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Environmental impact assessment: Geologic tool to investigate the proposed Enji dam construction, Offa, Kwara state

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ABSTRACT

The proposed dam axis geographical locations are on Latitude N080 39' 38.5'', longitude E040 46' 28.6'' and latitude N080 39' 26.9'', longitude E04° 46' 33.3'' and its axis traverses various communities like Enji (40 rooms), Gbomi, Fatraj (Ile mojedun), Atooba (Ariya), St. Claire's junction (Ikotun road), Keraaje site. Detailed laboratory analyses of air, noise, water and soil pollutants using collected samples of the area gave reliable baseline data. Geotechnical report of the area revealed basic information of the area. More importantly, questionnaires were designed and administered to assess positive and adverse impacts. Results obtained revealed the proposed area for the construction of a dam will be feasible to impound water for storage with catchment area of 38 km2 envisaged, annual runoff has been estimated to be about 52,988,620 m^3. The freeboard is assessed to be 2 meters. Crest length and elevation are 106.9 m and 45 a.s.l. (above sea level) respectively. Spillway type and discharge rate were considered to be broad crested and 377 m^3 s^{-1} respectively. But adverse impacts will be recorded and include among others silting of the dam, risk of eutrophication/growth of non-native and/or invasive species, growth of aquatic macrophytes in the littoral and sub-littoral zone of the proposed reservoir, creation of favorable habitats for the growth and proliferation of disease vectors, risk of introduction of new diseases like schistosomiasis, bilharzias. With more positive impacts than the adverse effects, the study concluded that the project is feasible and will contribute to economic prosperity of the area.

Keywords: Freeboard, Sedimentation, Silting, Spillway and Eutrophication.

1. INTRODUCTION

An Environmental and social impact assessment (ESIA) was conducted to assess the feasibility of constructing a dam that can store water for public township water supply. The building of dams can have far-reaching and often unintended social

and environmental impact consequences on the lives and means of livelihood of people, thus the main reason for conducting this impact assessment. It is estimated that almost a quarter of a million square kilometers of land has been inundated by the impoundment of river water over the last century. The effects of dams on rivers can have dramatic consequences both upstream and downstream as the natural flow and drainage of the land is altered (Olorunfemi et al., 2004). As the sediment-laden upstream water flow into the impoundment behind the dam, suspended sediments drop out and form thick layers of silt at the bottom of the impoundment. Also, as a result, when water is released through the dam it is relatively sediment-free, and hungrily picks up a sediment load as it moves downstream, leading to increased erosion of the riverbanks and streambed for dozens and sometimes hundreds of kilometers downstream from the dam. Proposed Enji dam has been investigated for salient ecological and environmental factors that may make its construction feasible.

Location of study

The proposed dam axis/site is located across Enji River in Enji settlement of Offa Local Government Area, Kwara State for the purpose of township water supply. The proposed dam axis geographical locations are on Latitude N080 39' 38.5'', longitude E040 46' 28.6'' and latitude N080 39' 26.9'', longitude E04 46' 33.3''. The average length of the river is about 742 km along its axis and traverses various communities. The project is proposed to be located along Enji River that empties into river Niger (Figure 1).

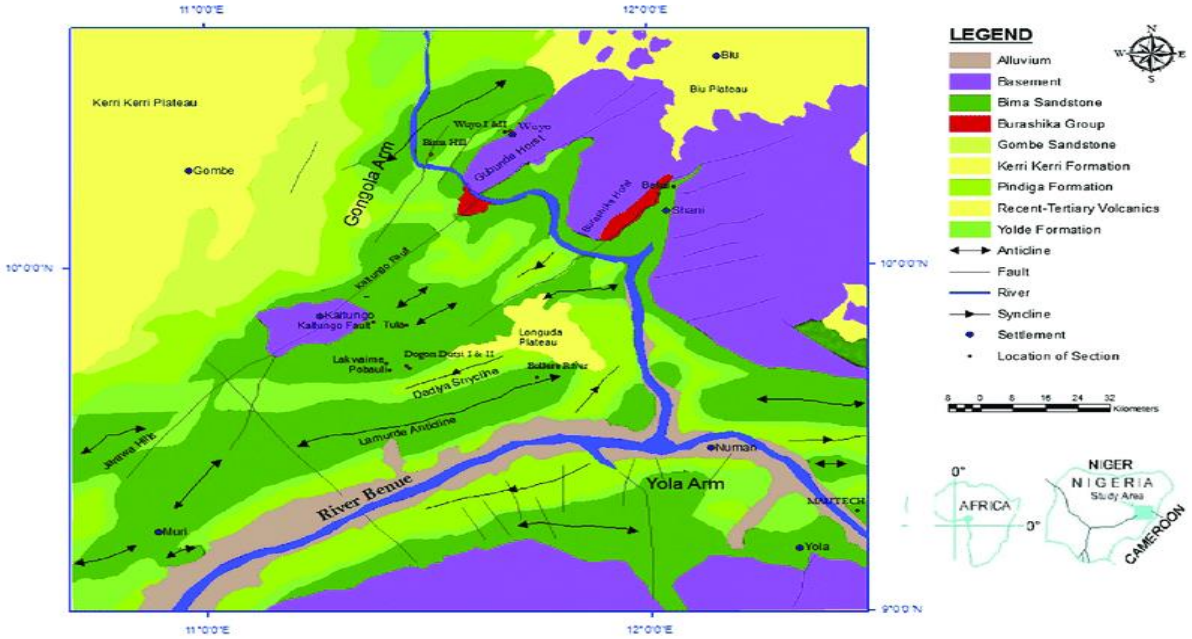

Figure 1 Geologic map showing River Niger and its tributary of Enji River. Adapted from (Bayowa et al., 2011).

The dam shall impound approximate gross storage of 4 million cubic meter of water with good rainfall pattern in the area Figure 2 and it's expected to be treated in a designed treatment plant and supply Enji and other notable Offa township areas with potable water to improve the socio-economic condition in the areas. Proposed project study area which is located around Enji is dominated by students from College of Health Technology, Offa and other family inhabitants and the place is motorable with gullies due to lack of drainage for water runoff discharge into the river. Screening of the project has shown that the proposed Enji water works will be of immense benefit to the people and their source of livelihood, most especially on food production, fishery production and public health improvement with envisaged yearly amount of rainfall volume of about 52,988,620 m3.

2. METHODOLOGY

Enji river water sample that will be diverted for the dam storage purpose was collected in a well labeled plastic container for laboratory analyses of salient physical and chemical components. Furthermore, a treatment plant has been designed for the raw water to pass through for further separation and purification process before it can be distributed to the inhabitants of the area for public

consumption. Designed questionnaires were equally administered along the representative communities of Ojoku area, covering the Offa General hospital as the target population to get the salient baseline condition and other critical impacts of the project on public health, climate impacts and adaptation trend.

This was extended to Gbomi, Fatraj (mojedun site), Atooba (Ariya), St. Claire's junction (Ikotun road), Keraaje settlements with Atooba (Ariya) to get detail environmental information of the area. More importantly, site photographs were taken to give a vivid description of the condition as they occur in each settlement of the investigated areas. Also, laboratory analysis of the water and soil samples were done at the Lower Niger River Basin Development Authoritys soil and water laboratory to have salient physico-chemical composition of the samples and know the level of treatment that the water sample will be needing for further purification process and alum chemical dosing exercise.

3. RESULTS AND DISCUSSIONS

Major findings of this study has revealed the proposed area for the construction of a dam will be feasible to impound water for storage that will be treated for the inhabitants to serve them with good potable water. Catchment area of 38 km2 is envisaged, annual runoff has been estimated to be about 52,988,620 m^3, total volume of earth fill will be about 38,826.0 m3 - 41, 432 m3. More importantly, maximum base width and maximum height of the dam are expected to be 35.95 m and 12.m respectively. Freeboard is expected to be 2 meters. Crest length and elevation are 106.9 m and 45 a.s.l. (above sea level) respectively. Spillway type and discharge rate are expected to be broad crested and 377 $m^3 s^{-1}$ respectively.

Rainfall and humidity of the area

With a total annual rainfall of about 902 mm (Figure 2) expected around the proposed site of the dam the chance of recharge of the dam is high for its raw water need. The catchment area of the dam is expected to be about 38 km2 which will contribute greatly to the impoundment of the river water. Average annual runoff is expected to be 52,988,620. This volume of water runoff is expected to contribute greatly to the source of raw water into the dam for treatment purpose.

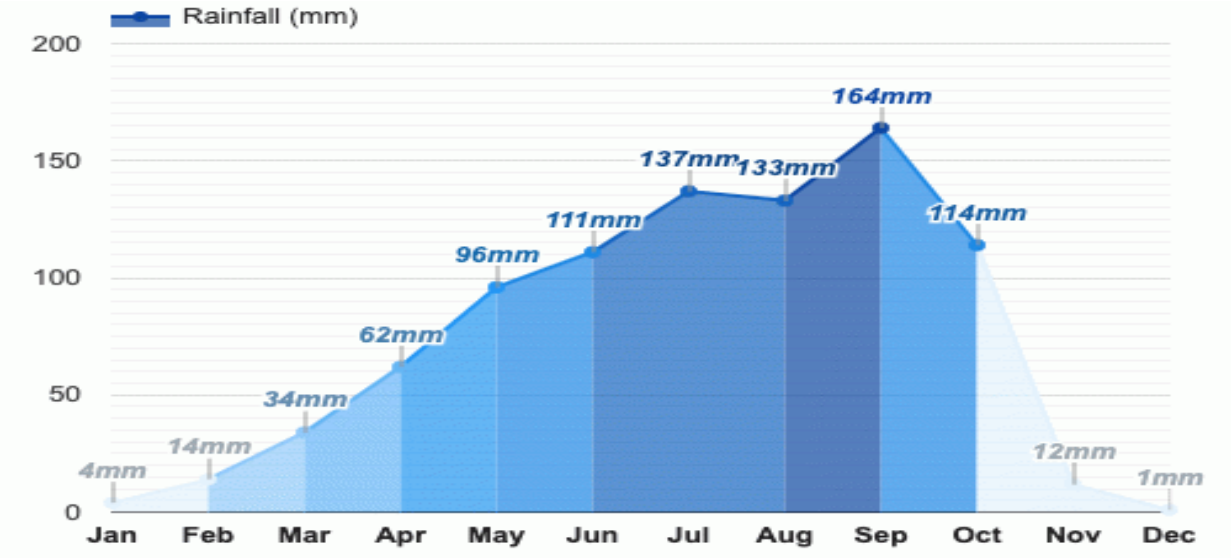

Figure 2 Rainfall pattern in the Enji study area

It can be well deduced from the data in the chart that the highest rainfall and humidity pattern of the study area ranges from around July to October. July recorded 137mm, August 133 mm, September 164 mm and October 114 mm of rainfall to be recorded (Figure 2 and 3). Similarly, January recorded 4mm, February 14mm, March 34 mm, April 62 mm, May 96 mm, June 111 mm with November and December recording 12 and 1 mm respectively. Furthermore, precipitation follows almost the same trend in the Enji study area. The lowest precipitation is around January, February, November and December every year in the study area (Figure 3). The

highest precipitation of the study area is known to be recorded around June, July, August, September and October every year. This climatic condition and many more conditions observed on field visit are favorable for the proposed project to be located in the area for the intended purpose of public township water supply. The sunlight hours of the area varied from around 10 hours that occurs around January. It drops to around 9.8 hours in February. This further drop to around 9.5 hours in the month of March. April, the value drops further to 9.2 hours.

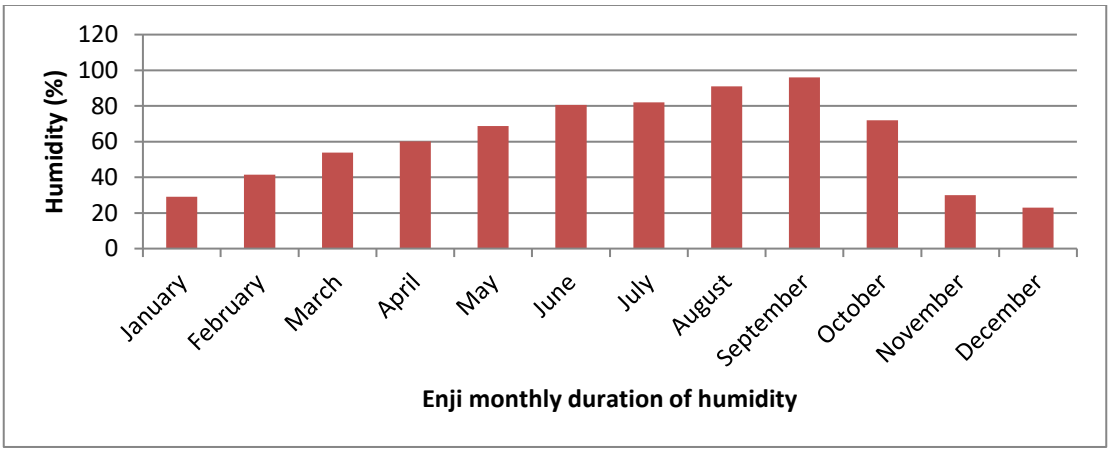

Figure 3 Graph of humidity (%) around the Enji study area

The district's yearly temperature is 29.23ºC (84.61ºF) and it is -0.23% lower than Nigeria's averages. The study area typically receives about 902 mm of precipitation and has 146.83 rainy days (40.23% of the time) annually. Enji area has an average humidity of 61.02%. The relative humidity ranges from 29.12% in January to 61.02% in December every year (Figure 3). All these factors point towards a favorable climatic condition that will be harnessed for the rainfall impoundment and storage in the proposed dam as raw water.

Air, Noise, water and soil pollutant analyses

Rapid industrialization and urbanization have caused contamination of the air, water and soil in the environment and their rates of mobilization and transport in the environment have greatly accelerated since 1940s as clearly evidenced by Khan et al., (2004) in their published manuscript. Water quality performs important role in health of human, animals and plant. Water quality is the critical factor that influences human health as well as the quantity and quality of grain production in semi-humid and semi-arid area (Vallack et al., 1998). Environmental pollution due to climate change is one of the major challenges in the modern human society. Flooding, desertification, ocean surge, flora and fauna extinction amount several others are obvious signs of the changes in environmental condition of the world. Water, air and soil are the main medium through which these anomalies befall man on earth. Water pollution is harmful not only to fish breeding and agricultural products but also to public health in surrounding areas. As such, during the environmental study of pollutants contained in the air, water and soil of Enji study area the baseline information on critical aspect of the environmental impact assessment of the study was established.

Enji air pollutant analysis

Measured parameters were higher in wet season than the dry season. SPM was measured to be 19.2 [ug/m3] during the wet season compared to 12.11[ug/m3] recorded during the dry season. TSP was measured to be 26.1[ug/m3] in wet season compared to 17.11 [ug/m3] in dry season. SO2 was measured to be the same for the seasons at 0.11 ppm. NO3 was measured in wet season as 0.03 ppm, while during the dry season it was measured as 0.01 ppm. Other measured parameters of Enji study area has revealed a higher wet season recorded values than dry season with the exception of H2S and NH3 that recorded 0.02 and 0.01 ppm respectively (Table 1).

These spatial and seasonal variations are expected to be due to the combined effects of rainfall, humidity and evaporation pattern in the area. Revealed the pollutants of Oshin River for the construction of Gbugudu dam with the need for treatment of the raw water if it will be utilized for township water supply. World Health Organization has given a benchmark of 150-230 µg/m3 (Daily average) for

suspended particulate matter (Table 1). Similarly, for CO, 10 µg/m3 (for 8 hr) must not to be exceeded as recommended by WHO. The severity of the air pollution in the area is high and can be traced to varieties of suspended particulates in the atmosphere and this can be contained with reduction in the amount of burning of fossil fuel that is rampant in most homes and small-scale businesses that litter the area.

Table 1 Air pollutants contained in the atmosphere of the study area

S/N	PARAMETER	Wet season conc	Dry season conc	FMenV	WHO
1	SPM [ug/m3]	17.2	12.11	250	150-230 µg/m3 (Daily average)
2	TSP [ug/m3]	26.1	17.11	-	
3	SOx (as SO2) [ppm]	0.11	0.11	0.1	100-150 µg/m3 (Daily average)
4	NOx (as NO2) [ppm]	0.03	0.01	0.04-0.06	150 µg/m3for 24 hr mean; 400 µg/m3: Not to be exceeded
5	CO [ppm]	2.91	1.11	10	10 µg/m3 (for 8 hr); not to be exceeded.
6	H2S [ppm]	0.02	0.02	0/006	0.001-0.02
7	CH4 ppm	1.27	1.98	-	-
8	VOC ppm	12.6	11.22	-	11.9
9	CO2 ppm	-	-	0.29	-
10	NH3 [ppm]	0.01	0.01	90	0.03

SPM = Suspended particulate matter, TSP = Total suspended particulate, ppm= Parts per million and VOC= Volatile organic compound

Noise pollution analysis in the area

The noise pollution of the area was measured to have a basic baseline data that will be compared to the condition that will be obtainable when construction is ongoing and when heavy duty machines will be operated. Sound is produced by any vibrating body and is transmitted in air only as longitudinal wave motion. Noise levels recorded at the study area in the wet season varied from 49.2 – 29.2 dB(A) (Table 2), while the dry season recorded values ranging from 28.3-39.2 dB(A) (Table 2). Wet and dry season noise level recorded around Enji dam site area will allow better preparation for construction work.

According to FEPA (1991) ie Federal Environmental Protection Agency, Permissible exposure noise limit is given as 0.25 hours or less = 115 dB(A), 0.5 hours = 110 dB(A) 1 hr= 105 dB(A), 1.5 hour = 102 dB(A), 2 hours = 100 dB(A), 3 hours = 97 dB(A), 4 hours = 95 dB(A), 6 hours = 92 dB(A), 8 hours = 90 dB(A). It is worthy of note that the noise level measured and recorded in the wet and dry seasons of Enji dam site area are close with no significant changes and almost normal. Locations of the investigated areas have all shown the noise level in the study area can be managed and this baseline data can be compared to values that will be obtained at construction stages and after completion of the project. At these coordinates of 6° 11' 9.124"N Northing and 3° 12' 22.224" E Easting, recorded 31.7 and 31.3 Db A. This is location is farthest to the point of dam location a distance of about 129 meters apart.

Table 2 Wet and dry season recorded noise level in Enji dam site area.

S/N	MEASURING LOCATIONS		NOISE CONC dB (A) (Wet season)	NOISE CONC dB (A) (Dry season)
	Northing	Easting		
L 1	8° 10' 9.954" N	4° 42' 12.234" E	29.2	31.2
L 2	8° 11' 7.871" N	4° 29' 12.121" E	38.0	37.3
L 3	8° 11' 9111" N	4° 22' 11.234" E	49.2	42.1
L 4	8° 15' 7.332" N	3° 22' 12.234" E	38.7	39.1
L 5	8° 12' 9.344" N	5° 23' 15.224" E	41.3	39.2

L 6	7° 11' 9.924" N	3° 29' 11.224" E	29.3	28.3
L 7	7° 11' 9.952" N	4° 42' 12.244" E	37.1	33.1
L 8	7° 14' 9.299" N	4° 12' 12.924" E	37.9	32.1
L 9	6° 12' 9.322" N	3° 13' 12.204" E	39.2	35.1
L 10	6° 11' 9.124" N	3° 12' 22.224" E	31.7	31.3

Water pollution in the Enji study area

Water sampling and laboratory analysis exercise carried out on the Enji study area facilitated the identification of salient features of environmental importance to deduce the impacts on the proposed facility i.e. treatment plant and other associated pipeline distribution network and the people i.e. inhabitants of the area (Table 3). Water quality performs important role in health of human, animals and plant and was proposed by (Adebola et al., 2013).

Table 3 Physico-chemical characteristics of sampled Enji River water

S/N	Parameters	Analytical result	Permissible level (NIS)	FMEnv (Nigeria)
	PHYSICAL PARAMETERS			
1	Temperature (°C)	19.2	Ambient	30
2	Colour (TCU)	2.97	3.0	
3	Turbidity (NTU)	5.06	5.0	1.0
4	Odour	No odour	Unobjectionable	
	CHEMICAL PARAMETERS			
5	Ph	7.60	6.5-8.5	6.5-9.2/ 6.5-8.5*
6	Electrical conductivity (μS/cm)	85	1000	
7	Chloride (mg/L)	2.71	100	
8	Total Dissolved Solids (mg/L)	190	500	1500/ 500
9	Total Hardness (mg/L)	22.95	100	
10	Calcium (mg/L)	2.24	-	200
11	Magnesium (mg/L)	20.58	2.0	150
12	Total Alkalinity (mg/L)	0.25	-	-
13	Total Acidity (mg/L)	0.00	-	-
14	Lead (mg/L)	Nil	0.01	0.05
15	Nitrate (mg/L)	22.74	10.0	0.05
16	Sodium (mg/L)	101.08	100.0	
17	Residual Chlorine (mg/L)	1.92	0.2	600
18	Potassium (mg/L)	Nil	-	-
19	Manganese (mg/L)	Nil	0.1	-
20	Total Iron (mg/L)	63.12	0.3	1
21	Cadmium (mg/L)	Nil	0.003	0.01
22	Arsenic (mg/L)	Nil	0.01	-
23	Zinc (mg/L)	0.06	5.00	15

Soil pollution in the area

Soil being an important part of the environmental and ecological habitat was studied to reveal salient points of interest. Earthwork for dam construction commonly leads to soil disturbance, degradation and alteration of original soil composition. As such, there is usually reduction in vegetation cover and removal of the topsoil, with more vulnerability to erosion and transportation of the loose materials. It also leads to reduction of the nutrients of the soil. This is commonly aided and experienced during excessive rainfall and most times the

soil nutritional value will be lost. In essence, the need to investigate the soil of the area. Organic matter of such soil may be lost in the process.

Secondary source of information through the farmers and visual inspections for the investigated area revealed the textural type of the soil is loamy soil which will support the germination of varieties of crops to be planted in the area. The total organic carbon content (TOC) is 12.8-14.2% (Table 4). This is enough to fertilize the soil to proper germination of crops. Physicochemical characteristics of the soil of Enji area were carried out over two seasons (wet and dry) and at two strata (0-15 cm and 15-30 cm). Ten surface and subsurface samples were collected and used for the assessment. Results of the field and laboratory analysis are presented in Table 4 for the dry and wet season respectively. The pH exhibited little seasonal variation, being slightly more acidic during the wet season.

Table 4 Physico-chemical analysis of collected soil samples in Enji dam site area

S/N	PARAMETERS	UNITS	WET SEASON MEASUREMENT	DRY SEASON MEASUREMENT	Mean conc
PHYSICAL PARAMETERS MEASURED					
1	Temperature	oC	27.2	20.1	23.65
2	Colour	TCU	2.87	1.88	2.37
3	Turbidity	NTU	5.36	5.91	5.63
4	Odour		No odour	No odour	
CHEMICAL PARAMETERS MEASURED					
5	Ph		7.20	7.23	7.21
6	EC	µS/cm	175	136	155
7	Chloride	mg/L	3.71	3.99	3.85
8	Total dissolved solid (TDS)	mg/L	140	136	138
9	Dissolved oxygen	mg/L	6.8	4.9	5.85
10	Calcium	mg/L	2.25	2.11	2.18
11	Magnesium	mg/L	20.50	14.9	17.7
12	Total Alkalinity	mg/L	0.35	0.22	0.28
13	COD	mg/L	11.1	10.2	10.65
14	Lead	mg/L	Nil	Nil	
15	Nitrate	mg/L	24.74	29.1	26.92
16	Sodium	mg/L	103.08	98.22	100.65
17	Residual chlorine	mg/L	2.02	1.9	1.96
18	Salinity	%	5.99	4.01	5.00
19	Total suspended solid (TSD)	mg/L	7.9	8.2	8.05
20	Total iron	mg/L	66.12	71.3	68.71
21	Zinc	mg/L	0.06	0.02	0/04
22	TOC	%	14.2	12.8	13.5

TOC = Total organic carbon, COD = Chemical oxygen demand

Positive impacts analysis of Enji dam construction in the area

Construction of the Enji dam and provision of treatment plant for public township water supply will go a long way to solve the acute water shortage in the area. More importantly, socio-economic, food production, livestock impact and more importantly public health are the obvious benefits among others the project will have on the inhabitants. Furthermore, the yearly menace of flooding in the area

will be reduced drastically as most of the water will be stored in the reservoir for public township supply. With a proposed designed installation of penstock inlet/outlet works, construction of embankment and related facilities, the construction of spillway and related facilities and construction/installation of pump house, pump assemblage and main pipeline for transporting raw water from the proposed dam to the treatment plant and many distribution pipelines to various business outlets, ponds, homes, recreational facilities that will be springing up soon, the proposed project is a noble one. It will have tremendous socio-economic impact and inclusive growth of the inhabitants in the area, Offa town and Kwara state in general.

Impact on socio-economic activities of inhabitants

Construction of Enji dam is expected to have a higher impact on the socio-economic activities of the people in the area, because better means of extra source of income is generated. Housing types varied from the respondents answer and quite visible on field. Most houses consist of modern brick apartments with iron roofing sheets and others not roofed ie under construction. Also, some plastered while others not. The other dwelling factors considered in the interaction was the decorations (painting and thatching), accessibility to water, recreational and entertainment facilities for the children. Respondents were reluctant in giving out such basic information but still had better answers from about 48% of the respondent. Residents of migrants, indigenes and foreigners mostly students category all enjoy cordial relationship with everyone going about his or her normal economic business activities. It is worthy of note that most tiled houses are occupied by students. Detailed statistical result of painted, unpainted, tiled and uncompleted houses are contained in Figure 4 as part of the environmental analysis of the study.

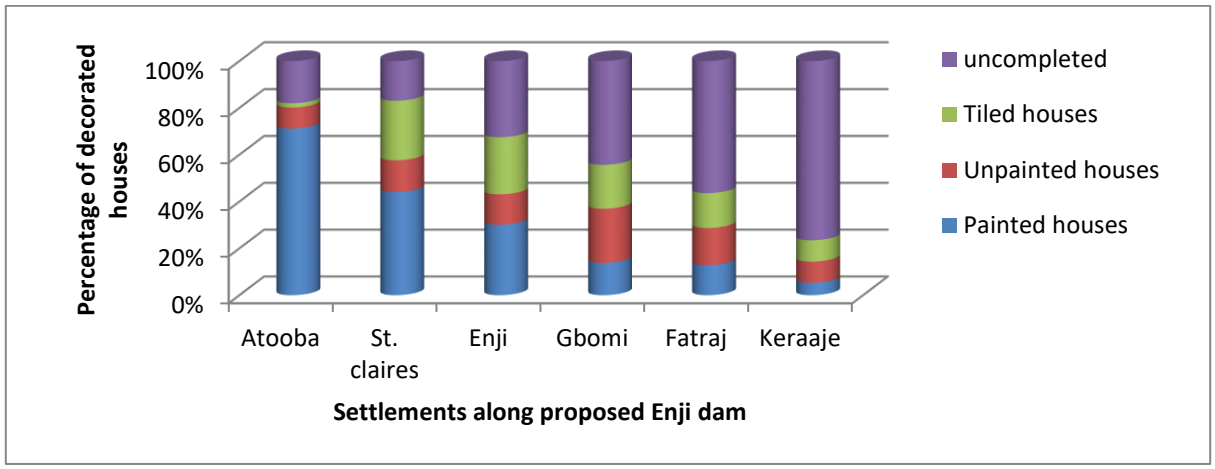

Figure 4 House decorations in the investigated areas along Enji study area

From all indications, lifestyle of the inhabitants revealed majority are single which can be traced to studentship of the investigated areas. This critical aspect of the environmental impact assessment showed married inhabitants are 364 and 351 at Atooba and st. Claire's respectively. It is worthy of note that these areas are further far from the location of Offa health technology school which is of about 2-4 km apart. There is high inter and intra-tribal conjugal bliss among the students from Lagos, Oyo, Ogun, Edo and Osun states.

As part of the socio-economic analysis of the area, major occupation of the people in the area is government job ie civil servants (state and local council), others are operating businesses while some are into petty trading with shops and kiosks around. It is worthy of note that the artisans are classified under the business category in the area. Atooba recorded 39%, 34%, 22% and 5% for civil servants, business (inclusive of artisans), shop owners and kiosk operators respectively. St. claires recorded 28%, 31%, 11% and 30% for civil servants, business (inclusive of artisans), shop owners and kiosk operators respectively (Figures 5 to 7). Enji recorded 29%, 30%, 09% and 32% for civil servants, business (inclusive of artisans), shop owners and kiosk operators respectively.

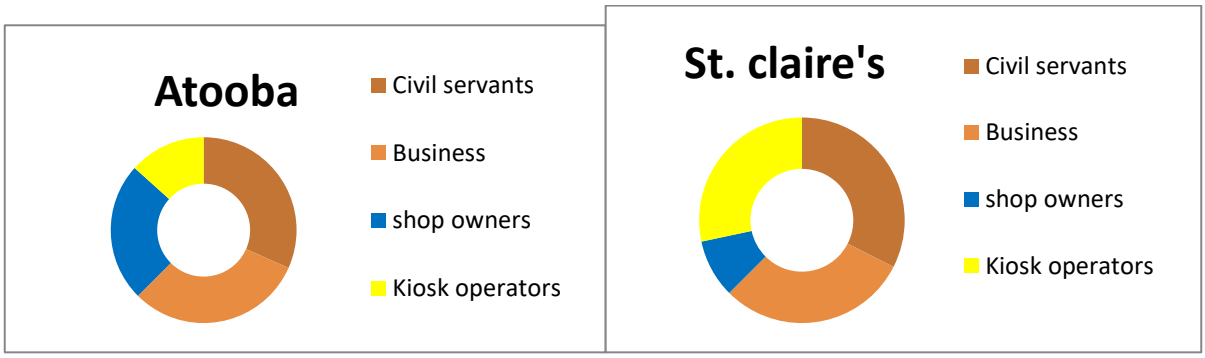

Figure 5 Major occupation of Atooba and St. claires study areas.

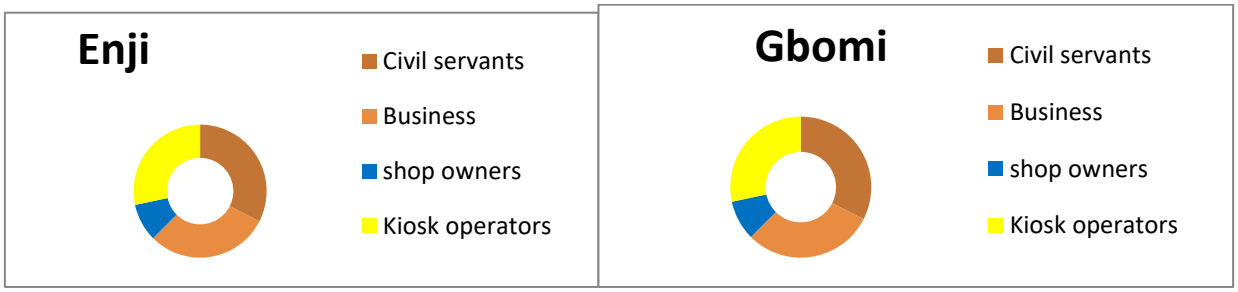

Figure 6 Major occupation of Enji and Gbomi study areas.

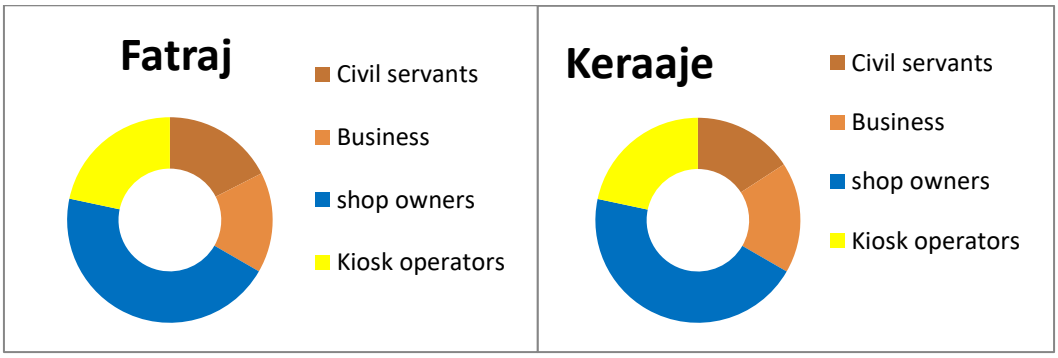

Figure 7 Major occupation of Fatraj and Keraaje study areas.

Impact on food production

Food production in these areas have diminished to the level of planting for just household purposes. Availability of land is also a major factor that has influenced the cultivation of food for large- or small-scale purposes and all traced to urbanization. At Atooba, there is no single land that is available for cultivation, as such, planting is just strictly at household scale where it was observed that sweet potato, tomato and banana are the favorites of the inhabitants (Figure 8). Detailed investigation of the area has shown that 69% of cultivation at home scale level is sweet potato, 28% is for tomato and 3% for banana cultivation. Moreover, at st. claire's the situation is not too different from that of the Atooba area where most land available have been used to construct houses for rentage purpose. Food production in this area also occurs at small scale with 61% of cultivation at home scale level being sweet potato, 32% is for tomato and 7% for banana cultivation. Furthermore, at Enji area where the proposed Enji water works is to be located 71% of cultivation at home scale level is sweet potato, 23% is for tomato and 6% for banana cultivation (Figure 8).

Conversely, the situation is different at Fatraaj area where physical construction of hostels for students is ongoing with little land available for planting of crops. 91% of cultivation at home scale level around this area is sweet potato, 8% is for tomato plantation and 1% for banana cultivation. At Gbomi area, the assessment revealed that 59% of cultivation at home scale level is sweet potato (Figure 8), 38% is for tomato and 3% for banana cultivation (Figure 8). More importantly, Keraaje still has largest expanse of land among all

investigated areas for large food production, but the farmers are also gradually loosing the arable land to the money bags in the society for immediate cash investment by constructing hostels for students at exorbitant rates. 71% of the arable land is having sweet potato being planted, 22% is for tomato and 7% for banana cultivation (Figure 8). In essence, the coming on stream of the proposed Enji dam will have a tremendous impact on food production especially in areas like Keraaje, Gbomi, Fatraj and Enji.

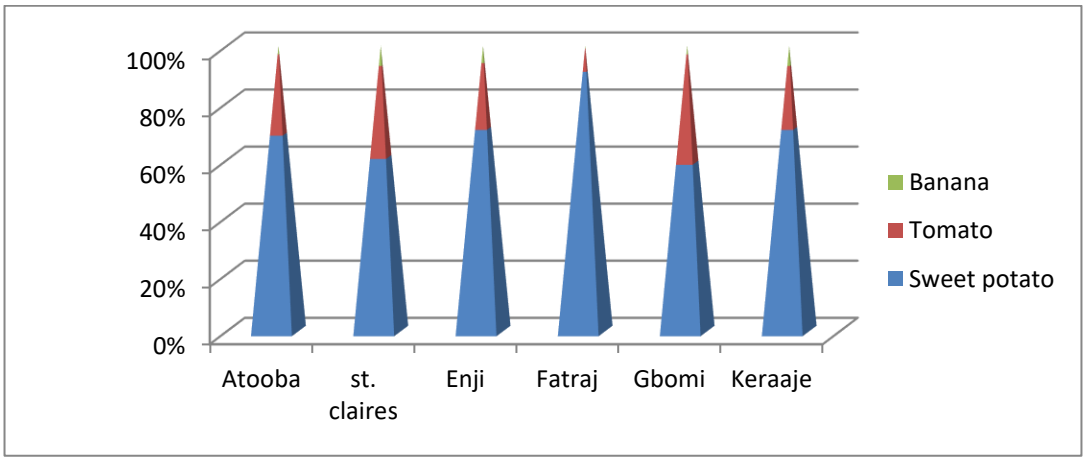

Figure 8 Major food production along investigated areas

Impact on Public Health

Malaria is the commonest health problem commonly facing the inhabitants (Figure 9). Cholera and Bilharzia occurs in very minute amount in the area so not represented in the chart. Atooba (Ariya) is faced with few malaria cases traced to prompt and timely evacuation of their accumulated waste in the area. St. Claire's area around ikotun road is equally a densely populated area with low amount of malaria with few cholera cases that can be traced to moderate mode of disposal of their waste ie public waste disposal which are commonly evacuated timely by state or local environmental protection agency. Furthermore, Enji, Gbomi and Fatraj are having higher cases of malaria and cholera cases because the mode of refuse diaposal is through neibourhood and waterways which is highly instrumental to the flooding episodes that occur around this area (Figure 9). This can vividly be seen around the fence of Health Technology, Offa where there are heaps of refuse unattended to for months.

During the rainy season this refuse find their way into waterways blocking the very drainage system, as such cause the massive flooding prone to that area. Information available showed the main road is commonly cut off by flooding such that motorists will have no choice than to park at the peak of rainy season. Low amount of back pain has indicated few active farmers in the area using hoe and cutlasses (Figure 9). The situation at Keraaje is more worrisome because there is virtually no sign of any waste disposal system in the area and the local and state government environmental protection agency do not go to this area to evacuate the generated waste. More disturbing is that no sign of observation of monthly environmental exercise in the area as most inhabitants do not give the monthly environmental the attention it deserves, they only use the period of the exercise to clean their apartment and they are the major producer of the generated waste in the area. Major sources of water are through the shallow wells with few boreholes that dry up at the peak of dry season.

Main health challenges in the area are malaria and cholera with very few cases of backpain and dysentery recorded (Figure 9). It is worthy of note that the back pain recorded ailment succession has an arithmetic progressive trend from Atooba down to Keraaje area and this can be traced to availability of land in that order, so with less land availability at Atooba, less farmers are present with more urbanization compared to Keraaje where there is still more land that are cultivated for crops plantation in that area. Conversly, the recorded cases of malaria reduce from Atooba area to Keraaje area which can be traced to availability of water for environmental sanitation and hygiene condition. Moreover, with a proposed Enji dam and its associated water works, most communities will have a drastic reduction in most of the recorded ailment.

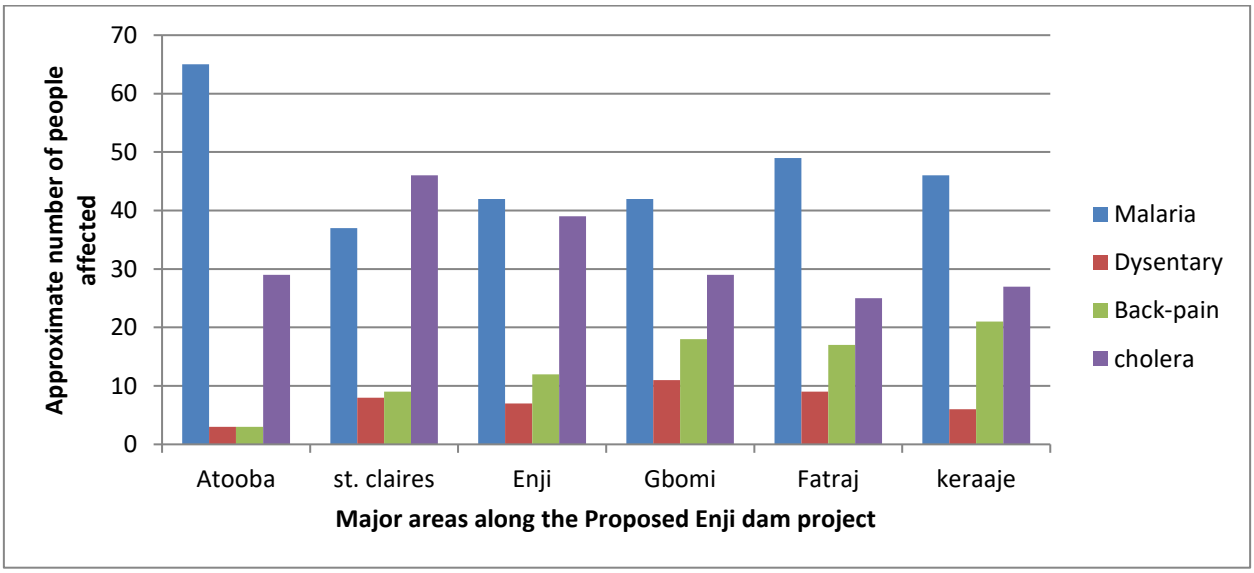

Figure 9 Health care ailments recorded in the areas

Mitigation efforts on adverse effects

Notable adverse impact will include among others sedimentation i.e. silting of the dam, changes in primary productivity due to biochemical reactions, risk of eutrophication/growth of non-native and/or invasive species, growth of aquatic macrophytes in the littoral and sub-littoral zone of the reservoir, creation of favorable habitats for the growth and proliferation of disease vectors, alterations in the flow of water and changes in water quality during the construction of the dam, embankment, impacts due to air pollutant emissions/noise and dust generated during earthwork, changes in downstream ecology, loss of land, risk of introduction of new diseases like schistosomiasis, bilharzias, conflicts resulting from insensitivities of dam construction personnel to the local culture, traditions and lifestyles. All these are categorized into ecological, socio-economic and health impacts and their mitigation measures provided (Tables 5, 6 and 7).

It is worthy of note that a comprehensive waste management plan will be needed for the Enji area for waste reduction, reuse, recycling, and recovery. All wastes that require treatment will have to be treated in accordance to acceptable standards prior to disposal (in a responsible manner). This will enhance the lifespan of the proposed dam when eventually constructed. Monitoring and periodic assessments shall involve sampling and analysis of environmental components like soils, vegetation, water, air and biota, as well as emissions, effluents or systems, at regular intervals of the dam area. At the end of the design life, the dam shall be decommissioned and abandoned i.e. site abandonment. A comprehensive plan should be prepared for the restoration and subsequent protection of the ecosystem and the environment.

Table 5 Major ecological impacts and mitigation efforts

ECOLOGICAL EFFECTS AND MITIGATION MEASURES OF THE PROPOSED DAM		
	Ecological Impacts	Mitigation measures
1	Sedimentation in the reservoir	• Ensure regular penstock releases • Increase frequency of releases when sediment load of inflowing water increases. • Ensure catchment protection and watershed management
2	Release / accumulation of bye-products of anaerobic decomposition	• Ensure regular penstock releases • Monitor water quality, including penstock releases
3	Changes in downstream ecology	• Ensure minimum ecological releases, • Monitor seepage /penstock release volumes
5	Release / accumulation of bye-	• Ensure regular penstock releases

	products of anaerobic decomposition	• Monitor water quality, including penstock releases

Table 6 Adverse socio-economic impacts and mitigation efforts

ADVERSE SOCIO-ECONOMIC IMPACTS AND MITIGATION MEASURES		
	Socio-economic Impacts	Mitigation measures
1	Compensation due to loss of land, farmland, fishponds etc	• Gender equity in compensation • ensure payment is to affected women. • Use verifiable documents to compensate all claims, irrespective of gender, class, ethnic or religion inclination
2	Skilled work-force from outside the Enji area	• Ensure all unskilled workforce comes from the immediate communities. • Ensure food vendors are from the immediate localities of the area
3	Conflicts commonly arise between the communities, cultural heritage, tradition and customs.	• Encourage community meetings • Accessibility to the facility should be the same across tribes and tradition, irrespective of the precise location. • Sensitization on any destruction of heritage site.
4	Unwillingness of farmers to pay the token water rates	• Collection of water rates through community meetings
5	Risk of accidental drowning. Injuries during dam construction and/or due to vehicular traffic	• Keep unauthorised persons away from dangerous zones • Put warning signs (written in English and local languages) at strategic sites • Ensure regular monitoring of embankment, penstock and spillway.

Table 7 Major public health impacts with mitigation efforts

ADVERSE PUBLIC HEALTH IMPACTS AND MITIGATION MEASURES		
	Public health Impacts	Mitigation measures
1	Opportunistic growth of aquatic macrophytes in the littoral and sub-littoral zone of the reservoir could hinder public health	• Monitor for any unusual floral species • Remove such species when seen.
2	Creation of favorable habitats for the growth and proliferation of disease vectors	• Monitor the presence of disease vectors • Contribute to strengthening of local health facilities through public enlightenment • Contribute public health programmes to eradicate / protect against malaria, schistosomiasis, etc • Continuous flow of spillway, hence the likelihood of creation of habitats for bilharziasis
3	Conflicts commonly arise between the communities, cultural heritage, tradition and customs.	• Encourage community meetings • Accessibility to the facility should be the same across tribes and tradition, irrespective of the precise location. • Sensitization on any destruction of heritage site.
4	Risk of introduction of new diseases as schistosomiasis	• Monitor for the presence of snails of Bulinus species • Contribute to strengthening of local health facilities

4. CONCLUSIONS

The construction of the Enji dam will be feasible to impound water for storage that will be treated for the inhabitants to serve them with good potable water. Catchment area of 38 km2 is envisaged, annual runoff has been estimated to be about 52,988,620 m^3. This will contribute greatly to the amount of raw water that will go into the reservoir. Freeboard is expected to be 2 meters. Crest length and elevation are 106.9 m and 45 a.s.l. (above sea level) respectively. Spillway type and discharge rate are expected to be broad crested and 377 m^3 s^{-1} respectively. Highest rainfall and humidity pattern of the study area ranges from around July to October. July 137mm, August 133 mm, September 164 mm and October 114 mm of rainfall will contribute to the seasonal storage of water in the proposed reservoir.

Positive impact prediction on socio-economic, food production and public health are high and good across investigated areas, but adverse impacts will be recorded and include among others sedimentation ie silting of the dam, changes in primary productivity due to biochemical reactions, risk of eutrophication/growth of non-native and/or invasive species, growth of aquatic macrophytes in the littoral and sub-littoral zone of the reservoir, creation of favorable habitats for the growth and proliferation of disease vectors. Alterations in the flow of water and changes in water quality during the construction of the dam, embankment, impacts due to air pollutant emissions/noise and dust generated during earthwork, changes in downstream ecology. Loss of land, risk of introduction of new diseases like schistosomiasis, bilharzias, conflicts resulting from compensation for land lost to the project, destruction of some local culture, tradition and lifestyle heritage.

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Ethical approval

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Informed consent

Not applicable.

Conflicts of interests

The authors declare that there are no conflicts of interests.

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Data and materials availability

All data associated with this study are present in the paper.

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