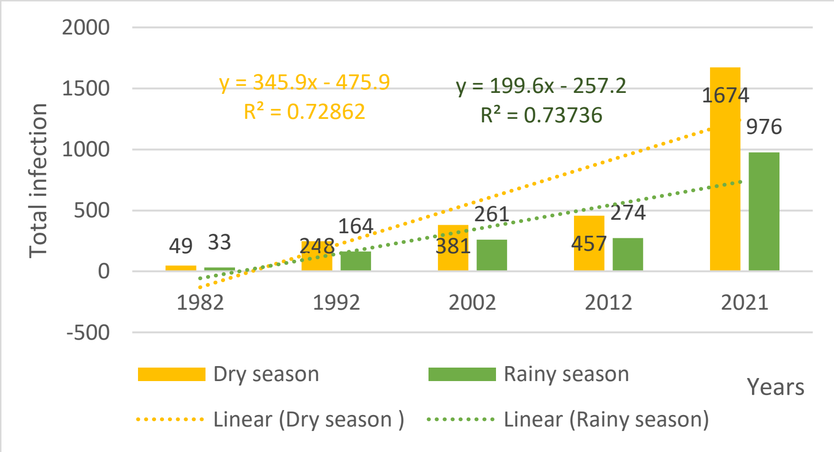

Figure 6: Monthly variation of the evolution of typhoid infection.
Source: DHIS2, RDPHNW, DDPHNG

Data obtained during our research showed a significant variation in the evolution of typhoid fever seropositive cases with changes in seasons (dry season and rainy season). As such, typhoid infection varied consistently with changes in seasons. The total number of infections shows great disparities over the period under study (1982-2021) as indicated by the case studies of the years 1982, 1992, 2002, 2012 and 2021. Generally, we observed an increase in the rates of infection in the dry season. More typhoid seropositive cases were recorded in the dry season as compared to the rainy season. In 1982, 49 out of 82 persons infected in the years was recorded in the dry season as opposed to 33 persons in the rainy season. In the years 1992, 2002, 2012 and 2021 a similar record was established with an exceptional rise in the number of infections in the dry season. This is explained by the fact that higher temperatures in the dry seasons causes a drastic fall in the water table bringing about a fall in discharge of potential water sources. Most water courses dry up reducing accessibility to potable water in the area and exposing the population to unsafe water sources which have higher risks of contamination.

4.7 Annual Trends of typhoid fever seropositive cases from 1982-2020

Annual trends of typhoid fever seropositive cases in the Ndop area reveal remarkable evolution over the period under study. Annual records on the number of infected cases were obtained and very intrinsic data collected. These data showed how the number of typhoid cases changed from one year to the next successive year. The numeric data were inserted in an excel page and later converted to figure 7. The equation of trend line was added in order to render variability more comprehensive.

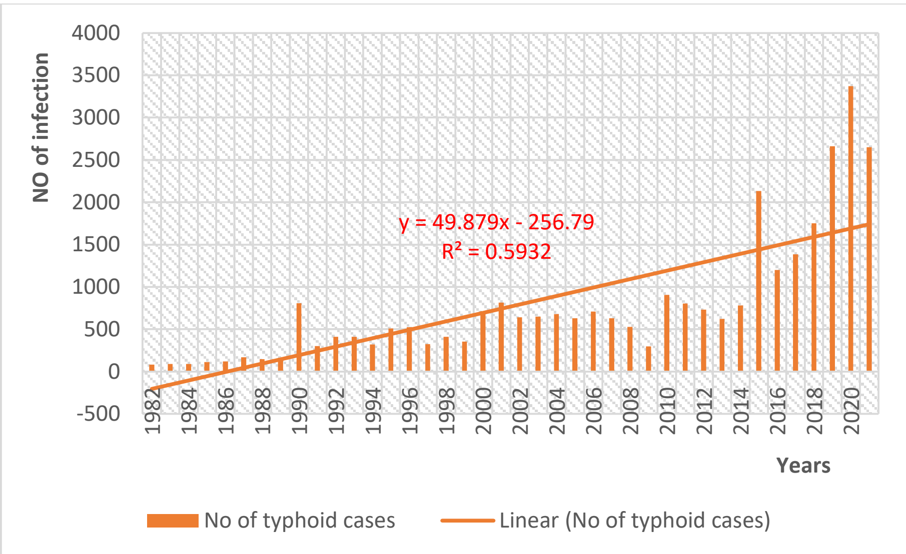

Figure 7: Annual Trends of typhoid fever seropositive cases from 1982-2020
Source: DHIS2, RDPHNW, DDPHNG

The number of typhoid seropositive cases rose significantly in Ngoketunjia Division between 1980 and 2021though not very consistent. The highest number of typhoid seropositive cases were registered in 2020 (3,372 persons), 2019 (2,663 persons) and 2021 (2,605 persons) while lowest annual number of cases occurred in the years 1982 (82), 1984 (89) etc. A drastic drop was observed between the years 1987 and 1988. The number of typhoid seropositive cases fell from 170 in 1987 to 140 in 1988. This same falling trend was recorded between 2008 and 2009 wherein the total number of typhoid infected cases dropped from 529 to 298 persons. Again, such a drastic fall was registered between 2015 and 2016 as the number of seropositive cases fell from 2131 to 1200 persons.
On the contrary, some years recorded an exceptional rate of increase in typhoid seropositive cases in the area. From 1989 to 1990, the number of typhoid cases rose from 162 to 806 persons. This supposes that within a one-year period an additional 644 persons tested positive of the presence of *salmonella typhi.* This same increase trend was recorded between the years 2015 and 2016 when the number of typhoid infected cases rose from 780 to 2,131 marking an increase in the number of typhoid seropositive cases by 1,351 just within a year. This figure however is extremely high and so required very specific management system. These inconsistencies in the number of infected cases can be attributed to variation in health care measure due to inconsistent intervention from the state and other health base agencies operating in the area

4.8 Results of Bacteriological Analyses of Water Samples

Water samples collected from various potable water sources in the area (pipe borne, wells, bore hole, streams and springs) were tested for S.typhi. In each potable water source, 3 samples were collected in different localities following a designed transects in the rainy season and dry season making up a total of 15 water samples per season. With regard to water samples collected in the dry season, all tested positive of *S. typhi, E.coli and Campylobacter* except for 2 water samples collected from 2 boreholes in Bamunkumbit. In the same manner 15 water samples were tested in the rainy season and a significant bacterial (*S. typhi, E.coli and Campylobacter)* were isolated in 12 samples while 03 water samples tested were found fit for consumption. This shows that a greater proportion of potable water in Ngoketunjia Division are contaminated with S.typhi thus increasing vulnerability to typhoid fever infection.

4.9 Correlations between average annual temperature and trend of typhoid fever seropositive cases.

Average annual temperature data obtained from UNVDA and the Bamendjin dam was placed side-by-side total annual cases of typhoid seropositive cases in area. The resulting data were inserted in an excel page and converted to Figure 8 with temperature represented by bars while typhoid cases are represented with a line. The equation of trend line was fitted in order to render relationship between the two variables more comprehensive.

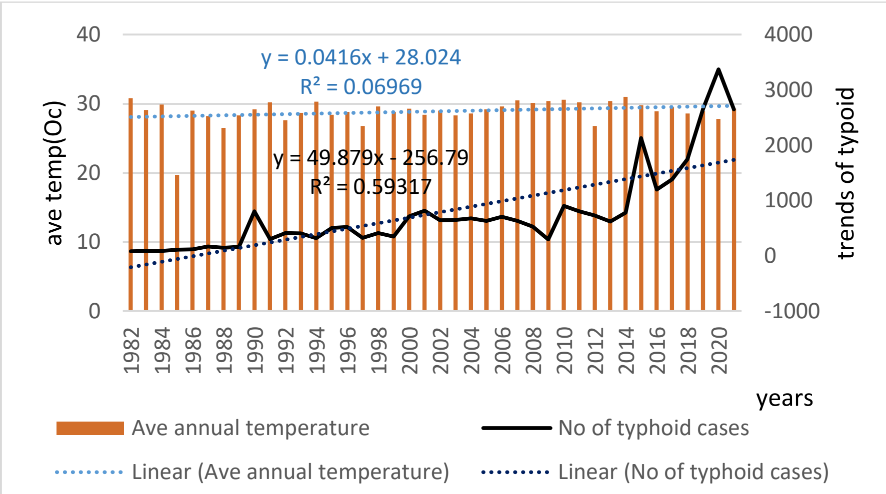

Figure 8: Correlations between average annual temperature and trend of typhoid fever seropositive cases
Source: Bamendjin weather station, UNVD/DHIS2, RDPHNW, DDPHNG

In a general manner, average annual temperature has significantly varied over the period under investigation in the Ndop plain. This variation was immediately followed by remarkable inconsistencies in the evolution of typhoid seropositive cases in the area. However, as indicated by the equation of trend lines both variables have increased substantially across the period under study (y = 0.0416x + 28.024 R^2 = 0.06969 for average annual temperature and y = 49.879x 256.79 R^2 = 0.59317 for typhoid seropositive cases). The independent variable (temperature) has shown an increasing trend as well as the dependent variable

(typhoid). One can quickly notice that in some of the years an increase in average annual temperature was accompanied by a considerable increase in the number of typhoid seropositive cases in the area meanwhile in other years an increase in temperature resulted in a fall in the total number of typhoid infected cases.
Between the years 1985 and 1986 a fall in average annual temperature from 19.7 °C to 29 °C let to a rise in the number of typhoid seropositive cases from 120 to 170 persons. Again, when temperature rose from 29.2 °C to 29.6 °C, the number of typhoid cases responded by rising from 630 to 709 persons. This implies an additional 79 persons were newly infected between 365 days. This same correlation was observed between 2013 and 2014 where in a rise in average annual temperature from 30.4°C to 30.1°C led to an increase in typhoid cases from 620 to 780 persons, a range of 160 persons within a year.
On the contrary, between the year 1998 and 1999, a drop in average annual temperature from 29.6 °C to 28.8 °C brought about a fall in the number of typhoid cases from 412 to 352 persons. This same trend was observed between 2008 and 2009 where a reduction in average annual temperature from 30.5 °C to 30.1°C was responded to by a reduction in the number of typhoid cases from 520 to 298 persons. This might possibly occur as a result of improvement in medical care and external intervention with measures of typhoid prevention and treatment. A contrary situation was recorded between the years 1993 and 1994. During these years, a rise in average annual temperature from 28.7 °C to 30.3 °C resulted to a fall in the number of typhoid seropositive cases from 409 to 320 persons. It is thus realized that variations in temperature brought about changes in the number of typhoid cases in the area and thus one can conclude that temperature highly influence the evolution of typhoid cases in the Ndop plain.

4.10 T-test correlation between average annual temperature and trend of typhoid seropositive cases in the Ndop plain.

Data on the evolution of typhoid cases in the Ndop plain obtained during our investigation is placed side-by-side the average annual temperature of the area. Totals and averages for the period under study were calculated. Average annual temperature column was considered to be (x) while typhoid data column was (y). X^2 and y^2 were calculated and their totals used to calculate the t-test value using the following formula and presented in table 1.

- Formula for T-TEST, $t = \dfrac{\text{Difference between the means}}{\text{Standard Error of Difference}}$

$$\text{Or } t = \frac{/\bar{x} - \bar{y}/}{\sqrt{\dfrac{\dfrac{\sum x^2}{nx} - (\bar{x})^2}{n-1} + \dfrac{\dfrac{\sum y^2}{ny} - (\bar{y})^2}{n-1}}}$$

- Where $\bar{y}$ = mean of dependent variable
- $\bar{X}$ = mean of independent variable
- n = number of observation
- ∑= (big sigma) sum
- Degree of freedom = nx + ny – 2

Table 1: T-test correlation between average annual temperature trend and trend of typhoid seropositive cases

Years	Ave annual temp (x)	Typhoid cases (y)	x^2	y^2
1982	30.8	82	948.6	6724
1983	29.1	90	846.8	8100
1984	29.9	89	894.0	7921
1985	19.7	113	388.1	12769
1986	29	120	841.0	14400
1987	28.2	170	795.2	28900
1988	26.5	147	702.3	21609
1989	28.3	162	800.9	26244
1990	29.2	806	852.6	649636
1991	30.2	302	912.0	91204
1992	27.6	412	761.8	169744
1993	28.7	409	823.7	167281
1994	30.3	320	918.1	102400
1995	28.4	508	806.6	258064
1996	28.8	525	829.4	275625

1997	26.8	325	718.2	105625
1998	29.6	412	876.2	169744
1999	28.8	352	829.4	123904
2000	29.3	712	858.5	506944
2001	28.4	816	806.6	665856
2002	29	642	841.0	412164
2003	28.3	650	800.9	422500
2004	28.6	680	818.0	462400
2005	29.2	630	852.6	396900
2006	29.6	709	876.2	502681
2007	30.5	630	930.3	396900
2008	30.1	529	906.0	279841
2009	30.4	298	924.2	88804
2010	30.6	906	936.4	820836
2011	30.2	803	912.0	644809
2012	26.8	731	718.2	534361
2013	30.4	620	924.2	384400
2014	31	780	961.0	608400
2015	29.8	2131	888.0	4541161
2016	28.9	1200	835.2	1440000
2017	29.5	1383	870.3	1912689
2018	28.6	1750	818.0	3062500
2019	28.9	2663	835.2	7091569
2020	27.8	3372	772.8	11370384
2021	29.3	2650	858.5	7022500
TOTAL	**1155.1**	**30629.0**	**33488.9**	**45808493**

Source; 2021 Field investigation.

From this calculation, our mean annual temperature for the period under study (1980-2021) i.e $\bar{X}$ was **28.9**, $\bar{Y}$ Mean Typhoid Infection stood= 765.7 persons,

Number of observation **(n)** = 40

Calculated T-Test = *6.06*.

Degree of freedom = nx + ny – 2 = 40 + 40 – 2 = **78**.

With the degree of freedom being **78,** considering the level of significance at **0.001**, the critical value for a two-tail t-test is **3.46.** The calculated t value is **6.06**, which is greater than the critical value **(3.46).** This supposes that the null which states that "variability in temperature has NO influence on the prevalence of typhoid in the Ndop plain" is refuted. The alternative which stated that "temperature variability influences the prevalence of typhoid in the Ndop Plain" is accepted. This conclusion is based on the evolution of typhoid seropositive trend and the average annual temperature data of the Ndop plain.

V. TEMPERATURE REQUIREMENT FOR *SALMONELLA TYPHI* BACTERIUM

S.typhi is a very temperature sensitive bacteria. As global temperature rise due to climate change, the frequency and intensity of temperature variability increased due to leading to more frequent typhoid outbreak. *Salmonella* thrives at it maximum when temperature is between 37^0 C and 45^0C. The best temperature for it growth and development was found to be 37^0C (WHO, 2023, the effects of temperature and incubation time of bacteriocins produced by lactobacillus isolates growol against salmonella typhi in vitro, 2024). At low temperature less than 5^0C, the bacteria witness a significant slowdown in its growth (Semenov *et al* 2009). However the survival rate is at its lowest at cooking point (70^0C). This is because at this point the bacteria is completely killed. With changes in seasons, a greate variation is observed in the rate of salmonella typhi infection. Increase temperatures in the dry season and summers shows an increasing trend in the rate of transmission of S.typhi bacteria especially in the tropical and sun tropical areas where the risks of outbreak increases in warmer months. Again in water sources salmonella typhi rate has shown a dramatic rise. This has become very severe in areas with inadequate sanitation measures. Ngoketunjia Division, located in the tropical zone exhibits the tropical climate that influence the outbreak and transmission of S.typhi. With occasional rise and fall in temperature of the area an increase in the incidence and outbreak of S.typhi is observed. This area have witnessed an increase in its temperature over the study period (1980-2021). This temperature increase account for the persistent rise in the rate of S. typhi infection. The rate of infection rose significantly in the dry season due to higher temperatures recorded.

VI. DISCUSSIONS

The relationship between temperature variability and the prevalence of *salmonella typhi* infection in Ngoketunjia division has significant implication for public health and disease management. Our study indicates a clear correlation between temperature variability and the incidence of *salmonella typhi* infection. Higher temperatures have been associated with increase bacterial survival and proliferation, as salmonella typhi thrives in warmer conditions. Hales *et al*. (2000) found that for each 1^{o} C rise in temperature, the risk of non-typhodal *salmonella* infection increase by approximately 5%. This suggest that similar dynamics may apply to salmonella typhi as realised during our investigation. In a study conducted by Colford *et al* (2006), climate change and rising temperature significantly impacts the spread of food borne pathogens including *salmonella*. Again temperature can influence human behaviour, such as increase outdoor activities during warmer periods which can enhance exposure to contaminated environments. This is more severe in areas where food and water safety practices are compromised. A study by Rojas et al (2016) indicated that warmer weather could lead to increased consumption of potentially contaminated food and water thereby increasing rates of infection. Research has equally shown that *salmonella* species exhibit altered virulence factors in response to temperature changes. This view was reported in a study conducted by Hohmann (2001) indicating that *salmonella typhi* and other serovars regulate their motility and invasion capabilities based on temperature which can impact their ability to infect hosts during periods of elevated temperatures.

Amuakwa, 2017 and Bomba 1999 found out that there was an acceptable level of correlation between climate variability and certain infectious diseases. Utilizing the Swedish Infectious Disease Model, Amuakwa illustrated the nexus between climate variability and infectious diseases. Bomba, 1999, illustrated the relationship between climate trends and pathologic rhythm in Central African Republic. His result show that variation in climate rhythm/trends influences the evolution of pathogens of some tropical diseases including typhoid. These results are quite similar to what we obtained during our investigation. We realized that temperature variability have severely influenced the prevalence of typhoid fever in the Ngoketunjia Division. Results from our investigation show that daily, annual, sub decadal and decadal temperature variability were partly responsible for the outbreak and evolution of typhoid in the area. Several extreme temperature anomalies were observed during the study period (in relation to temperature, the most remarkable anomalies were recorded in 1982 (+2.2ºc), 1985 (-8.9ºc), 2003 (-2.4ºc) and 2014 (-2.1) and 2014 (+2.1) were responsible for the exceptional rise in the typhoid cases in the Ngoketunjia division. An increased risk of typhoid fever was detected with the increase of temperature (Each 2°C rise resulted in 6%, 95% [confidence interval] CI: 2–10% increase in typhoid cases), while the increased risk was associated with the higher temperature for paratyphoid. After the onset of mild precipitation, the relative risk of typhoid fever increased in a short-lasting and with a 13–26 days delay, and the risk was no significant after the continuous increase of precipitation. Significant temperature-typhoid and rainfall-typhoid fever associations were found in both genders and those aged 0–4 years old, 15–60 years old, farmers, and children. Characterized with a lagged, nonlinear, and cumulative effect, high temperature and rainfall could increase the risk of typhoid fever in regions with a subtropical climate. Qi Gao *et al* results greatly reflect the result of our research which shows variability in temperature as a major factor of typhoid infection.

We observed a distinct seasonal pattern for enteric fever in the area. Rainfall and temperature records varied greatly across the dry and rainy season. Average daily, monthly and annual Temperature was highest in the dry season. In the same manner, Bacterial load varied remarkably according to seasons and water type. Some water sources witnessed a rise in *salmonella typhi* load in the rainy season while others recorded a fall. This was equally true for the dry season as bacterial load witnesses a substantial increase. With respect to spring water for instance, the quantity of bacterial load increased rapidly from 766666CFU/ml in the rainy season to 1100000CFU/ml in the dry season. Therefore, bacterial load for salmonella rose by 333,334CFU/ml. This supposes that the risk of contamination through the consumption of spring water was higher in the dry season as compared to the rainy season. According to studies made by Neil. J *et al*., 2018, Typhoid and paratyphoid fever may follow a seasonal pattern, but this pattern is not well characterized. The result presented in this study and that of Qi Gao *et al*, 2021 clearly show a positive association between temperature variability and the prevalence of typhoid-something that was not concluded by *Neil. J, et al.,* 2018.

Studies conducted by Andreas Tornevi, 2014, published by the Nation Center for Biotechnology Information, Rainfall elevates microbial risks year-round in river Göta Älv and other freshwater source and acts as the main driver of varying water quality. Heavy rainfall appears to be a better predictor of fecal pollution than water turbidity. An increase of wet weather and extreme events with climate change will lower river water quality even more, indicating greater challenges for drinking water producers, and suggesting better control of sources of pollution. Our study let to the realization of the major cause factors of typhoid fever prevalence in the Ngoketunjia Division. The continuous prevalence of enteric fever incidence in the area is explained by the changing availability of microbiologically safe water. The consumption of contaminated water, consumption of contaminated food, person to person transmission through body contacts, and utilization of public toilettes, poor waste disposal and animal droppings in water sources especially streams, springs and rivers were the fundamental factors responsible for the persistent rise in typhoid cases in the Ngoketunjia Division. While increased rainfall could lead to greater contamination of rivers that are often used for bathing, higher rainfall could also reduce the occurrence of waterborne disease due to the fall in the consumption of contaminated water as discharge in water courses increase causing a fall in pressure on the resource. The association between enteric fever and temperature was more consistent across the area. There was a positive correlation between temperature and enteric fever. This could be explained by the improved growth of *S. Typhi* and *S. Paratyphi* in warmer conditions. Increased temperature results in exponential growth of the bacteria, particularly on food.

VII. CONCLUSION RECOMMENDATIONS

The relationship between environmental factors and the prevalence of infectious diseases has garnered significant attention in public health research (Xue *et al*, 2022). In particular, temperature variability is a critical determinant that can influence the survival and transmission of pathogens. This study focusses on “temperature variability and the prevalence of salmonella typhi infection in Ngoketunjia Division, Cameroon” from 1989-2021, examining how variability in temperature may correlate with the incidence of typhoid fever, a serious illness caused by *salmonella typhi*. Results have shown a systematic increase in the temperature trend of the area characterized by meaningful variability provoking a dramatic rise and fall in the incidence and prevalence of typhoid fever over the period under study (1980-2021). Understanding this relationship is essential for developing effective public health strategies and interventions as well preparing the health system toward proper regional policy action and climate adaptation strategies. This contribution can be achieved systematically and include the following;

- **Understanding the impacts of climate on human health**: This research provides bases for the understanding of the impacts of climate change on human health which may include;

i. **Establishing a link between temperature and diseases:** This investigation elucidate facts on the various ways in which temperature variability affects transmission dynamics of *salmonella typhi* promoting the understanding of climate related health risks.

ii. **Development of predictive models**: the results of this investigation can help in developing predictive models on the outbreak of climate related diseases base on temperature trends and raising proactive health measures.

- **Informed public health interventions:** In ensuring targeted surveillance, policy makers can explore the results of this investigation to implement targeted surveillance program in high-risk areas during specific temperature ranges. Data from this research can equally help in improving emergency preparedness as it initiate a proper understanding of the relationship between temperature and the prevalence of infectious diseases.
- **Allocation of health base resources:** finding from this research is important in determining the allocation of healthcare resources and infrastructural development to ensure that areas with the most infection receives adequate support (water supply, sanitation facilities, medications, vaccines etc)
- **Strategies of climate adaptation:** Facts from this study can be used to enhance long term planning as well as integration of environmental policies on health. Result from this investigation can help in developing climate adaptation strategies that takes into account impacts on health, reducing vulnerability and improving on resilience. This research encourages the integration of health, environment and climate policies bring about a holistic approach in regional policy planning.
- **Education and community engagement:** this research work can be used in educating communities and decision makers on the risk linked to changes in temperature trends and measures to fights associated diseases. By providing information to communities it can lead to changes in behaviour such as improvement in sanitation practices especially during warmer periods.

This investigation can significantly promote regional policy planning and adaptation by providing technical insights in to the relationship between climate variability and the prevalence of diseases. Owing to the rise in *S. typhi* infection intensified by temperature variability, we outlines certain proposals to improve on the understanding and management of relationship between temperature variability and typhoid infection ultimately widening the gap between the two variables and improving on public outcome in the Ngoketunjia Division.

I. Improvements on surveillance system: There is need to implement enhanced surveillance system to track *salmonella typhi* cases related to temperature variability. This will help in early detection and response to potential outbreak.

II. Conduct longitudinal studies: longitudinal studies to monitor temperature changes and correlation with typhoid fever incidence over time should be intensified. Such study will help to establish a clearer causal relationship.

III. Public Health Campaigns: There is need to develop and intensify more public health campaigns focused on hygiene and sanitation, especially during period of extreme temperature fluctuation in order to reduce the risk of infection.

IV. Climate adaptation strategies: formulate climate adaptation strategies that takes into account the impact of temperature variability on disease prevalence, ensuring healthcare systems and prepare for potential increase in typhoid cases.

V. Community engagement: involve local communities in education about the risk associated with temperature variability and typhoid fever, empowering them to take proactive measures in health practices.

VI. Collaborative research: encourage collaboration among researchers, local health authorities and climate scientists to investigate the broader implication of climate change on infectious diseases in the area.

By addressing these recommendations, stakeholders can better understand and mitigate the impacts of temperature variability on *S.typhi* infection in Ngoketunjia Division, ultimately improving public health outcomes.

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