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# A Field Study on the Use of Clay Ceramic Water Filters and Influences on the General Health in Nigeria

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**Abstract**

Field study and surveys were conducted to evaluate interdisciplinary parameters influencing the health of people using ceramic filters for water purification. A total of 52 families were distributed with filters at Eweje Village, Odeda local government area, Ogun State, Nigeria. Surveys contained questions related to hygiene, health, water source and treatment, socio-economic and educational status of people and their use of clay ceramic water filters. Several parameters were studied including time of use of water filter, maintainability, education, societal economics, and social the status of the people using the filters. There was interdependence between these parameters. Health of the Eweje village community was greatly influenced by the number of people using the filter, the time of filter usage, education, maintainability, access to medical facilities, and economic status. A novel multi parameter multivariate regression approach clearly enumerates the hierarchy of the effects of the influencing variables on the health of Eweje community. Apart from population and time of filter use, access to medical services also influenced health of this rural community.

*Key words*: Rural, Health, Water, Filters, Education, Regression, Africa

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## INTRODUCTION

Eight hundred eighty-four million people are still without potable water with only four years to meet the Millennium Development Goal of the WHO-UN (WHO 2010). 34% of the deprived people live in Sub-Saharan Africa. In the last eighteen years there has been a 10% increase in total population who has access to potable water (WHO 2010). As per predictions by the World Bank in 2003, by 2015 5-10% of the population of Middle East, North Africa, Latin America

and the Caribbean will still be without reliable potable water. It is predicted that 15% of South Asia and 25% of Sub Saharan Africa will not be having access to potable water resources in 2015 (Hillie et al. 2009). Several water filtration technologies have been started by educational initiatives and non-governmental organizations recently to resolve potable water scarcity (Sobsey et al. 2008). Chlorination with safe storage, chemical coagulants such as WaterMaker (Control Chemical , Alexandria, VA), PuR (Proctor and Gamble, Cincinnati, OH), sodium hypochlorite (SFH/Nigeria) , nut/seed organic medicinal materials, sunlight exposure techniques such as SODIS, SOLAIR, UV radiation techniques, filtration techniques such as nano-membrane filtration, reverse osmosis technique, Pureit (HLL Ltd., Unilever Inc., India), organic additive based ceramic filters, Kanchan MIT arsenic filter and bio-sand filters are some of the most studied and surveyed techniques used around the globe for water purification (Brown et al. 2007; CDC 2008; Clasen et al. 2006a; Clasen et al. 2007; Hillie et al. 2009; Duke et al. 2006; Ngai et al. 2006; Plappally et al. 2010; Sobsey et al. 2008).

UNICEF joined with a local non-governmental organization in Myanmar formed the Community Development Association to initiate water purification technology to the household level (Naing 2007). More than 3,000 ceramic water filters have been distributed in the Phyu village and schools in Myanmar. More than 80% of the households near the delta and coastal areas use these filters regularly and the customer satisfaction is about 90% (Naing 2007). Any particle or organisms larger than 1 micron are trapped with this filter.

Millions of these porous clay ceramic water filters are in use at numerous locations in Africa, Asia, and South America (Plappally et al. 2009). Studies on performance of clay ceramic filters in Bolivia conducted under the nongovernmental organization Food for the Hungry International showed a decrease in the cases of diarrhea by around 45% (Clasen et al. 2006b). In the studies conducted by Sobsey et al. (2008), ceramic filters and biosand filters were found to best fit the sustainability criteria in the field with consumers.

For the present study, ceramic filters were distributed to Eweje village community in Ogun State, Nigeria. Educational initiatives including field studies have been implemented under the research auspices of Potters for Peace, Princeton University, New Jersey, USA, The Ohio State University, Ohio, USA and University of Agriculture, Abeokuta, Nigeria.

The main objectives of this socioeconomic, educational and behavioral study were,

a)  To assess the impact of ceramic water filters on the health of the people.
b)  To evaluate the economic and social parameters that influences the health of the people using the ceramic filters for more than 6 months.
c)  Study the interaction between the social and economic variables
d)  A novel approach is proposed for modeling impact on health discussed in (a) above, taking into consideration time of filter use, educational, socio-economic and behavioral attributes of the people at Eweje.

**METHODS**

**Manufacturing Process**

Ceramic water filters were manufactured with locally available clay and sawdust. These filters were low cost but considered as efficient and sustainable technology to treat drinking water in developing countries (Sobsey et al. 2008). The porous clay ceramic filters were manufactured from moistened suspensions containing clay – sawdust (C-S) in 45-55, 65-35, 50-50 and 55-45 ratio by volume. Due to the plasticity of the moistened clay-sawdust blend, it could mold under stress to any shape as required. The filters were cast in the shape of a frustum (Donachy 2004). Sintering these filter molds to around $900^{o}$C introduce numerous pores into the mold serving its filtration capabilities (Lee 2001; Franz 2005; Dies 2003; Oyanedel-Craver and Smith 2008). These frustum shaped filters had axis dimension of 26cm, lower base diameter of 20cm, and upper base diameter of 23cm respectively. The filter wall and base had a thickness of 0.5cm and 1cm respectively (Plappally et al. 2009). The flow characteristics of the 50-50 filter were far better than that from the other C-S ratios mentioned above (Lee 2001; Plappally et al. 2009; Plappally et al. 2010). The structural feasibility studies for ceramic water filter were performed by several authors (Plappally et al. 2011; Watters 2010). The 50-50 configuration filter material was more prone to structural fracture in comparison to other filter configurations with lesser sawdust ratios by volume (Plappally et al. 2011).

**Microbial Removal Efficiency test for the filters**

Before distribution of the filters for the field testing and survey, microbial filtration experiments were performed on series of filters of 45-55, 50-50, 55-45 and 65-35 volume ratios. To determine the filtration efficiency, 10–20 ml cultures of the non-pathogenic *Escherichia coli* K-12 strain W3110 were grown in Miller's LB agar at $37^{o}$ C for 18–24

hrs with vigorous aeration either by shaking at approximately 200-220 rpm or by stirring (VWR digital stirrer/hotplate) (Malatesta 2010). This testing was carried out at Mechanical and Aerospace department at Princeton University, NJ, USA.

Four milliliters of this stationary phase culture were mixed into 4 L of sterile purified water, producing a pre-filtrate suspension containing $10^6$ to $10^7$ cells/ ml. The entire 4 L of pre-filtrate was poured rapidly into a water-saturated filter, and 3–4 L of the filtrate was collected in a 5 gallon plastic pail lined with sterile plastic. The number of viable cells in the pre-filtrate and filtrate suspensions were determined by appropriate dilution into sterilized purified water and plating onto Miller's LB agar (Malatesta 2010).

The colonies were counted after overnight incubation at $37^{o}C$ and used to calculate viable cells/ml. If the viable count of the filtrate was low, cells present in larger filtrate samples (10-100 ml) were collected using sterile filtration assemblies (Millipore). The filter was then removed from the filtration assembly, placed directly onto Miller's LB agar and incubated overnight at $37^{o}C$. To disinfect filters between experiments, filters were either rinsed thoroughly with purified water and dried in full sunlight for 5–8 hrs or rinsed with 95% ethanol followed by drying at room temperature. The log reduction value, LRV, is defined as, LRV = $\log_{10}$ [Viable E. Coli Count in Pre filtrate/ Viable E.Coli count in filtrate] (Lantagne 2001).

**Setting**

For testing these filters in real life conditions in a developing country, they were manufactured and tested in Eweje, Odeda Local Government Area, Ward 1, Abeokuta, Ogun State, Nigeria (OSG OdedaLGA 2010). Fig.1 illustrates that Odeda local government shares boundaries with South Abeokuta in the south, North Abeokuta in the west, Obafemi Owode local governments in the east, and Oyo state in the north respectively. The climate is tropical with heavy rainfall from April to July and from September to October. Average temperature is about $32^{o}C$ but humidity is high at about 95% (OSG Odeda LGA 2010). It is very important to know the climate before surveying health since climatic change is a very pertinent factor influencing the health of the population.



**Figure 1** The map of Ogun State in Nigeria showing Odeda which is located in the north central region of Ogun State ( Courtesy: Ogun Land Information Systems, Ogun State Bureau of Lands and Survey).

Each and every family in Eweje was asked for their consent of participation in this survey. The main sources of water are ponds and rivulets running near Eweje village. The manufactured ceramic filters were distributed to 53 families (free of cost) in February 2009. These families were surveyed on the effectiveness of the ceramic filters in purifying water. The survey was initiated in February 2009 when the filters were distributed. Survey was carried out every 3 months while the filters were being used by the people. The survey was quantitative and qualitative in nature with an objective to reveal the effects of the ceramic filter on the social and economic status as well as the health of the people surveyed.

It was important to notice that several people (23 people) moved out of the Eweje locality to cities for employment opportunities between April and June 2009. All of them took the filter along with them. There was only one person who resisted in participating in this survey. He did not believe in any new technology. Hence the results of 30 families have been documented in this study.

**Personnel**

Collaborators and graduate students from The Ohio State University, Princeton University and University of Agriculture, Abeokuta, Ogun State, Nigeria were involved in data collection, filter use dissemination, and health survey. The Ministry of Health, Nigeria played an important role in the health survey by allocating a resident physician as a part

of this project. Important inputs were provided by the resident physician while preparing the survey sheet.

The visits of personnel were devoted primarily to educate the people, interview the filter users based on questions in the survey sheet. Each of the visits was carried out by a team comprising of two students acting as the investigator and coordinator. For each visit the team filled out duplicate copies of the questionnaire in their native Yuroba tongue as well as in English. The resident physician reviewed the survey on a monthly basis and included his personal health investigation to the specific sections in the survey.

### The Questionnaires
It is very important to have significant population for such a survey. A sample set of 53 families were surveyed on the effectiveness of the potable water filter. The survey was discussed and explained individually to the users of the filter. The consent of the users were obtained. The questionnaire contained questions pertaining to economic status, level of education, water literacy, family demographics, individual hygiene and health concerns before and after filter use, availability of medicine or medical consultation facility, potable water source, filter use and cleaning frequency, and number of filter units in use per family. This also became the major parameters being studied in this technical chapter to influence health [Survey is available in French and English from the authors by request].

Health issues may be due to multiple factors, therefore it is assumed to have nonlinear characteristics. The survey looked at multiple parameters. Health of the people was predicted with the help of 8 parameters which were expected to influence the filter usage. The number of filters for each family is represented by $X_1$. The parameters filter cleaning frequency, children below 5 years of age and members in a family are represented by $X_2$, $X_3$ and $X_4$, respectively. These are four quantitative predictor variables used in this study. Qualitative predictor variables used in this study were wealth statistics $X_5$, educational qualification $X_6$ and availability of medical consultation $X_7$. The time of filter usage was represented by variable $X_8$. Qualitative variables were expressed in percentages (Ogunyale 2009; Soboyejo 2006). The criteria for judging these qualitative variables were developed and approved by the collaborators.

### Theoretical Development
The nonlinear behavior of health response (Y) can be visualized from the results in Fig 2 to Fig 6. A lognormal stochastic multi-parameter model has been proposed in this research to model the health response Y, of the people. Health response Y, can be expressed mathematically as,

$$Y_i/Y_{i-1} = X_i^{b_i} \quad \text{For } i = 1, 2, 3.....k \tag{1}$$

The above expression of $X_i^{bi}$ is known as the transfer function. This function mathematically expresses the step-by-step effects of the variables mentioned above with time on the health of the community (Soboyejo and Nestor 2000). This nonlinear behavior is simulated with a stochastic step function from step 0 to step 1 as shown below in Eq. 2.

$$Y_1/Y_0 = X_1^{b_1} \quad \text{For } i = 1 \tag{2}$$

where $Y_0 = a$ , the initial value of the stochastic process model. The Eq. 2 is rewritten for n number of predictor variables in the form,

$$Y_n/Y_{n-1} = X_n^{b_n} \tag{3}$$

$$Y = Y_n = Y_{n-1}X_n^{b_n} = aX_1^{b_1}X_2^{b_2}.......X_n^{b_n} \quad \text{For } n = 1, 2,.....k. \tag{4}$$

Eq. 4 can be expressed as,
$$y_i = \ln Y_i = \ln a + \sum_{i=1}^{k} b_i \ln X_i \tag{5}$$

Since the predictor random variables have different dimensions, Eq. 4 can be mathematically reformulated as
$$Y = Y_0 \prod_{i=1}^{k}(X_i/X_{i0})^{b_i} \tag{6}$$

$$a = Y_0\left\{\prod_{i=1}^{k} X_i^{b_i}\right\}^{-1} \tag{7}$$

where $X_{io}$ is any reference constant with the same units as $X_i$. Non dimensionalization of predictor random variables $X_i$ is performed in Eq. 6.

### RESULTS

#### Microbial Removal Efficiency Test
The removal of *E. coli* by the different water filter configurations are presented in Fig. 2 below. All of the filters exhibited very high *E. coli* removal rates. 50-50 filters were having a comparatively better flow characteristic as compared to others. From Fig. 2 it is found that in test 1, 50-50 filters had competitive microbial filtration efficiency and was better than EPA standard LRV value of 6 (Clasen et al. 2009).
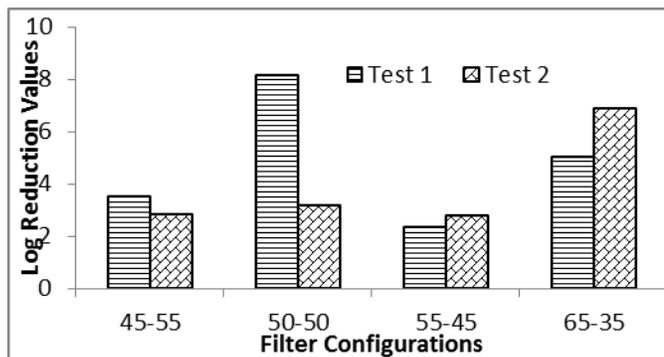
**Figure 2** Microbial filtration results for ceramic water filters.

Oyanedel-Craver and Smith (2008) and Bielefeldt et al. (2009) reported bacterial removal greater than 3log removal

of *E. coli* pulse-spiked onto 50-50 filters. Hence 50-50 filters are estimated to provide efficient service at Eweje.

**Survey results**

Population is a major parameter without which the survey on the effectiveness of the filters cannot be carried out. It is found that 30 people responded to the survey regularly for more than 6 months. The other 23 people out of the 53 person sample population under survey were able to provide their inputs only once at the initiation of the survey. Hence their comments have been neglected in the studies.

The health status of the 30 families were recorded in percentage and plotted in Fig. 3. Reponses for survey sections D-I and physical health exams performed by the resident physician were considered for assessing health.
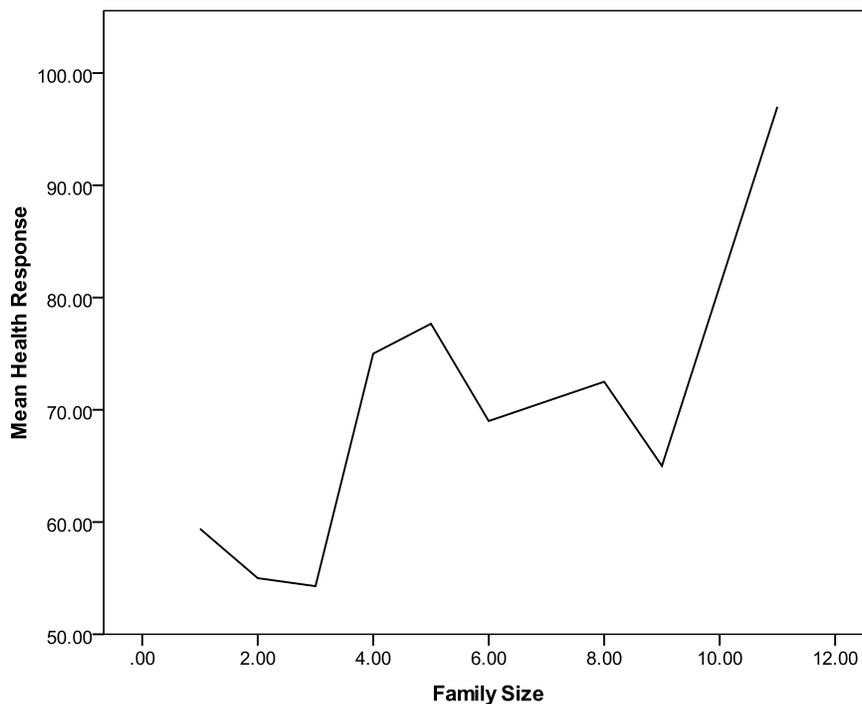


**Figure 3** The variation of health as a function of family size ($X_4$).

**Figure 4** The variation of health as a function of number of children below 5 years of age ($X_3$).

Fig. 3 illustrates that family size is directly related to their health. Improved health reflects the combined influence of the use of purified water, survey and feedback from the physician. Families with children below 5 years of age were more receptive to survey and feedback on health (Ogunyale 2011). It was estimated by World Health Organization in 2002, that nine out of ten were child deaths and 54.2 million disability adjusted life years were lost due to unhygienic condition and scarcity of potable water (Parikh et al. 1999). In Fig.4, the X axis represents the distribution of the number of children below 5 years of age. The survey data ($X_3$) is included in the Appendix I. Children and mothers were more susceptible to health problems compared to others in the family residing in rural areas in developing nations (Montgomery et al. 2007). It is also true that women and children spent much time fetching potable water preventing them from attending schools (Jalan and Ravallion 2003; Hillie et al. 2009).

There is a significant influence of wealth on making a decision either to consult a doctor, to pursue education or to adopt a new technology. There was no anticipated improvement of health in families with higher economic status. This can be confirmed from Fig 5. The families with higher economic status were found to have either sound or worse health characteristics. This randomness is due to other

influencing parameters such as presence of children below 5 years of age or low maintainability of filter. The other factor which influences health is education. Education of females proved to be a positive influence to health of the family (Jalan et al. 2003).

Education is the only edge to restore a sense of normalcy when illiteracy influences disastrous health. From Fig. 6, it is seen that with increase in educational qualifications the health of the people improved. People with more than 60% level of education (above tenth grade) have better health. People having 20-60% level of education contributed to low health percentage. It is important to know that time spent in a school had an important role to play in determining the health of an individual (UNICEF 2007). WASH programs implemented at schools in Thailand, Mongolia and Niger imparted awareness on washing hands and other sanitation methods (MNN 2010; UNICEF 2008; UNICEF 2009a).

Lack of potable water and sanitation facilities in schools prevented female attendance and impacted their learning environment (Hillie et al. 2009; UNICEF 2009b). Large families with school going children were highly interested to know about the uses of the ceramic water filter and its effect on their health (Ogunyale 2011). Awareness of drinking pure water and the exposure to mass media has significantly

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affected people in developing countries. As a result, the number of deaths due to cholera decreased from 8,500 in 2007 to 42 in 2009 in Africa (MNN 2010).

Fig. 7 shows improvement in health with increase in maintainability (filter cleaning frequency $X_2$). The survey data has been plotted in Figs. 3 to 7 using the SPSS statistical software version 16 (SPSS 16.0 for Windows IBM® 2007). From the results, the family size ($X_4$) emerges as the most influencing parameter of health. This result can be used to develop a novel framework to improve the predictability and extend the behavioral model in Eq. 4. Therefore, a new response variable is derived using the principle of minimal realization using a quotient variable (Sussman 1977). The new quotient variable G is the fraction of the most influencing predictor variable to the response variable (Tabuada and Pappas 2005). Hence a predictor variable transformation is performed (Sussman 1977). Eq.5 can now be rewritten as.

$$G = X_4/Y = a\prod_{i=1}^{k=8} X_i^{b_i} \qquad (8)$$

The predictor variable transformation is applied such that it does not affect the actual behavior of the response variable Y. To test the validity of the assumed transformation in Eq. 8 as well as raw data Y, a Kolmogorov Smirnov goodness of fit test was performed at a 99% level of confidence and is

enumerated in Table 1. Since the $D_n$ value is less than the critical $D_n^\alpha$ at α=0.01, the proposed model distribution for prediction of health Y, in Eq. 8 is accepted (Ang and Tang 1975).

**Table 1** $D_n$ and $D_n^\alpha$ for Kolmogorov Smirnov Test for the different models for the Health Response Y (Ang and Tang 1975).

| Kolmogorov Smirnov Test at α=0.01 | | | Critical Value $D_n^\alpha$ |
|---|---|---|---|
| | Eq. 5 | Eq. 8 | n | |
| $D_n$ | 0.127 | 0.2 | 30 | 0.29 |
| p value | 0.15 | 0.009 | 30 | 0.01 |

All the predictor parameters for health response (Y) were highly correlated to each other and have been enumerated in Table 2 below. High correlation between filter cleaning frequency $X_2$ and family size $X_4$ is confirmed. Educational status $X_5$ is also found to improve with increase in wealth $X_6$ and vice versa. This is because better education provided people with high paying jobs or people with enough money were able to avail good education.
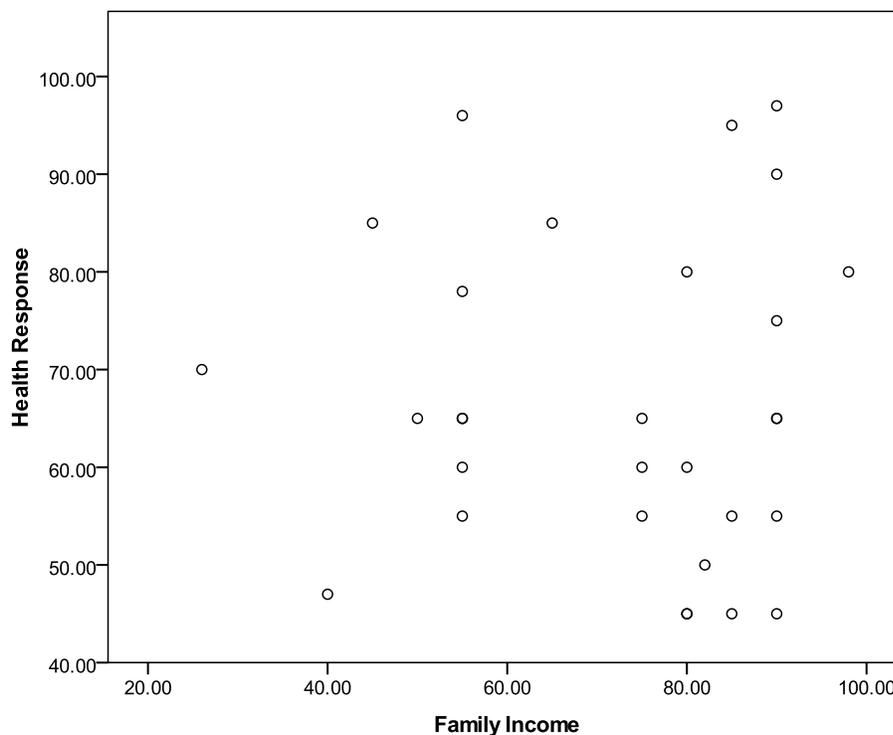


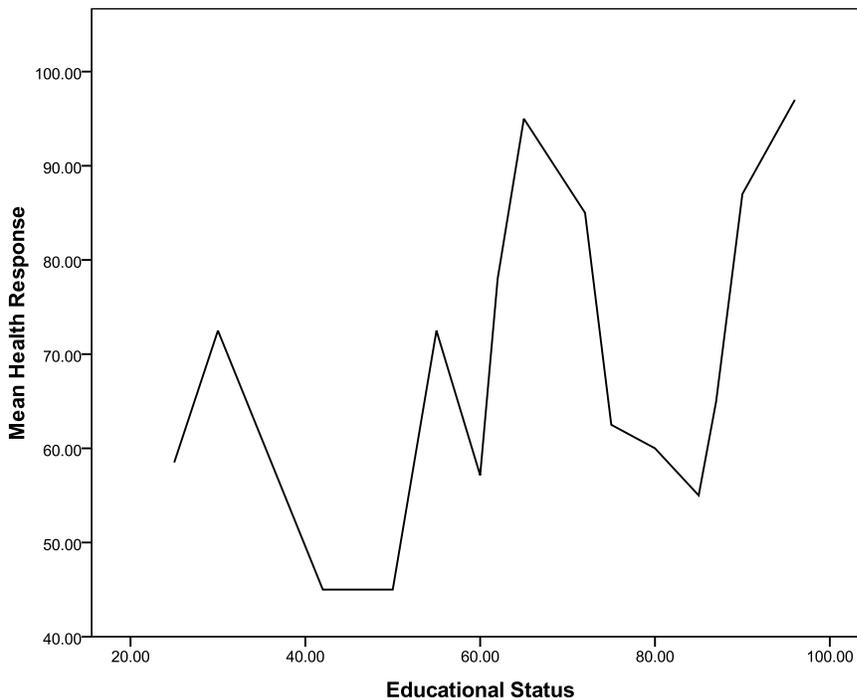**Figure 5** The variation of health as a function of family income ($X_5$) (expressed in percentage).

**Figure 6** The variation of health as a function of education ($X_6$) (expressed in percentage).
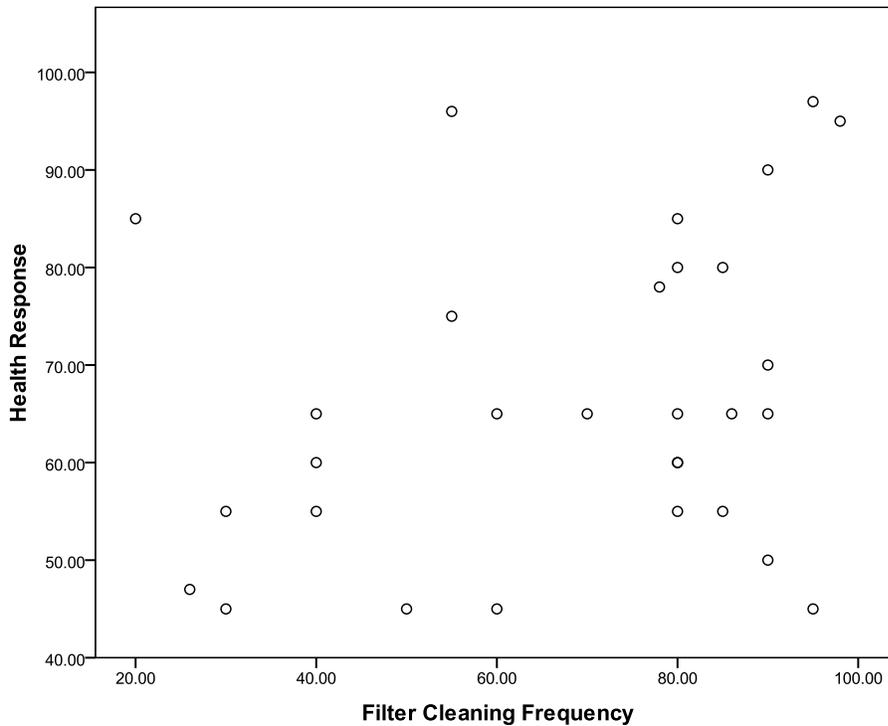


**Figure 7** The variation of health response as a function of filter cleaning frequency ($X_2$).

**Table 2** A correlation matrix tabulating correlation coefficients $\rho_{x_{i,j}}$ for each pair of the random parameters influencing health namely, the number of filters for each family $X_1$, filter cleaning frequency $X_2$, children below 5 years of age $X_3$, members in a family $X_4$, wealth statistics $X_5$, educational qualification $X_6$, and availability of medical consultation $X_7$ and time of filter usage $X_8$.

|        | $X_1$  | $X_2$ | $X_3$  | $X_4$ | $X_5$ | $X_6$ | $X_7$ |
|--------|--------|-------|--------|-------|-------|-------|-------|
| $X_2$  | 0.23   |       |        |       |       |       |       |
| $X_3$  | 0.04   | 0.406 |        |       |       |       |       |
| $X_4$  | 0.149  | 0.508 | 0.734  |       |       |       |       |
| $X_5$  | -0.032 | 0.421 | 0.339  | 0.482 |       |       |       |
| $X_6$  | -0.015 | 0.16  | 0.123  | 0.568 | 0.55  |       |       |
| $X_7$  | 0.01   | 0.03  | -0.263 | 0.02  | 0.064 | 0.441 |       |
| $X_8$  | 0.065  | 0.41  | 0.208  | 0.313 | 0.288 | 0.181 | 0.035 |

The multi-parameter econometric behavioral regression modeling assumes independence of the predictor variables.

The correlated predictor matrix column elements ($X_i$ for i= 1, 2 ….8) in Table 2, with correlation coefficient $\rho_{x_{i,j}}$ are linearly transformed to the independent variables ($\overline{V_{i,j}}$=$V_i$) and are scaled as (Haldhar and Mahadevan 2000; Krishnamoorthy 2006).

$$\left[ ln\overline{X_{i,j}} - \mu_{\overline{X_{i,j}}} \right] / \xi_{\overline{X_{i,j}}} = [\overline{T}]\left( \overline{V_{i,j}} / \sqrt{\overline{\lambda_{i,j}}} \right) \tag{9}$$

The left hand side of Eq. 9 is standard variates of the predictor variables (ln $X_{i,j}$) for $i \neq j$ and i=1, 2 …..8. The left hand side of Eq. 9 has zero mean and unit standard deviation. Here $\mu_{\overline{X_{i,j}}}$ and $\xi_{\overline{X_{i,j}}}$ are the parameters of lognormal distribution. $[\overline{T}] = [\phi]^t$, which constitutes all the principal components in the transformation matrix. The $V_i$ for i=1, 2 ...8 in Eq. 9 is the independent normal predictor variables with the corresponding variances $\lambda_{i,j}$ (for i=1, 2, 3…..8). Eq. 8 can be rewritten as.

**Table 3** Summary of multivariate model constants, coefficient of determination $R^2$ and error S for Eq. 10.

| Correlated Variables $X_i$ |            | $X_1$    | $X_2$   | $X_3$   | $X_4$   | $X_5$   | $X_6$   | $X_7$   | $X_8$    |       |        |
|----------------------------|------------|----------|---------|---------|---------|---------|---------|---------|----------|-------|--------|
| Independent Variables $V_i$ |            | $V_1$    | $V_2$   | $V_3$   | $V_4$   | $V_5$   | $V_6$   | $V_7$   | $V_8$    |       |        |
| Coefficients of $V_i$      | $\bar{a}$  | $\bar{b_1}$ | $\bar{b_2}$ | $\bar{b_3}$ | $\bar{b_4}$ | $\bar{b_5}$ | $\bar{b_6}$ | $\bar{b_7}$ | $\bar{b_8}$ | $R^2$ | S      |
| G                          | 0.29       | 0.0842   | -0.018  | -0.022  | -0.027  | -0.024  | -0.014  | -0.030  | -0.103   | 99%   | 0.0184 |

$$G = X_4 / Y = \bar{a} + \sum_{i=1}^{8} \bar{b_i} V_i \tag{10}$$

**Influences of the predictor variables on health**

The multivariate approach developed is applied to fulfill the assumptions of independent variables for regression (Plappally 2010). The multivariate approach helps in identifying the actual independent influences of the predictor variables on the newly transformed response variable G which consolidates the health parameter Y. Accordingly, the regression model coefficients in Eq. 10 are shown in Table 3.

Table 3 has been derived with the help of Minitab 15 statistical software (Minitab 15 2007). It is found that with time there has been a steady decline in water related health issues in the Eweje locality. This confirms that long term use

of filters influence health positively (Brown et al. 2007). Secondly, people who had close access to medical facilities $X_7$ rarely had health problems. This means that people did see their local medical officer for his/her advice on health issues. 83 out of 124 people who participated in the survey sought medical services.

Even though Odeda people are less educated academically they have good knowledge of traditional medicine (Olatokun and Ayanbode 2009). Out of 83 people, who used medical services 39 were either traditional healers or people with knowledge of medical herbs or traditional medicine. Within these 39 people there were 26 who traded medicinal herbs. A total of 21 women had knowledge of traditional medicine (Olatokun and Ayanbode 2009; McCarton 2009).

Financial status $X_5$ has a prominent effect in determining the health trends in Eweje but was less influential than the availability of medical facilities and time of filter use. WHO confirmed that 1.8 million water related diseases were basically from low income regions. This provides an insight on basic psychology of the low income people to sway away from buying expensive new technology to avail potable water. Education and awareness played a pertinent role but not as expected (Jalan et al. 2003). This would support a need for vigorous awareness programs in educating people about sanitation, water and hygiene and their correlations (UNICEF 2009a).

### IMPLICATIONS

The implications of the survey and its results are significant. First, significant health improvement at Eweje is observed over a short period after the project implementation. Medical advice and proper survey feedback stimulated the behavior of the individuals on sanitation, cleanliness and water-health relationship. Health improved with family size and educational status. The frequency of medical consultation was higher for people with better education (Ogunyale 2009). This implies that academic literacy is very important for a high awareness towards health not only in Eweje but also the human society in general.

Secondly, population of children and wealth in a household introduce major variability in health status. The data collected in this survey relating to demographics, education, economics, medical awareness and time are interdependent. One major consequence of this multiparameter framework is the natural incorporation of all the data collected to predict health. It is not the number of the filters that is important but it is the water filter maintenance, time of usage, the number of people using the water filter, socio-economic standard of people as well as their education status. The other major variables that affect health and use of ceramic water filters are the structure of a family and its culture values. These predictor variables need specific attention in future studies which when added may improve the predictive capability of the multiparameter econometric behavioral regression model proposed. There should be another predictor variable to define the effect of survey feedback.

Thirdly, from the survey it is obvious that traditional medicine and its use by the people have enormous influence on health and sanitation. It is implied that improvement in traditional medicine knowledge base is a must for the upliftment and development of the rural sector not only in Nigeria but Africa as a whole. The model of Ayurvedic colleges in India may be role models for traditional medicine education (Patwardhan et al. 2009). Finally, it is important to understand that multiparameter expressions used in this technical document are difficult to integrate with any specific deterministic model. The regression models derived are specific and are used only to characterize location specific parameters studied at Eweje, Nigeria. Similar multiparameter approaches may be developed for studying health variations at other locations but may differ with variables such as process studied, process parameters, health scenario, survey approach, cultural change, socio-economic background, demography, education, rural or urban societies, country and climate.

### CONCLUSION

Multivariate stochastic regression formulation was used for identifying the individual socio-economic parameters affecting the health. Summarizing the major outcomes due to clay ceramic water filter use is summarized below.

1. Apart from population, the duration of filter use has been a major parameter, influencing health at Eweje.
2. Accessibility of medical facilities or knowledge of traditional medicine within the people at Eweje had a great influence on the health outcome. The knowledge of traditional medicine should be accounted under education($X_6$).
3. Financial status played a major role in influencing health.
4. Random parameters influenced health in an order as shown below,
   Number of filters for each family, $X_1$ < educational qualification, $X_6$ < filter cleaning frequency, $X_2$ < children below 5 years of age, $X_3$ < wealth statistics, $X_5$ < availability of medical access, $X_7$ < time of filter usage $X_8$, < members in a family $X_4$.
5. The random parameters discussed above, were introduced in a stochastic framework to obtain a novel multi-parameter lognormal regression model for predicting health at Eweje.

It is suggested and advised that Nigeria as well as other African nations should improve their educational policy and cater education to each and every citizen irrespective of race, caste, tribe, religion and financial status of people. Another major suggestion is that knowledge of traditional medicine of the people should not be ignored and provisions should be provided to educate and transfer it to newer generations. This would also support development in the fields of bio materials,

agriculture and medicine. Survey feedback to the families by the resident physician may have helped to stimulate health behavior. This procedure is to be studied carefully inorder to understand its effect on health.

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Appendix I

13

**Data Collected from 30 Families at Eweje Village, near Abeokuta, Ogun State, Nigeria, Africa**

| Y-Health Response in % | $X_1$- Number of Filters for each family | $X_2$- Filter Cleaning Frequency | $X_3$ - Children Below 5 Years of Age | $X_4$ - Members in a Family | $X_5$- Wealth Status in % | $X_6$ - Education Status in % | $X_7$- Availability of Medical consultation | $X_8$- Time for Filter Usage |
|---|---|---|---|---|---|---|---|---|
| 80 | 1 | 80 | 3 | 4 | 80 | 30 | 40 | 3 |
| 70 | 1 | 90 | 0.4 | 1 | 26 | 25 | 85 | 3 |
| 50 | 1 | 90 | 0.2 | 3 | 82 | 60 | 60 | 3 |
| 45 | 1 | 95 | 2 | 5 | 85 | 42 | 28 | 3 |
| 65 | 1 | 80 | 2 | 5 | 90 | 87 | 88 | 3 |
| 96 | 1 | 55 | 0.4 | 5 | 55 | 90 | 90 | 3 |
| 47 | 1 | 26 | 0.2 | 1 | 40 | 25 | 15 | 2 |
| 97 | 1 | 95 | 2 | 11 | 90 | 96 | 80 | 3 |
| 78 | 2 | 78 | 2 | 6 | 55 | 62 | 40 | 3 |
| 80 | 1 | 85 | 0.3 | 5 | 98 | 75 | 65 | 3 |
| 95 | 2 | 98 | 0.3 | 5 | 85 | 65 | 90 | 3 |
| 75 | 1 | 55 | 0.5 | 4 | 90 | 90 | 95 | 3 |
| 65 | 1 | 86 | 0.2 | 2 | 75 | 60 | 85 | 3 |
| 55 | 1 | 40 | 0.3 | 3 | 85 | 80 | 55 | 3 |
| 45 | 1 | 30 | 0.2 | 2 | 90 | 75 | 87 | 3 |
| 45 | 1 | 60 | 1 | 3 | 80 | 60 | 45 | 3 |
| 65 | 1 | 70 | 0.2 | 3 | 55 | 80 | 85 | 3 |
| 90 | 1 | 90 | 3 | 8 | 90 | 90 | 55 | 3 |
| 55 | 1 | 85 | 0.2 | 3 | 90 | 80 | 50 | 3 |
| 55 | 1 | 80 | 2 | 8 | 75 | 85 | 55 | 3 |
| 65 | 1 | 90 | 3 | 9 | 90 | 80 | 55 | 3 |
| 85 | 1 | 20 | 1 | 5 | 45 | 55 | 60 | 3 |
| 85 | 1 | 80 | 0.3 | 4 | 65 | 72 | 65 | 3 |
| 65 | 1 | 60 | 0.1 | 1 | 50 | 30 | 55 | 3 |
| 60 | 1 | 80 | 1 | 4 | 75 | 60 | 45 | 3 |
| 60 | 1 | 80 | 2 | 6 | 80 | 55 | 80 | 3 |
| 60 | 1 | 40 | 0.2 | 1 | 55 | 60 | 55 | 3 |
| 55 | 1 | 30 | 0.2 | 1 | 55 | 60 | 80 | 0.5 |
| 65 | 1 | 40 | 1 | 3 | 55 | 60 | 80 | 3 |
| 45 | 1 | 50 | 1 | 3 | 80 | 50 | 60 | 3 |