ANALYZING THE INCIDENCE OF REPORTED CASES OF MALARIA IN SOUTH-EAST OF NIGERIA VIA FACTORIAL DESIGN

BY

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Abstract

The study examined the incidence of reported cases of malaria in South East geopolitical zone of Nigeria using factorial design. A 3^2 factorial design with mixed factors was employed for the data on the number of various malaria reported cases. The two factors involved served as the exponent, whereas the three levels of each factor served as the base 3; hence the 3^2 factorial design. The data for the study were collected from the three randomly selected states in the South East geopolitical zone of Nigeria based on the yearly reported cases of malaria from 2014 to 2021 in four purposively private owned hospitals in each of the state. In addition, the levels of factor R (state) were randomly chosen while those of factor C (status of malaria patient) were fixed, hence the mixed effect aspect of the design. The error term of the model was subjected to normality test via the Kolmogorov smirnov, and it was concluded that the normality assumption was fulfilled. The findings of the study showed that the average yearly malaria treated, death and active cases per state in South-East of Nigeria were about 162, 24 and 167 respectively for the period between the year 2014 and 2021. Furthermore, the average yearly number of confirmed malaria cases was 117 per state in South-East for the year under study. The study concluded that the mixed effect model is not appropriate for the prediction of the various reported cases of malaria since the error term is not normally distributed.

Keywords: Factorial Design, Malaria Cases, Mixed Effect Model, Random Factor, Residual, Fixed Factor

Introduction

Malaria is a mosquito borne disease caused by a parasite called plasmodium (Kelechi & Omuemu, 2022). This plasmodium has four species which include plasmodium falciparum, plasmodium vivax, and plasmodium ovale and plasmodium malariae (Abdalla, Abdalla & Eltayeb, 2017). Malaria parasite is transmitted from one person to another through the bite of a female Anopheles Mosquito which require blood to nurture her eggs (Gontie et al., 2020). When Malaria parasites enter the blood stream of a person, they infect and destroy the red blood cells. The destruction of these essential cells leads to fever and flu-like symptoms such as chills,

headache, muscle aches, tiredness, nausea, vomiting and diarrhea. Malaria, when not treated, can lead to coma and death (Adebayo et al., 2015).

Globally, Malaria is increasingly becoming a disease of serious concern to everybody (WHO, 2022). This is because day by day, the impact of Malaria in human existence, the world over, becomes more ravaging and damaging as a result of high morbidity and mortality experienced in different parts of the globe especially the developing countries of which Nigeria is one (Odikamnoro et al., 2014). Malaria parasite has been with man since the dawn of time. Hippocrates, a physician born in ancient Greece, today regarded as the "father of medicine" was the first to describe the manifestation of the disease.

The association with stagnant water (breeding grounds for the Anopheles Mosquito) led the Romans to begin drainage program, the first intervention against Malaria. The first recorded treatment of Malaria dated back to 1600, when the bitter bark of cinchona tree in Peru was used by the native Indians (Gontie et al., 2020). Not until 1889 was the protozoa (single celled parasite) cause of Malaria discovered by Alphonse Laveran and only in 1987 was the Anopheles Mosquito demonstrated to be the vector for the disease by Ronald Ross. The discovery of Ronald Ross was followed by a series of important works which not only enlarged the understanding of Malaria but also supplied useful knowledge in the combat against Malaria and prevention of Malaria (Chaponda et al., 2015). Despite initial success, there was a complete failure to eradicate Malaria in many countries (Fana et al., 2015).

According to World Health Organization (WHO), Center for Disease Control and Prevention (CDCP), Roll Back Malaria Partnership (RBM), (2010), 3.3 billion people-half the world's population- are at risk of Malaria; one million people die each year from Malaria; every 30 seconds a child dies from Malaria. Also, in Africa, 91% of all Malaria death cases occur in Sub- Sahara Africa; 1 in 5 childhood deaths are caused by Malaria; 10, 000 pregnant women and 200, 000 infants die from Malaria every year.

In 2015, malaria was the third most common cause of death among women of reproductive age in Africa (Fana et al., 2015) and in 2020, children under 5 years accounted for about 80% of all the malaria deaths in the African region (WHO, 2022).Malaria contributes to an estimated 11% of maternal mortality in Nigeria (Nega et al., 2015). In Nigeria, malaria affects about 70% of pregnant women mu, 2022) and it is responsible for 30% of childhood mortality, 25% of deaths in children under the age of one year, and 11% of maternal deaths. In

2021, Health Aid For All Initiative (HAFAI) reported the results from maternal and child health survey carried out by United Nations Children's Fund (UNICEF) in Nigeria, that Nigeria lost about 2,300 under five year-olds and 145 women of childbearing age in a day, making it the second largest contributor to the under-five and maternal mortality rates in the world (Kelechi & Omuemu, 2022). Also, in 2020, the four countries in Africa that accounted for over half of all malaria deaths worldwide were: Nigeria (31.9%), the Democratic Republic of the Congo (13.2%), United Republic of Tanzania (4.1%) and Mozambique (3.8%) (WHO, 2022). In terms of the actual number of maternal deaths, Nigeria was ranked second in the world behind India and in terms of the maternal mortality ratio. Nigeria is ranked eighth in Sub-Saharan Africa behind; Angola, Chad, Liberia, Niger, Rwanda, Sierra Leone and Somalia (Odikamnoro et al., 2014)

Malaria accounts for an estimated 2 to 3 million deaths annually and is also responsible for untold morbidity in approximately 300 to 500 million people annually. Susceptible groups are children and adults who have host or never acquired immunity (Smith et al, 2002). Malaria is said to kill about one African (whether child or adult) every 15 secs and roughly 300, 000 Nigerian children annually (Salako, 2002).

Malaria is currently one of the world's most serious public health problems. It is a parasitic infection that is transmitted to humans through the bite of an infected female Anopheles mosquito (WHO, 2022). Malaria affects nearly half of the world's population ((Tilla, Sorsa & Asnake, 2019). Globally, 241 million cases of malaria was reported in 2020, with 627,000 people dying and majority of them were children in Africa (WHO, 2022). The African Region carries a disproportionately high share of the global malaria burden (Kelechi & Omuemu, 2022). In 2015, the Sub- Saharan Africa accounted for 90% of malaria cases and 92% of malaria deaths (Kelechi & Omuemu, 2022). Sub-Saharan Africa is responsible for a disproportionately high percentage of the global malaria burden (CDC, 2020). Approximately 35 million pregnant women in Sub-Saharan Africa are at risk of contracting malaria each year (Gontie et al., 2020) and at least 25% of pregnant women are predicted to have the disease each year (Abdalla, Abdalla & Eltayeb, 2017). In Nigeria, malaria affects 100% of the population, with at least half of the population contracting the disease once a year (CDC, 2020). Nigeria accounts for a quarter of all malaria cases in the 45 malaria-endemic countries in Africa (Adebayo et al., 2015). Twenty-five million pregnant

women are at risk of malaria in Nigeria and according to the World Health Organization in 2015, the region experienced up to 90% malaria cases and 92% malaria deaths (Chaponda et al., 2015). Globally, malaria is estimated to cause at least 10,000 maternal deaths and 200,000 newborn deaths per year (Bawa, Auta, & Liadi, 2014). Therefore, it imposes a great burden on the country in terms of pains and trauma suffered by its victims as well as loss in output and cost of treatments.

Hence, the study examined the incidence of reported cases of malaria in South East geopolitical zone of Nigeria using factorial design.

Materials and Methods

Two-Factor Factorial Design Concept

Table 1 shows generally the two-factor factorial design. Let x_{ijk} be the observed response when factor R is at the ith level $(i = 1,2,\cdots,r)$ and factor C is at the jth level $(j = 1,2,\cdots,c)$ for the kth replicate $(k = 1,2,\cdots,n)$. For instance, x_{235} implies the $5th$ replicate (observation) taken at the second level of factor R, and the third level of factor C. The order of the recordings is in correspondence with the order at which the n observations per cell are arranged. Again, the total of all the observations under the ith level of factor R is represented by $x_{i..}$; the total of all the observations under the jth level of factor C is represented by $x_{.j.}$; the total of all the observations in the $ijth$ cell is represented by $x_{i.j.}$; whereas, the grand total of all the observations in the whole data set is represented by $x_{...}$.

In addition, $\bar{x}_{i..}, \bar{x}_{.j.}, \bar{x}_{ij.}$ *and* $\bar{x}_{...}$ are the corresponding row, column, cell and grand means. The terms are defined mathematically as;

$$x_{i..} = \sum_{j=1}^{c}\sum_{k=1}^{n} x_{ijk} \Rightarrow \bar{x}_{i..} = \frac{x_{i..}}{cn}, (i = 1,2,\cdots,r)$$

$$x_{.j.} = \sum_{i=1}^{r}\sum_{k=1}^{n} x_{ijk} \Rightarrow \bar{x}_{.j.} = \frac{x_{.j.}}{rn}, (j = 1,2,\cdots,c)$$

$$x_{ij.} = \sum_{k=1}^{n} x_{ijk} \Rightarrow \bar{x}_{ij.} = \frac{x_{ij.}}{n}, (i = 1,2,\cdots,r;\ j = 1,2,\cdots,c)$$

$$x_{...} = \sum_{i=1}^{r}\sum_{j=1}^{c}\sum_{k=1}^{n} x_{ijk} \Rightarrow \bar{x}_{...} = \frac{x_{...}}{rcn}$$

Table 1: General Layout for the Two-Factorial Design

Factor R	Factor C				Row	Row
	1	2	. . .	c	Totals	Means
1	$x_{111}, x_{112}, x_{113}, \cdots, x_{11n}$ $x_{11.}\ \bar{x}_{11.}$	$x_{121}, x_{122}, x_{123}, \cdots, x_{12n}$ $x_{12.}\ \bar{x}_{12.}$	. . .	$x_{1c1}, x_{1c2}, x_{1c3}, \cdots, x_{1cn}$ $x_{1c.}\ \bar{x}_{1c.}$	$x_{1..}$	$\bar{x}_{1..}$
2	$x_{211}, x_{212}, x_{213}, \cdots, x_{21n}$ $x_{21.}\ \bar{x}_{21.}$	$x_{221}, x_{222}, x_{223}, \cdots, x_{22n}$ $x_{22.}\ \bar{x}_{22.}$	. . .	$x_{2c1}, x_{2c2}, x_{2c3}, \cdots, x_{2cn}$ $x_{2c.}\ \bar{x}_{2c.}$	$x_{2..}$	$\bar{x}_{2..}$
. . .	. . .	. . .	. . .	. . .	. . .	. . .
r	$x_{r11}, x_{r12}, x_{r13}, \cdots, x_{r1n}$ $x_{r1.}\ \bar{x}_{r1.}$	$x_{r21}, x_{r22}, x_{r23}, \cdots, x_{r2n}$ $x_{r2.}\ \bar{x}_{r2.}$	. . .	$x_{rc1}, x_{rc2}, x_{rc3}, \cdots, x_{rcn}$ $x_{rc.}\ \bar{x}_{rc.}$	$x_{r..}$	$\bar{x}_{r..}$
Column Totals	$x_{.1.}$	$x_{.2.}$	. . .	$x_{.c.}$		
Column Means	$\bar{x}_{.1.}$	$\bar{x}_{.2.}$	. . .	$\bar{x}_{.c.}$	$x_{...}$	$\bar{x}_{...}$

Estimation of Parameters from Model Formulation

Considering the situation where one of the factors (R) is random and the other (C) is fixed, a mixed effects model arises and it is given by:

$$x_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk} \tag{1}$$

Where μ is the overall mean effect, α_i is the effect of the ith level of factor R, β_j is the effect of the jth level of factor C, $(\alpha\beta)_{ij}$ is the effect of the interaction between α_i and β_j, and ε_{ijk} is the random error component.

It can be shown that the normal equations employing the least squares technique are:

$$\mu : rcn\hat{\mu} + cn\sum_{i=1}^{r}\hat{\alpha}_i + rn\sum_{j=1}^{c}\hat{\beta}_j + n\sum_{i=1}^{r}\sum_{j=1}^{c}\widehat{(\alpha\beta)}_{ij} = x_{...} \tag{2}$$

$$\alpha_i : cn\hat{\mu} + cn\hat{\alpha}_i + n\sum_{j=1}^{c}\hat{\beta}_j + n\sum_{j=1}^{c}\widehat{(\alpha\beta)}_{ij} = x_{i..} \tag{3}$$

$$\beta_j : rn\hat{\mu} + n\sum_{i=1}^{r}\hat{\alpha}_i + rn\hat{\beta}_j + n\sum_{i=1}^{r}\widehat{(\alpha\beta)}_{ij} = x_{.j.} \tag{4}$$

$$(\alpha\beta)_{ij} : n\hat{\mu} + n\hat{\alpha}_i + n\hat{\beta}_j + n\widehat{(\alpha\beta)}_{ij} = x_{ij.} \quad (5)$$

To obtain a unique solution, the following restrictions are imposed:

$$\sum_{i=1}^{r} \hat{\alpha}_i = \sum_{j=1}^{c} \hat{\beta}_j = \sum_{i=1}^{r} \widehat{(\alpha\beta)}_{ij} = \sum_{j=1}^{c} \widehat{(\alpha\beta)}_{ij} = 0$$

Results in Equations (6) to (9) are obtained when Equations (2) to (5) are simplified considerably.

$$\hat{\mu} = \bar{x}_{...} \quad (6)$$

$$\hat{\alpha}_i = \bar{x}_{i..} - \bar{x}_{...} \quad (7)$$

$$\hat{\beta}_j = \bar{x}_{.j.} - \bar{x}_{...} \quad (8)$$

$$\widehat{(\alpha\beta)}_{ij} = \bar{x}_{ij.} - \bar{x}_{i..} - \bar{x}_{.j.} - \bar{x}_{...} \quad (9)$$

Checking Model Adequacy

Before taking a conclusion on the accuracy of a model, it is imperative to check the adequacy of the underlying model. The residual analysis check is the primary diagnostic tool for model adequacy. Thus, the residual of each observation for two-factor factorial model is:

$$\varepsilon_{ijk} = x_{ijk} - \hat{x}_{ijk}$$

But $\hat{x}_{ijk} = \bar{x}_{ij.} \Rightarrow \varepsilon_{ijk} = x_{ijk} - \bar{x}_{ij.}$

The residual analysis consists of two main categories, which are the numerical residual analysis, and the graphical residual analysis. in the numerical residual analysis, the standardized residual (d_{ijk}) is computed via the equation

$$d_{ijk} = \frac{\varepsilon_{ijk}}{\sqrt{MS_E}} \quad (10)$$

Where ε_{ijk} is the largest residual among the other residuals and MS_E is the mean sum of the squares of the error component, which is also given by

$$MS_E = \frac{SS_E}{rc(n-1)} \quad (11)$$

Where SS_E is the sum of the squares of the error component, r is the number of levels under factor R, r is the number of levels under factor C and n is the number of replicates (observation) per cell. If the value of d_{ijk} falls within $\pm 3 (i.e -3 \leq d_{ijk} \leq 3)$, then the normality assumption of the residuals (errors) is assured, hence the residuals would not reveal anything troublesome. Hence, the model is adequate.

Results

The detail of the raw data on the malaria cases, comprising the number of treated cases, death cases and active cases for Anambra, Abia and Enugu states for the period of 2014 to 2021 are presented in Table 2. These data were collected from four randomly selected private owned hospitals from each of the selected state in South East Geo-political zone of Nigeria.

Table 2: Data on Annual Malaria Recovery, Death and Active Cases in Selected States in Nigeria

		Status of Malaria Patient		
State	Year	Treated Cases	Death Cases	Active Cases
Anambra	2014	123	14	132
	2015	105	9	115
	2016	132	23	143
	2017	121	11	121
	2018	143	22	165
	2019	164	32	174
	2020	186	43	202
	2021	165	24	197
Abia	2014	123	15	143
	2015	105	12	115
	2016	123	10	114
	2017	107	9	165
	2018	119	19	133
	2019	145	26	158
	2020	113	35	198
	2021	154	21	167
Enugu	2014	146	21	154
	2015	165	19	115
	2016	156	32	156
	2017	176	17	179
	2018	187	34	158
	2019	263	42	278
	2020	368	54	279
	2021	289	29	239

Table 3 shows the raw data collected for a two-factor factorial design with mixed factors. The states with level headings Anambra, Abia and Enugu represent the row factor, the status of the malaria patient with level headings Treated cases, Death cases and Active cases represent the column factor. However, each cell contains 8 observations (replications) arranged in correspondence with the order of the years in which they are recorded for the period from 2014 to 2021 with k = 1, 2, 3, …, 8 term of x_{ijk} assigned to the years correspondingly.

Table 3: Two-Factor Factorial Design with Mixed Factors for the Data on Malaria Cases in Anambra, Abia and Enugu

State	Status of Malaria Patient			Row Totals $(x_{i..})$	Row Means $(\bar{x}_{i..})$
	Treated Cases	Death Cases	Active Cases		
Anambra	123 143 105 164 132 186 121 165 $x_{11.} = 1139\ \bar{x}_{11.} = 142.375$	14 22 9 32 23 43 11 24 $x_{12.} = 178\ \bar{x}_{12.} = 22.25$	132 165 115 174 143 202 121 197 $x_{13.} = 1249\ \bar{x}_{13.} = 156.125$	2566	106.917
Abia	123 119 105 145 123 113 107 154 $x_{21.} = 989\ \bar{x}_{21.} = 123.625$	15 19 12 26 10 35 9 21 $x_{22.} = 147\ \bar{x}_{22.} = 18.375$	143 133 115 158 114 198 165 167 $x_{23.} = 1193\ \bar{x}_{23.} = 149.125$	2329	97.042
Enugu	146 187 165 263 156 368 176 289 $x_{31.} = 1750\ \bar{x}_{31.} = 218.75$	21 34 19 42 32 54 17 29 $x_{32.} = 248\ \bar{x}_{32.} = 31$	154 158 115 278 156 279 179 239 $x_{33.} = 1558\ \bar{x}_{33.} = 194.75$	3556	148.167
Column Totals $(x_{.j.})$	3878	573	4000	$x_{...} = 8451$	
Column Means $(\bar{x}_{.j.})$	161.583	23.875	166.667		$\bar{x}_{...} = 117.375$

The sum of squares is computed as follows:

$$SS_T = \sum_{i=1}^{r}\sum_{j=1}^{c}\sum_{k=1}^{n} x_{ijk}^2 - \frac{x_{...}^2}{rcn} = (123^2 + 105^2 + 132^2 + \cdots + 279^2 + 239^2) - \frac{(8451)^2}{3(3)(8)}$$

$$= 1{,}452{,}651 - 991{,}936.125 = 460{,}714.875$$

$$SS_R = \frac{1}{cn}\sum_{i=1}^{r} x_{i..}^2 - \frac{x_{...}^2}{rcn} = \frac{1}{3(8)}\left[2566^2 + 2329^2 + 3556^2\right] - \frac{(8451)^2}{3(3)(8)}$$

$$= 1{,}027{,}238.875 - 991{,}936.125 = 35{,}302.75$$

$$SS_C = \frac{1}{rn}\sum_{j=1}^{c} x_{.j.}^2 - \frac{x_{...}^2}{rcn} = \frac{1}{3(8)}\left[3878^2 + 573^2 + 4000^2\right] - \frac{(8451)^2}{3(3)(8)}$$

$$= 1{,}306{,}967.208 - 991{,}936.125 = 315{,}031.083$$

$$SS_{Subtotals} = \frac{1}{n}\sum_{i=1}^{r}\sum_{j=1}^{c} x_{ij.}^2 - \frac{x_{...}^2}{rcn} = \frac{1}{8}\left[1139^2 + 178^2 + 1249^2 + \cdots + 248^2 + 1558^2\right] - \frac{(8451)^2}{3(3)(8)}$$

$$= 1{,}357{,}919.125 - 991{,}936.125 = 365{,}983$$

$$SS_{RC} = SS_{Subtotals} - SS_R - SS_C = 365{,}983 - 35{,}302.75 - 315{,}031.083 = 15{,}649.167$$

$$SS_E = SS_T - SS_{RC} - SS_R - SS_C = SS_T - SS_{Subtotals} = 460{,}714.875 - 365{,}983 = 94{,}731.875$$

The mean sum of squares is computed as follows:

$$MS_R = \frac{SS_R}{r-1} = \frac{35{,}302.75}{2} = 17{,}651.375$$

$$MS_C = \frac{SS_C}{c-1} = \frac{315{,}031.083}{2} = 157{,}515.542$$

$$MS_{RC} = \frac{SS_{RC}}{(r-1)(c-1)} = \frac{15{,}649.167}{2(2)} = 3{,}912.292$$

$$MS_E = \frac{SS_E}{rc(n-1)} = \frac{94{,}731.875}{3(3)(7)} = 1{,}503.681$$

The variability of the effects about the random factor R (State), interaction between state and malaria status, and error, that is, the variance components of the model after eliminating the mean squares containing the fixed factors are estimated respectively as:

$$\hat{\sigma}_R^2 = \frac{MS_R - MS_E}{rn} = \frac{17{,}651.375 - 1{,}503.681}{3(8)} = 672.821$$

$$\hat{\sigma}^2_{RC} = \frac{MS_{RC} - MS_E}{n} = \frac{3{,}912.292 - 1{,}503.681}{8} = 301.076$$

$$\hat{\sigma}^2_E = MS_E = 1{,}503.681$$

The Prediction Model

There are three levels of factor R (State), which were randomly chosen from the five states in the South-East geo-political zone of Nigeria, and the three levels of factor C (the status of malaria patient) were fixed; hence, two-factor factorial design with mixed factors was employed. Thus, the mixed effect model becomes:

$$x_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk}$$

Through the model formulation processes and under some constraints, the number of malaria patients under a particular status per state may be estimated by the corresponding cell mean. Thus, this is given mathematically by:

$$\hat{x}_{ijk} = \hat{x}_{ij.}$$

The number of malaria patients under a particular status in South-East geo-political zone may be estimated by the column mean. This is:

$$\hat{x}_{ijk} = \hat{x}_{.j.}$$

Hence, the number of the treated, mortality and active malaria cases per year in South-East could be estimated as 161.583, 23.875 and 166.667 respectively; which to the nearest integer are 162, 24 and 167 respectively. In addition, the population mean of the number of confirmed malaria cases per year in South-East is estimated by the sample grand mean, which is 177.

Model Adequacy Checking Result

Having derived the model for the malaria incidence, it becomes necessary to examine the adequacy of the model. This was achieved by obtaining the residuals from the prediction model via the equation:

$$\varepsilon_{ijk} = x_{ijk} - \hat{x}_{ij.} = x_{ijk} - \bar{x}_{ij.}$$

The details of the results are showed in Table 4.

Table 4: Residuals from the Prediction Model

S/N	Actual value (x_{ijk})	Predicted value ($\bar{x}_{ij.}$)	Residual (ε_{ijk})
1	123	142.375	-19.375
2	105	142.375	-37.375
3	132	142.375	-10.375
4	121	142.375	-21.375
5	143	142.375	0.625
6	164	142.375	21.625
7	186	142.375	43.625
8	165	142.375	22.625
9	123	123.625	-0.625
10	105	123.625	-18.625
11	123	123.625	-0.625
12	107	123.625	-16.625
13	119	123.625	-4.625
14	145	123.625	21.375
15	113	123.625	-10.625
16	154	123.625	30.375
17	146	218.75	-72.75
18	165	218.75	-53.75
19	156	218.75	-62.75
20	176	218.75	-42.75
21	187	218.75	-31.75
22	263	218.75	44.25
23	368	218.75	149.25
24	289	218.75	70.25
25	14	22.25	-8.25
26	9	22.25	-13.25
27	23	22.25	0.75
28	11	22.25	-11.25
29	22	22.25	-0.25
30	32	22.25	9.75
31	43	22.25	20.75
32	24	22.25	1.75
33	15	18.375	-3.375
34	12	18.375	-6.375
35	10	18.375	-8.375
36	9	18.375	-9.375
37	19	18.375	0.625
38	26	18.375	7.625
39	35	18.375	16.625
40	21	18.375	2.625
41	21	31	-10
42	19	31	-12
43	32	31	1
44	17	31	-14
45	34	31	3
46	42	31	11
47	54	31	23
48	29	31	-2
49	132	156.125	-24.125
50	115	156.125	-41.125
51	143	156.125	-13.125
52	121	156.125	-35.125

53	165	156.125	8.875
54	174	156.125	17.875
55	202	156.125	45.875
56	197	156.125	40.875
57	143	149.125	-6.125
58	115	149.125	-34.125
59	114	149.125	-35.125
60	165	149.125	15.875
61	133	149.125	-16.125
62	158	149.125	8.875
63	198	149.125	48.875
64	167	149.125	17.875
65	154	194.75	-40.75
66	115	194.75	-79.75
67	156	194.75	-38.75
68	179	194.75	-15.75
69	158	194.75	-36.75
70	278	194.75	83.25
71	279	194.75	84.25
72	239	194.75	44.25

Three extreme residual values (149.25, 84.25 and 83.25) were recorded from Table 4 under treated cases, active cases and active cases in 2020, 2020 and 2019 respectively in Enugu for all of them. Using the greatest residual value ($\varepsilon_{317} = 149.25$), the standardized residuals (d_{ijk}) is given by:

$$d_{317} = \frac{\varepsilon_{317}}{\sqrt{MS_E}} = \frac{149.25}{\sqrt{1503.681}} \approx 3.849$$

The standardized residual which gives a value of 3.849 falls outside the interval ± 3, indicating that the normality assumption of the error term is not assured. The normal probability plot in Figure 1 via the Kolmogorov-Smirnov statistic also confirms that the residual is not from a normal distribution since the p-value (0.012) is less than the level of significance. The plot exhibits some kind of linearity from left to right in ascending order. Hence, we can conclude that the independence of the residual was not violated in a significant manner.

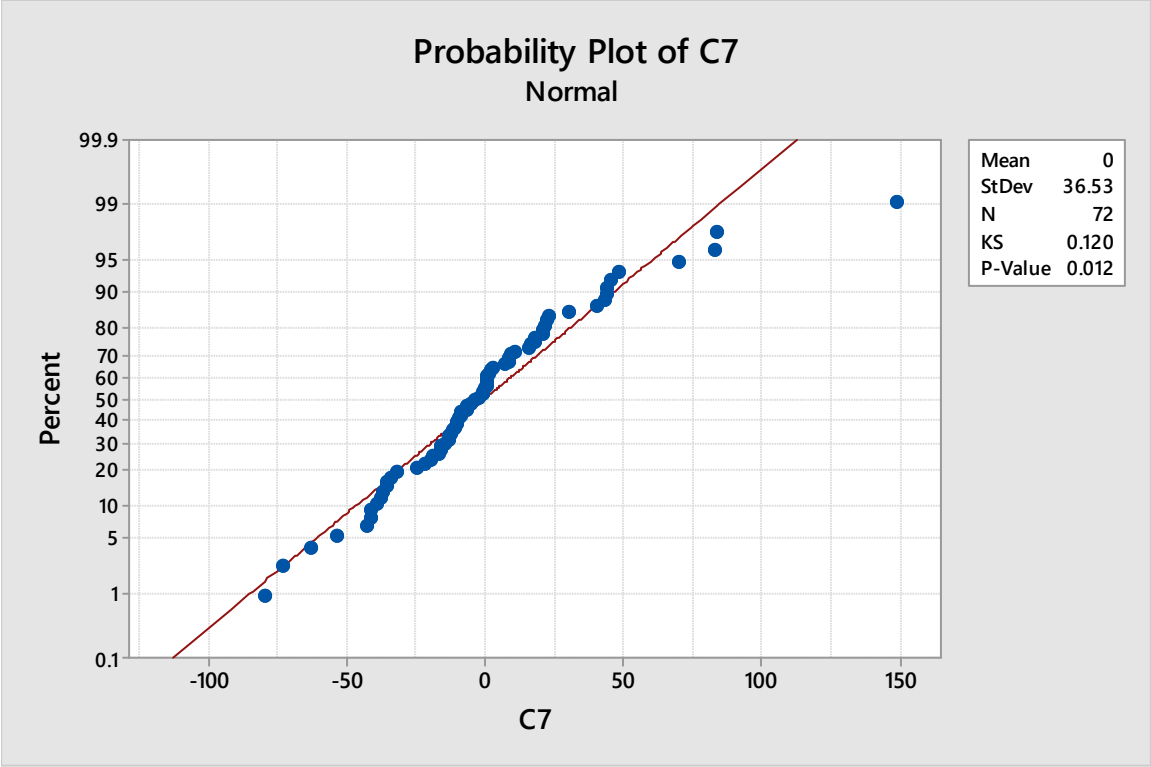

Figure 1: Normal Probability Plot via Kolmogorov-Smirnov

Discussion of the Findings

This study was aimed at using experimental design to derive a model for the incidence of malaria across the South-Eastern geo-political zone of Imo State, Nigeria. Hence, two-factor factorial design with mixed factors was employed. A 3^2 factorial design with mixed factors was employed for the data on the number of various malaria cases. The two factors involved served as the exponent, whereas the three levels of each factor served as the base 3; hence the 3^2 factorial design. In addition, the levels of factor R (state) were randomly chosen while those of factor C (status of malaria patient) were fixed, hence the mixed effect aspect of the design.

The findings of this study also shows that the average yearly malaria treated, death and active cases per state in South-East of Nigeria were about 162, 24 and 167 respectively for the period between the year 2014 and 2021. Furthermore, the average yearly number of confirmed malaria cases was 117 per state in South-East for the year under study. Again, since none of the estimated variance components gave zero or negative value, it then means that the effect of the state, the effect of malaria patient status, the effect of interaction between state and malaria patient status, and the effect of the error incurred during the process all assisted in explaining the incidence of malaria in the area of study.

The standardized error which falls outside the interval ± 3 implies that the normality of the error term is not fulfilled. Hence, the mixed effect model is not appropriate for the prediction of the various malaria cases. The results in Table 3 show that Enugu led in all the incidence of malaria among the three randomly selected state, followed by Anambra and Abia state.

Conclusion and Recommendation

Having carried out a research on 3^2 factorial designs with mixed factors for the data on the number of various malaria cases, the study concluded that the mixed effect model is not appropriate for the prediction of the various malaria cases since the error term is not normally distributed. The study also concluded that the average yearly malaria treated, death and active cases per state in South-East of Nigeria were about 162, 24 and 167 respectively for the period between the year 2014 and 2021. Furthermore, the average yearly number of confirmed malaria cases was 117 per state in South-East for the year under study.

The researcher recommends that future research study should be done on this area with the intension of using other experimental designs, apart from the one employed in this study. However, the design employed here can also be replicated on the condition of first examining the data for any possible outliers and removing it if detected. In this study, the sample size is not enough, hence the reason why manual computation was employed; therefore, the researcher recommends sufficient data for further studies and also employing a statistical programming software package for analysis of data.

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