Research Question:

What is the effect of the change in climatic conditions (temperature and humidity) on the change in the percentage of the population of ten African countries (Angola, Benin, Ghana, Democratic Republic of Congo, Mozambique, Kenya, Somalia, Malawi, United Republic of Tanzania and Niger) affected by malaria and cholera between the years 2011 and 2016?

Introduction:

In light of the recent global pandemic, I decided it would be worthwhile to explore diseases that have endangered human health greatly in the past. Malaria and cholera are both infectious diseases that gained prevalence in African countries over the years. Malaria developed into the primary source of sickness and death in countries that it infected. Younger children are the most vulnerable to this disease since their bodies have yet to establish an immunity to malaria, as well as pregnant women, due to decrease in their immunity. Governments are obligated to invest a great deal of money to contribute to health facilities; their drugs and general requirements; initiatives for the prevention of malaria, such as spraying of insecticides. People lose work days to sickness, causing a depletion of income. A rough estimation states that a child passes away because of malaria at a 2-minute interval.

Although cholera's prevalence has diminished by the introduction of sewage treatment, it is still one of the leading causes of diarrhoea and severe dehydration. Despite being less prevalent in Africa than malaria is, it can still cause death in extreme cases. In 1970, ever since the seventh cholera breakout arrived in Africa, cholera has become an endemic in multiple countries of Africa. It is still a cause of wide-reaching epidemics in West, Central, and East Africa.

Climatic conditions may seem to have an insignificant influence on the spread of these diseases as compared to drug resistance or vaccines, but research has shown that perhaps humans should be held far more responsible for the threat posed by these diseases. Increase in global warming over the years has given way to deadly infections, harming vulnerable people. This investigation will determine whether measures taken by authorities concerned were effective in lowering this threat between years 2011 and 2016. I decided to investigate a five-year gap since treatments and researches require time for implementation.

Background Information:

Pathogens are disease-causing organisms. There are many types of pathogens, two of which are bacteria and parasites. Bacteria are prokaryotic, unicellular organisms and can be killed by antibiotics. A parasite lives on or inside an organism acting as its host. The parasite obtains its nutrition from the host, usually by compromising the host's health. Diseases caused by parasites can be cured through antiparasitic medication. In this investigation, I am going to evaluate the prevalence of a parasitic infection (malaria) and a bacterial infection (cholera) in African countries.

Cholera[1] occurs when a person ingests or drinks food or water that is contaminated with *Vibrio cholerae*, a bacterial species. For this reason, cholera has been classified as a water-borne disease. Therefore, water vapour in the atmosphere can promote the spread of cholera. Cholera can result in watery diarrhoea and severe dehydration. It can take anywhere from 12 hours to 5 days to exhibit cholera symptoms following the consumption of the tainted food or water. The bacterium releases a toxin that enters the cell and triggers the release of chloride ions from the cells to the intestine. To remove the concentration gradient, water flows out of the cell into the intestine as well. To recover from the loss of water, cells draw water from the blood, leading to dehydration which can lead to death in extreme situations. Cholera avoidance measures include providing clean water and sanitation, along with vaccination through oral cholera vaccines.

Parasites[2] can be classified into the following categories: protozoa, helminths, and ectoparasites. Infection by protozoan *Plasmodium* parasites results in malaria. "Malaria vectors" cause the outspread of the parasites. Malaria vectors are the bites of female *Anopheles* mosquitoes that are infected. Two of the five parasitic species which can infect humans with malaria – *P. falciparum* and *P. vivax* – are the deadliest. On its body's surface, there is a protein that the parasite can change to avoid being detected. It uses this protein to invade an erythrocyte. The gene that codes for this particular protein can switch "on and off" at a convenient frequency as a result of changes in gene expression, which controls its manifestation on the parasite's surface. Once the parasite has entered an erythrocyte, it reproduces to form daughter parasites. Malaria transmission is usually promoted by increase in temperatures, since *Plasmodium* parasites tend to reproduce quicker inside the malaria vectors.[3]

Hypotheses

Hypothesis A- Pearson's Tests

Test 1

H_0 (null): The change in humidity will have no correlation with the change in the percentage of the population affected by cholera in African countries.

H_1 (alternative): The change in humidity will have a positive correlation with the change in the percentage of the population affected by cholera in African countries.[4]

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[1] "Cholera." *World Health Organization*, World Health Organization, www.who.int/health-topics/cholera.

[2] Feldscher, Karen. "Malaria Parasite Transforms Itself to Hide from Human Immune System." *News*, Harvard School of Public Health, 9 Jan. 2014, www.hsph.harvard.edu/news/features/duraisingh-malaria-parasite-transforms/.

[3] "Communicable Diseases Module: 6. Factors That Affect Malaria Transmission." *Communicable Diseases Module: 6. Factors That Affect Malaria Transmission: View as Single Page*, www.open.edu/openlearncreate/mod/oucontent/view.php?id=89&printable=1.

[4] Rajendran, K, et al. "Influence of Relative Humidity in Vibrio Cholerae Infection: a Time Series Model." *The Indian Journal of Medical Research*, Medknow Publications, Feb. 2011, www.ncbi.nlm.nih.gov/pmc/articles/PMC3089044/.

Test 2

H_0 (null): The change in temperature will have no correlation with the change in the percentage of the population affected by malaria in African countries.

H_1 (alternative): The change in temperature will have a positive correlation with the change in the percentage of the population affected by malaria in African countries.

Hypothesis B: t-tests

t-test 1

H_0 (null): There will not be a statistically significant difference between the percentage of population affected by cholera in African countries between 2011 and 2016.

H_1 (alternative): There will be a statistically significant difference between the percentage of population affected by cholera in African countries between 2011 and 2016.

t-test 2:

H_0 (null): There will not be a statistically significant difference between the percentage of population affected by malaria in African countries between 2011 and 2016.

H_1 (alternative): There will be a statistically significant difference between the percentage of population affected by malaria in African countries between 2011 and 2016.

Variables:

Independent Variable
The independent variables were change in temperature and change in humidity in each African country between the years 2011 and 2016. The temperature range of 21-36 degrees Celsius and the humidity range of 32-100% was chosen, keeping in mind the variability of temperatures and humidity across African countries, and each value within these ranges were chosen based on my individual research of the cities across each African country.

Dependent Variable
Change in the percentage of the population affected by malaria and cholera in each African country.

Controlled Variables
1. The continent from which countries were taken (Africa) was controlled, since malaria and cholera were more prevalent in that continent.
2. Only one bacterial (cholera) and one parasitic disease (malaria) were taken into consideration for the entire investigation.

3. Despite the option of using a calculator, I used Microsoft Excel for all my calculations, to reduce chances of human error. I used only one online calculator for both my t-tests.
4. Although Africa has 54 countries, I chose the ten countries which had temperatures and humidities within a narrower range as compared to other countries for the entire investigation.

Materials:

1. World Health Organization Report for cholera cases 2011 https://www.who.int/wer/2012/wer8731_32.pdf?ua=1
2. World Health Organization Report for cholera cases 2016 https://apps.who.int/iris/bitstream/handle/10665/258910/WER9236.pdf?sequence=1
3. Database of malaria cases by World Health Organization https://www.who.int/data/gho/data/indicators/indicator-details/GHO/malaria---number-of-reported-confirmed-cases
4. Database for populations of African countries data.worldbank.org/indicator/SP.POP.TOTL.
5. Database for temperature and humidity in African countries https://www.timeanddate.com/weather/
6. Microsoft Excel
7. t-test calculator https://www.socscistatistics.com/tests/studentttest/default2.aspx

Method:

1. I researched extensively to find verified health databases and contacted my school's librarian so that he could help me gather resources.
2. I found the number of reported malaria cases, cholera cases, total population, temperature and humidity in the years 2011 and 2016 of ten African countries; Angola, Benin, Ghana, Democratic Republic of Congo, Mozambique, Kenya, Somalia, Malawi, United Republic of Tanzania and Niger.
3. I calculated the percentage of each African country's population affected from malaria and cholera for the years 2011 and 2016, using Microsoft Excel.
4. I then found the correlation between the change in percentage of population affected by cholera in each African country, with the country's humidity. These calculations were also done using Microsoft Excel.
5. Similarly, I found the correlation between the change in percentage of population affected by malaria in each African country and change in temperature.
6. I then surfed the internet for reliable statistical calculators. After finding a suitable site, I performed the individual t-tests using an online calculator.

Raw Data:

Table 1: Population of each country in the years 2011 and 2016

	2011	2016
Angola	24,220,661	28,842,484
Benin	9,460,830	10,872,067
DR of Congo	66,755,153	78,789,127
Ghana	25,387,710	28,481,900
Kenya	43,178,257	49,051,686
Malawi	14,962,112	17,205,289
Mozambique	24,187,487	27,829,942
Niger	17,114,761	20,788,838
Somalia	12,376,302	14,185,613
Tanzania	45,673,338	53,050,790

Table 2: Number of reported malaria and cholera cases in each country in the years 2011 and 2016

	Malaria Cases		Cholera Cases	
	2011	2016	2011	2016
Angola	1632282	3794253	1810	78
Benin	422968	1324576	755	761
DR of Congo	4561981	15330841	21700	28093
Ghana	1,041,260	4,535,167	10628	175
Kenya	1002805	2783846	74	5866
Malawi	304499	4827373	120	1792
Mozambique	1756874	8520376	1279	883
Niger	780876	4148167	2324	38
Somalia	3351	35628	77636	15619
Tanzania	2150761	5193520	330	11360

Table 3: Temperature and humidity in each African country during 2011 and 2016

Year	2011		2016	
Climatic condition	Temperature (±2)/°Celsius	Humidity (±5)/ Percentage	Temperature (±2)/°Celsius	Humidity (±5)/ Percentage
Angola	23	74	25	69
Benin	27	89	29	74
DR of Congo	24	74	30	61
Ghana	27	79	29	70
Kenya	24	54	25	47
Malawi	24	34	25	34
Mozambique	21	100	29	29
Niger	36	34	35	39
Somalia	24	61	26	64
Tanzania	26	32	25	39

Data Processing:

Firstly, I calculated the percentage of the population of each African country affected by malaria and cholera using the following formula.

Sample Calculation:

$$\frac{number\ of\ reported\ cholera/malaria\ cases\ in\ a\ country\ in\ 2011/\ 2016}{total\ population\ of\ the\ country\ in\ 2011/\ 2016} \times 100$$

Percentage of cholera cases in Angola, 2011

$$\frac{1810}{24{,}220{,}661} \times 100 = 0.00747$$

Similar calculations were done for Tables 4 and 5.

Table 4: Percentage of population affected by cholera in each African country

	2011	2016
Angola	0.00747	0.00027
Benin	0.00798	0.00700
DR of Congo	0.03251	0.03566
Ghana	0.04186	0.00061
Kenya	0.00017	0.01196
Malawi	0.00080	0.01042
Mozambique	0.00529	0.00317
Niger	0.01358	0.00018
Somalia	0.62730	0.11011
Tanzania	0.00072	0.02141

Table 5: Percentage of population affected by malaria in each African country

	2011	2016
Angola	6.73921	13.15508
Benin	4.47073	12.18330
DR of Congo	6.83390	19.45807
Ghana	4.10143	15.92298
Kenya	2.32248	5.67533
Malawi	2.03513	28.05749
Mozambique	7.26357	30.61586
Niger	4.56259	19.95382
Somalia	0.02708	0.25116
Tanzania	4.70901	9.78971

Pearson's correlation tests

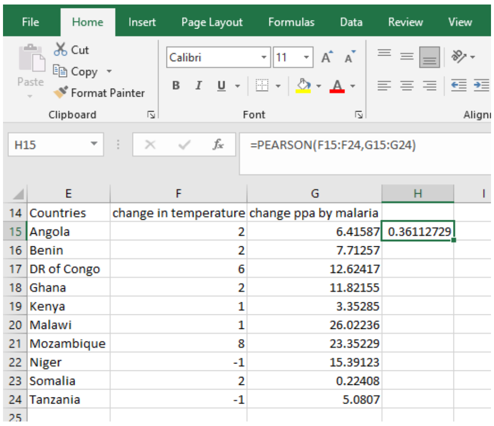
Change in climatic conditions were calculated using the following formula:
humidity/temperature of country in 2016 - humidity/temperature of country in 2011

Change in percentage of population affected by malaria and cholera was calculated using the following formula:
percentage population affected by malaria/cholera in 2016 in each country – percentage population affected by malaria/cholera in 2011 in each country

Figure 1: Pearson's correlation coefficient formula

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

Figure 2: Screenshot showing calculation of r value for Test 2 (malaria)


H15 =PEARSON(F15:F24,G15:G24)

	E	F	G	H
14	Countries	change in temperature	change ppa by malaria	
15	Angola	2	6.41587	0.36112729
16	Benin	2	7.71257	
17	DR of Congo	6	12.62417	
18	Ghana	2	11.82155	
19	Kenya	1	3.35285	
20	Malawi	1	26.02236	
21	Mozambique	8	23.35229	
22	Niger	-1	15.39123	
23	Somalia	2	0.22408	
24	Tanzania	-1	5.0807	

Table 6: Values used to calculate individual Pearson's tests

Note: PPA-Percentage of population affected

	Test 1: Cholera		Test 2: Malaria	
	Change in humidity from 2011 to 2016 (x)	Change in PPA by cholera from 2011 to 2016 (y)	Change in temperature from 2011 to 2016 (x)	Change in PPA by malaria from 2011 to 2016 (y)
Angola	-5.00000	-0.00720	2.00000	6.41587
Benin	-15.00000	-0.00098	2.00000	7.71257
DR of Congo	-13.00000	0.00315	6.00000	12.62417
Ghana	-9.00000	-0.04125	2.00000	11.82155
Kenya	-7.00000	0.01179	1.00000	3.35285
Malawi	0.00000	0.00962	1.00000	26.02236
Mozambique	-71.00000	-0.00212	8.00000	23.35229
Niger	5.00000	-0.01340	-1.00000	15.39123
Somalia	3.00000	-0.51719	2.00000	0.22408
Tanzania	7.00000	0.02069	-1.00000	5.08070
r- values	-0.20062		0.36113	

t-tests:

Figure 3: t-test formula

$$t = \frac{\overline{x}_1 - \overline{x}_2}{\sqrt{(s^2(\frac{1}{n_1} + \frac{1}{n_2}))}}$$

Figures 4(left) and 5(right): Screenshots showing the results of the t-tests to calculate the significance of the difference between percentage of population affected by cholera (left) and malaria (right) in each African country in 2011 (*Treatment 1*/Sample 1) and 2016 (*Treatment 2*/ Sample 2)

Significance Level:

- .01
- .05 (selected)
- .10

One-tailed or two-tailed hypothesis?:

- One-tailed
- Two-tailed (selected)

Difference Scores Calculations

Treatment 1

N_1: 10
$df_1 = N - 1 = 10 - 1 = 9$
M_1: 0.07
SS_1: 0.34
$s^2_1 = SS_1/(N - 1) = 0.34/(10-1) = 0.04$

Treatment 2

N_2: 10
$df_2 = N - 1 = 10 - 1 = 9$
M_2: 0.02
SS_2: 0.01
$s^2_2 = SS_2/(N - 1) = 0.01/(10-1) = 0$

T-value Calculation

$s^2_p = ((df_1/(df_1 + df_2)) * s^2_1) + ((df_2/(df_2 + df_2)) * s^2_2) = ((9/18) * 0.04) + ((9/18) * 0) = 0.02$

$s^2_{M_1} = s^2_p/N_1 = 0.02/10 = 0$
$s^2_{M_2} = s^2_p/N_2 = 0.02/10 = 0$

$t = (M_1 - M_2)/\sqrt{(s^2_{M_1} + s^2_{M_2})} = 0.05/\sqrt{0} = 0.86$

The t-value is 0.85806. The p-value is .40214. The result is *not* significant at $p < .05$.

Significance Level:

- .01
- .05 (selected)
- .10

One-tailed or two-tailed hypothesis?:

- One-tailed
- Two-tailed (selected)

Difference Scores Calculations

Treatment 1

N_1: 10
$df_1 = N - 1 = 10 - 1 = 9$
M_1: 4.31
SS_1: 48.76
$s^2_1 = SS_1/(N - 1) = 48.76/(10-1) = 5.42$

Treatment 2

N_2: 10
$df_2 = N - 1 = 10 - 1 = 9$
M_2: 15.51
SS_2: 800.02
$s^2_2 = SS_2/(N - 1) = 800.02/(10-1) = 88.89$

T-value Calculation

$s^2_p = ((df_1/(df_1 + df_2)) * s^2_1) + ((df_2/(df_2 + df_2)) * s^2_2) = ((9/18) * 5.42) + ((9/18) * 88.89) = 47.15$

$s^2_{M_1} = s^2_p/N_1 = 47.15/10 = 4.72$
$s^2_{M_2} = s^2_p/N_2 = 47.15/10 = 4.72$

$t = (M_1 - M_2)/\sqrt{(s^2_{M_1} + s^2_{M_2})} = -11.2/\sqrt{9.43} = -3.65$

The t-value is -3.64699. The p-value is .001844. The result is significant at $p < .05$.

Table 7: t-test statistics (3 s.f.)

Variable Pairs	Mean		Variance		N (Sample Size)		Degrees of Freedom	Critical t-value
Years	2011	2016	2011	2016	2011	2016		
PPA by cholera 2011 and 2016	0.07	0.02	0.04	0.00	10.0	10.0	9.00	2.26
PPA by malaria 2011 and 2016	4.31	15.5	5.42	88.9	10.0	10.0	9.00	2.26

Table 8: t-test results

t-test	t-value	Which hypothesis was supported?	p-value	Significance level
t-test 1 (cholera)	0.85806	Null hypothesis	0.40214	$p<0.05$
t-test 2 (malaria)	-3.64700	Alternative hypothesis	0.00184	$p<0.05$

Figure 6: Graph showing correlation between change in percentage population affected by cholera from 2011 to 2016 and change in humidity from 2011 to 2016

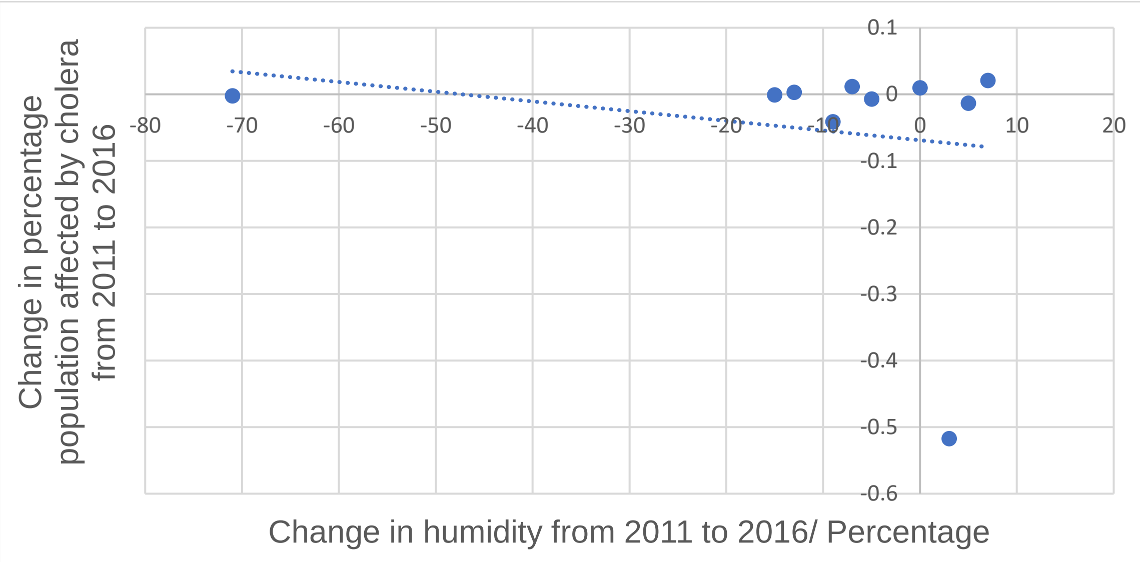
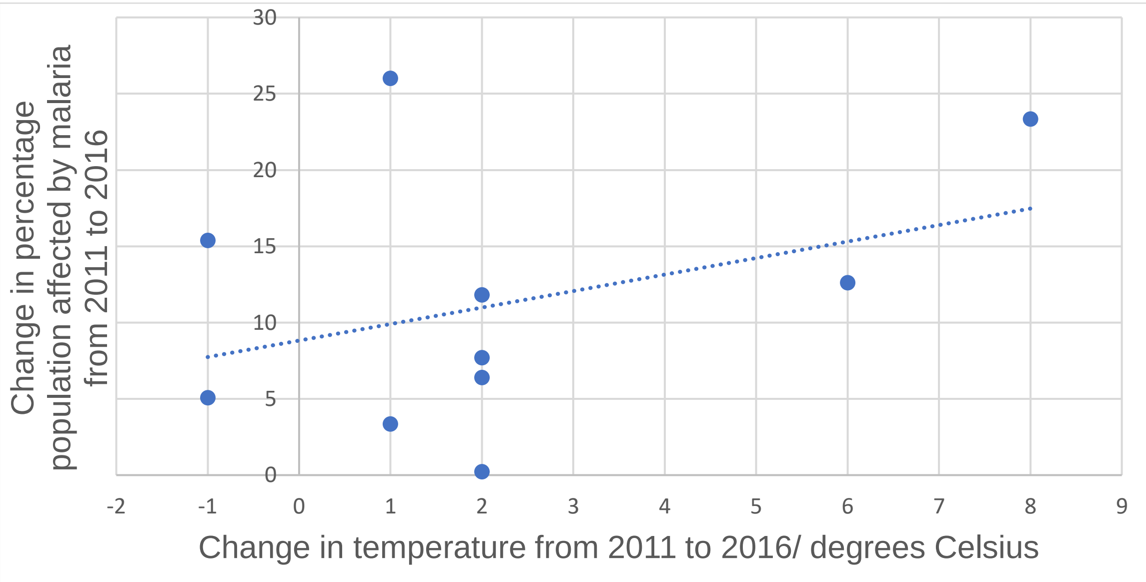


Figure 7: Graph showing correlation between change in percentage population affected by malaria from 2011 to 2016 and change in temperature from 2011 to 2016



Statistical Analysis:

Under Hypothesis A, the null hypothesis was supported for Test 1 and the alternative hypothesis was supported for Test 2, i.e., the change in percentage of population affected by cholera did not correlate with the change in humidity between the years 2011 and 2016, given the *r* value -0.20062. The change in percentage of population affected by malaria showed a positive correlation with change in temperature between the years 2011 and 2016, given the *r* value 0.36113. From Figure 6, two outliers are visible on the graph. The outlier (-71.00000,-0.00212) belonged to Mozambique, and the outlier (3.00000, -0.51719) belonged to Somalia.

Under Hypothesis B, the investigation proved that the difference between the percentage of the malaria affected population in 2011 and 2016 was significant (t-value: -3.64700). However, the difference between the percentage of the cholera affected population during 2011 and 2016 was not significant (t-value: 0.85806). Thus, the alternative hypothesis for malaria was supported, and the null hypothesis was supported for cholera. I used a two-tailed t-test because I wanted to test for both negative and positive differences between percentage of population affected by malaria and cholera during 2011 and 2016. In t-test 1 (Figure 4), it can be observed that the variance (R-squared value) was 0.04 for percentage of cholera affected population, and 0 for 2016. In t-test 2 (Figure 5), the variance for percentage of malaria affected population in 2011 was 5.42 and 88.9 for 2016. Variance refers to the degree of variability from the average/mean. There is a significant difference between the variance of percentage of population affected by malaria and cholera in both 2011 and 2016. This indicates that the resources for the prevention of cholera were evenly spread across Africa, while the resources for malaria were not. The variance became 0 for percentage of population affected by cholera in 2016, meaning that cholera was handled with the best resources in Africa. The variance increased drastically for percentage of population affected by malaria in Africa from 2011 to 2016, implying that the measures taken for prevention of malaria were deteriorating.

Conclusion:

Under both Hypothesis A and B, the null hypothesis was supported for cholera (Test 1) and the alternative hypothesis was supported for malaria (Test 2). Hence, the study has answered the research question by suggesting that changes in temperature have a significant effect on the spread of malaria and changes in humidity have negligible effect on the spread of cholera over the years 2011 and 2016. Some explanations are discussed below.

Malaria

The findings of this study are supported by the study of Lindsay et al[5], which states that mosquitoes were more likely to thrive at temperatures of 22 and 26 degrees Celsius. Multiple temperature values I obtained for the African countries are within ±5 of 22 and 26, with some exceptions of course.

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[5] Beck-Johnson, Lindsay M, et al. "The Importance of Temperature Fluctuations in Understanding Mosquito Population Dynamics and Malaria Risk." *Royal Society Open Science*, The Royal Society Publishing, 8 Mar. 2017, www.ncbi.nlm.nih.gov/pmc/articles/PMC5383843/.

A reason for the increase in malaria cases could be that resistance is shown by parasites to drugs. Drugs have been known to be an effective treatment for malaria. A biological explanation for this resistance is that natural selection has occurred. Mosquitoes and parasites have mutated genes that resist the effects of drugs. These parasites survive while those that are not mutated die. The surviving population passes on these alleles to their offspring. This is supported by a study[6] from 2015 which finds that some of the primary challenges that remain towards the eradication of malaria are the lack of knowledge about the *Plasmodium vivax*, a lack of funding towards malaria eradication campaigns, and the rapid development and spread of resistance to drugs.

Cholera
A reason that the study found that humidity had an insignificant influence on cholera spread could be because other environmental factors have been known to affect cholera outbreaks as well. Some of these factors include heavy rainfall and decrease in the levels of water.[7] It is possible that all these factors have a collective impact on cholera, and it would be difficult to find a substantial correlation with merely one. Plausible explanations for lack of spread of cholera could be that the individuals in these countries had started receiving better healthcare services, were completing their antibiotic courses and were maintaining hygiene. Moreover, the first FDA-approved cholera vaccine, Vaxchora, was released during the summer of 2016. [8]

Evaluation:

The strengths of this study are the strength of the reliability of the data used, since the sources of the data are known organizations such as NCBI and the World Data Bank with high accuracy. Additionally, all of the investigated countries were chosen from the same continent, Africa. Therefore, had they similar resources and healthcare systems to handle outbreaks of diseases. The data was obtained from legal and secure websites and databases with no history of cybercrime, reducing ethical or safety issues. Since the study was a database research, there were also no environmental issues.

Despite the strengths, the study also had limitations.

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[6] Tanner, Marcel, et al. “Malaria Eradication and Elimination: Views on How to Translate a Vision into Reality.” *BMC Medicine*, BioMed Central, 25 July 2015, www.ncbi.nlm.nih.gov/pmc/articles/PMC4514994/

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[8] “FDA Approves Vaccine to Prevent Cholera for Travelers.” *FDA NEWS RELEASE*, U.S. FOOD AND DRUG ADMINISTRATION, 10 June 2016, www.fda.gov/news-events/press-announcements/fda-approves-vaccine-prevent-cholera-travelers/.

Table 9: Limitations and Modifications

Limitations	Why is it important?	How can I improve?
The study only investigates African countries.	The results of the study cannot be generalized to other parts of the world as the spread of cholera and malaria may be more or less prevalent in different continents.	Evaluate prevalence of these diseases in countries from different continents, such as Asia.
The study only investigates years 2011 and 2016 as these were the latest years that all databases had in common.	The results of the study cannot be generalized to more recent years. Climatic conditions may have changed in order to support transmission of malaria and cholera in the past five years.	Try to collect data from the past five years using different databases.
Data was only collected from 10 countries, which may be considered a relatively small sample size.	Statistically speaking, a small sample size increases the margin of error which may decrease the validity of the conclusion drawn and the overall study.	Try to collect data from at least 30 countries to improve reliability and validity of study.
Only climatic conditions were taken into consideration.	There are multiple biological and environmental factors that can promote the spread of a disease, as well as prevent it. These factors differ from country to country, and climatic conditions are just one of them.	Research and consider at least four factors that can affect the spread of cholera, for example type-O blood, and malaria, for example the sickle cell trait.

Suggestions for further research

Some areas of research that can be further explored may include the collective effect of multiple biological and environmental factors that influence the spread of malaria and cholera. Over twenty countries per continent can be taken into consideration, and different resources to overcome such diseases can be compared. The difference between the effect of biological factors and environmental factors on the spread of both diseases can also be contrasted and analysed.

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6. Jutla, Antarpreet, et al. “Environmental Factors Influencing Epidemic Cholera.” *The American Journal of Tropical Medicine and Hygiene*, The American Society of Tropical Medicine and Hygiene, Sept. 2013, www.ncbi.nlm.nih.gov/pmc/articles/PMC3771306/.

7. Rajendran, K, et al. “Influence of Relative Humidity in Vibrio Cholerae Infection: a Time Series Model.” *The Indian Journal of Medical Research*, Medknow Publications, Feb. 2011, www.ncbi.nlm.nih.gov/pmc/articles/PMC3089044/.

8. Tanner, Marcel, et al. “Malaria Eradication and Elimination: Views on How to Translate a Vision into Reality.” *BMC Medicine*, BioMed Central, 25 July 2015, www.ncbi.nlm.nih.gov/pmc/articles/PMC4514994/