ResearchGate

See discussions, stats, and author profiles for this publication at: https://www.researchgate.net/publication/225525139

Post-project analysis: The use of a network diagram for environmental evaluation of the Barekese Dam, Kumasi, Ghana

Article *in* Environmental Modeling and Assessment · August 2006

DOI: 10.1007/s10666-005-9021-7

CITATIONS
9

READS
400

3 authors, including:

Isaac K. Tetteh
Kwame Nkrumah University Of Science and Technology
16 PUBLICATIONS **81** CITATIONS

SEE PROFILE

Esi Awuah
University of Energy and Natural Resources
103 PUBLICATIONS **631** CITATIONS

SEE PROFILE

Some of the authors of this publication are also working on these related projects:

Project Toilet technologies for faecal sludge management View project

Project Granger Causality Analysis of Some Macroeconomics Variables in Ghana View project

All content following this page was uploaded by Isaac K. Tetteh on 18 March 2017.

The user has requested enhancement of the downloaded file.

Environmental Modeling and Assessment (2006) **11:** 235–242
DOI: 10.1007/s10666-005-9021-7
© Springer 2005

Post-project analysis: The use of a network diagram for environmental evaluation of the Barekese Dam, Kumasi, Ghana

Isaac Kow Tetteh[a,‡,*], Esi Awuah[b] and Emmanuel Frempong[a]

[a] *Department of Theoretical and Applied Biology, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana*
E-mail: kowtet@yahoo.com, iktetteh.sci@knust.edu.gh, efrempong.sci@knust.edu.gh
[b] *Department of Civil Engineering, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana*
E-mail: eawuah.soe@knust.edu.gh

The paper presents an evaluation of post-project impacts of the Barekese Dam on three riparian communities downstream about 30 years after its construction. A network diagram, which incorporated a mathematical model, was used for impact identification and analysis. The expected environmental impacts, expressed as quantitative weighted impact scores, showed that the dam appeared to have exerted adverse impacts on the environmental quality of the communities. The impacts in the communities, however, increased with relative distances away from the dam and the river suggestive of cumulative impacts transmitted downstream. Strategic measures for improving environmental quality of the communities have been given.

Keywords: dam, environmental evaluation, expected environmental impacts, post-project impacts, riparian communities

1. Introduction

Post-project analysis (PPA) has been defined by Gilpin [1] as “an environmental study undertaken during the operational stage of a project (or programme) to assess compliance with terms required by an environmental impact statement, and to consider the quality and possible improvement of environmental management.” However, several projects were implemented before the advent of Environmental Impact Assessment (EIA), which originated in the USA [2], and therefore missed EIA requirements. In the case where projects met the requirements, most often, especially in the developing countries, post-project audits and monitoring are rarely conducted, and their repercussions are serious. Culhane [3], having evaluated the status of post-project monitoring, stated clearly and concisely: “relatively few post-EIS audits have been conducted by anyone.” In light of this, a lot of emphasis has been put on extensive post-project environmental monitoring since the 1970s [4]. Furthermore, two arguments have usually been advanced in support of post-EIS audits: “one concerns enhancing forecasting capabilities and the other is based on improving project outcomes” [4].

The World Commission on Dams (WCD), in a move to strengthen its knowledge base, wrote a report, *Dams and Development – A New Framework for Decision Making*, based on seven case studies, two country studies, one briefing paper, 17 thematic reviews of five sectors, a cross-check survey of 125 dams, four regional consultations and 1,000 topic-related submissions [5], addressing several issues on environmental impacts of dams. The Barekese Dam, just like some others, was constructed about two decades before Ghana adopted EIA in 1994 [6]. Having therefore missed EIA requirements, an attempt should be made to evaluate its post-operational impacts, both direct and indirect, primary or higher-order impacts about three decades of its operation to ascertain the status of environmental quality of the downstream riparian communities in proximity to it. An approach to realise this would be the use of a network diagram, which incorporates a mathematical model that relies on a weighting system [7]. The essence of this approach would be the transformation of all qualitative and quantitative direct and indirect, primary or higher-order impacts of the dam into a common quantitative denominator [4, 7, 8]. The summation of the impacts would be the expected environmental impacts [7], expressed as quantitative weighted impact scores [4, 7, 8], indicative of the environmental quality of the communities.

The aim of this study was to use a network diagram for evaluating the post-operational impacts of the dam on three riparian communities downstream, the outcome of which would enhance the design of strategic measures for improving environmental quality.

2. Methods

The study comprised methods that involved evaluation of the environmental changes occurring in three riparian communities downstream before and after about three decades of the operations of the dam. This required establishing environmental conditions in the affected

‡ Current address: ES King Village, Apartment M-12, 3810 Jackson Street Raleigh, NC 27607, USA
* Corresponding author.

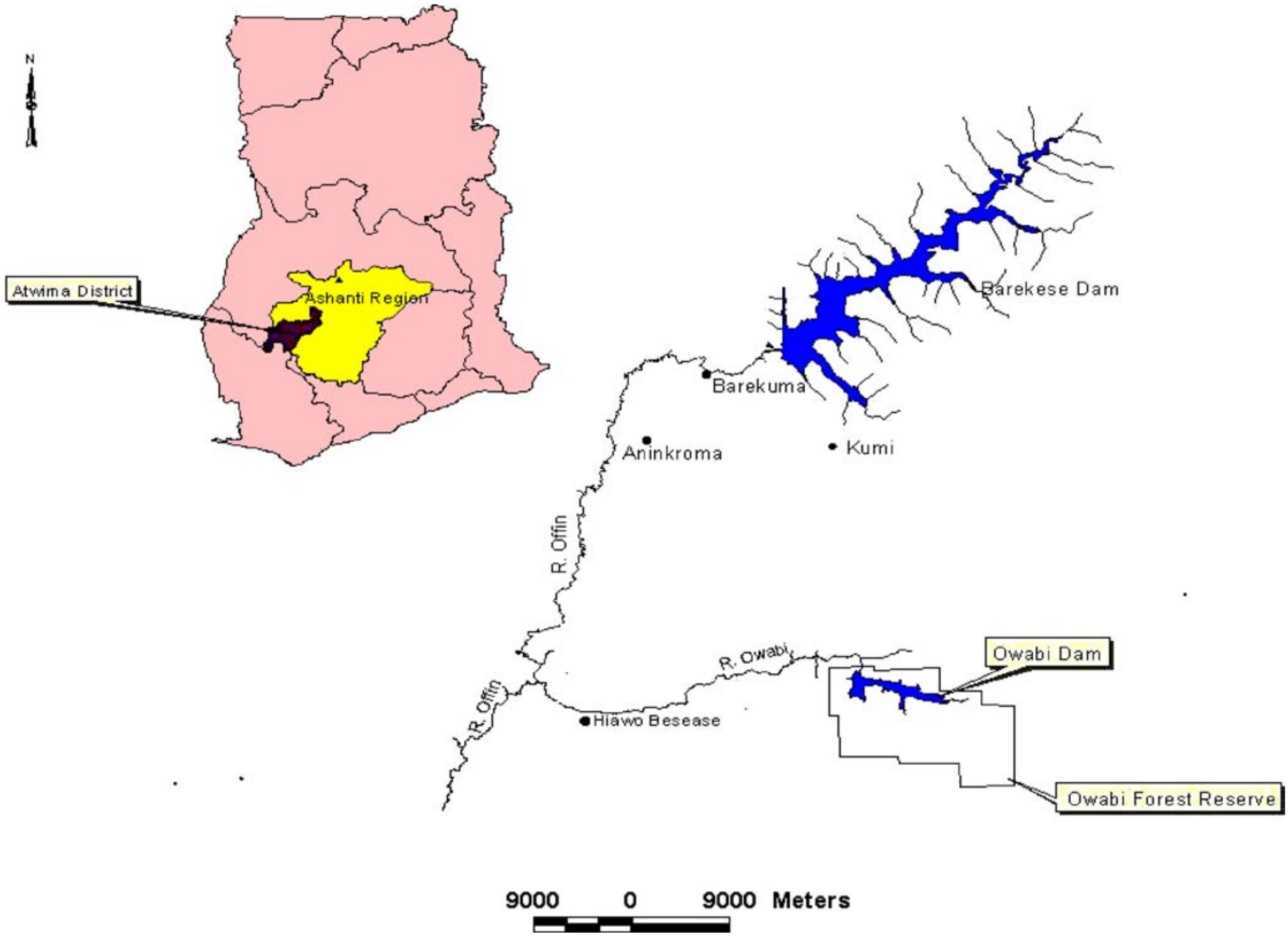

Figure 1. Map of Ghana showing the study areas in the Atwima District of the Ashanti Region.

communities in the pre-project and post-operational phases of the dam and the subsequent use of a network diagram that incorporated a mathematical model for evaluating the environmental changes.

2.1. Brief description of the study areas

The dam and the communities, namely, Barekuma, Aninkroma and Hiawo Besease (Figure 1), are located in the Atwima District in the Ashanti Region of Ghana. The Barekese Headworks, constructed between 1967 and 1972, comprise a dam on River Offin, pumping stations for both raw and treated water, treatment works and a 0.09 m transmission pipeline to the distribution centre and reservoir in the city. The dam was constructed primarily for production and supply of potable water. The second purpose for its construction was to generate hydropower to supplement the national grid provided by the Akosombo

Table 1
Locations of the study areas, distance from their water sources and brief demographic characteristics of the communities.

Study areas	Locations	Bearings and distance from the dam (°/km)	Main water source(s)	Distance from their water source(s)/km	Estimated population		Estimated number of households		Average household size	
					1966	1999	1966	1999	1966	1999
Barekese Dam	6°50′, 1°44′W									
Barekuma	6°49′, 1°46′W	082°14′; 1.3 km	R. Offin	0.3	750	2000	35	140	21	14
Aninkroma	6°48′, 1°46′W	072°21′; 1.5 km	R. Offin	0.4	600	1200	30	80	20	15
Hiawo Besease	6°44′, 1°47′W	031°03′; 4.1 km	R. Offin R. Owabi	0.9 0.3	1200	2500	50	160	24	16

Dam. However, this was abandoned when the government in power was ousted by the military and police on 24th February 1966 [9, 10]. The dam has served the first purpose since then. Having a gross reservoir capacity of 8 billion gallons (35.3 Mm^3) and a maximum depth of 13.7 m, it controls a catchment area of 906 km^2. The locations of the dam, the communities, their water sources and brief demographic characteristics are presented in Table 1.

The main occupation of the communities is agriculture, cocoa being the main cash crop cultivated and the leading traditional export crop of the country. This crop is cultivated by the rural folks that constitute about 70% of the population of the country. Other crops cultivated are maize, plantain, cocoyam, yam, cassava and vegetables.

2.2. Analytical approach

A network diagram that incorporated a mathematical model relying on a weighting system was used for impact identification and evaluation of expected environmental impacts (EEIs) of the dam [7, 11]. The EEIs of the dam were obtained by estimating the environmental change between pre-project (1966) and post-operational (1999) conditions in the communities. The magnitudes of the EEIs were indicative of the environmental quality of the communities. The functional relationships between the dam's impacts (EEIs)/the environmental quality of the communities and their variations with distance downstream and from the river were also estimated by a multiple linear regression analysis.

2.2.1. Network diagram

Following initial site visits to the headworks and the communities, a network diagram (Figure 2) was designed based on three main project actions/activities associated with the operation of the dam. The actions recognised as very critical in triggering off primary and higher-order impacts were:

(i) Impoundment of River Offin leading to the formation of the Barekese Dam.

(ii) Discharge of untreated wastewater downstream during water treatment that flows through the communities.

(iii) Occasional backwashing of clogged filters and subsequent emission of associated effluents downstream.

In the absence of environmental database on the baseline conditions of the communities and the post-

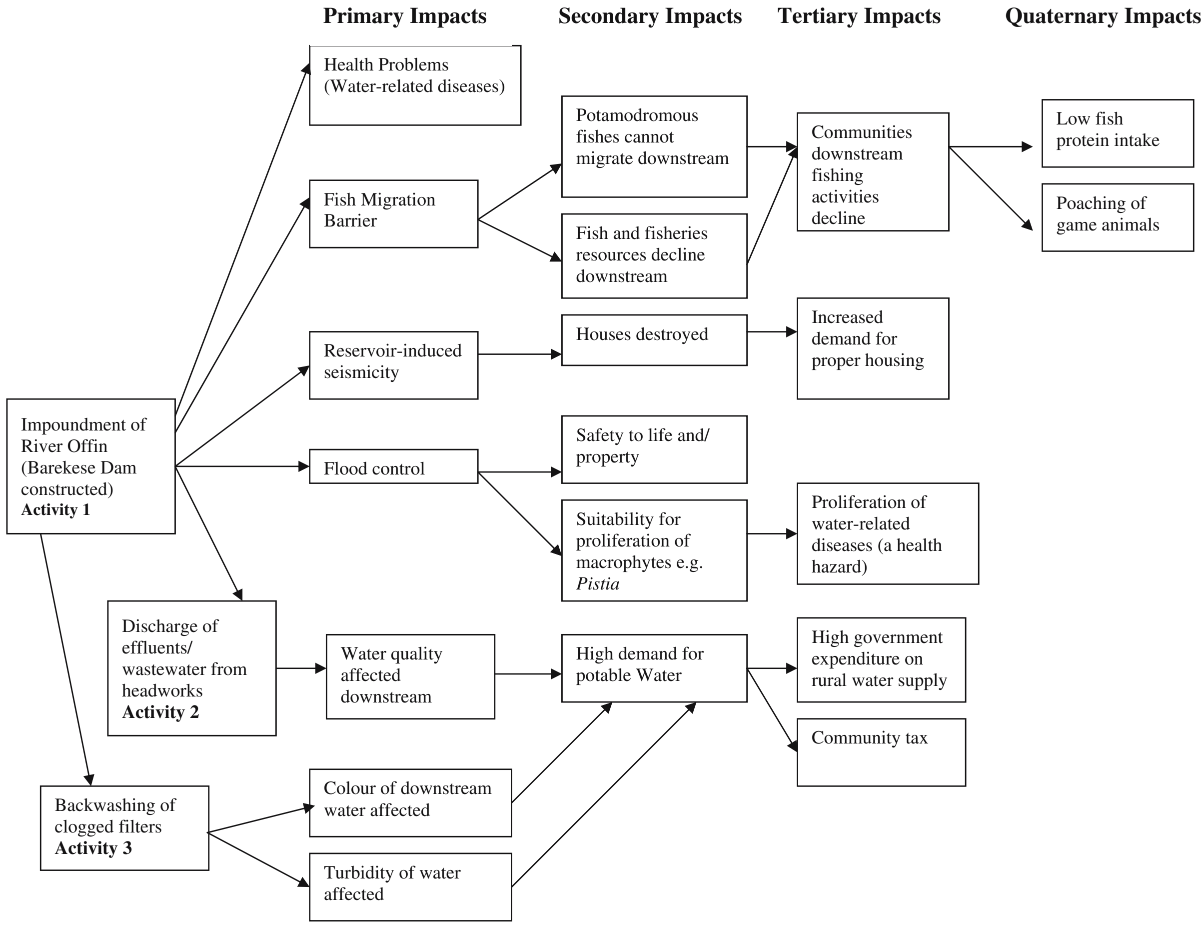

Figure 2. A network diagram for identification of post-operational impacts of the Barekese Dam.

operational impacts of the dam, a network diagram was then used for gathering primary data both for the environmental conditions of the downstream communities before and after about three decades of existence and for the operation of the dam for the purpose of impact identification, measurement, quantification and prediction [7]. The data collection involved field surveys and laboratory investigation of the quality of wastewater discharged downstream that flows from below the dam through the riparian communities.

In the field study, the same sample size and methodology used by Tetteh [12] and Tetteh et al. [13] involving administration of questionnaires in the same communities were employed for gathering relevant data for the events on every branch in the network diagram (Figure 2). The water quality was analysed in the dry season using standard method techniques [14]. The parameters analysed were colour, turbidity, temperature, conductivity, total hardness, total alkalinity, total aluminium concentration, total dissolved solids, pH, chemical oxygen demand and biological oxygen demand. The results were compared with the general effluents quality guidelines for discharges into natural water bodies [15] to assess the level of environmental pollution from which inferences were made to suggest the water quality in the communities before the dam was constructed. The third action was assessed qualitatively in the field study since this action had taken place before the commencement of the study. In this assessment, colour and turbidity, the only visual pollution indices used by the communities in such circumstances, were considered.

2.2.2. Model description

Three aspects of the model considered for the study were its features (characteristics), method of estimation and application. The features of the model are reflected in its specifications in terms of the variables involved and their mathematical relationships, among others. The estimation involves obtaining numerical estimates of the model parameters by gathering of statistical observations (data) on the variables included in the model in an applied research.

Table 2
Impact frequencies and the expected environmental impacts of Barekese Dam on the communities.

Impacts		Probability of occurrence			Magnitude of action, $\pm M(x)$	Importance weighting, $I(x)$		
		B	A	HB	B, A & HB	B	A	HB
1	Health problems	0.03	0.12	0.01	−9.5	0.4	1.4	0.2
2	Fish migration barrier	1.0	1.0	1.0	−10	10	10	10
3	Potamodromous fishes cannot migrate downstream	1.0	1.0	1.0	−10	10	10	10
4	Communities downstream fishing activities decline	0.74	0.79	0.64	−10	7.4	7.9	6.4
5	Low fish protein intake	0.74	0.79	0.64	−9.5	7.4	7.9	6.4
6	Low fish and fisheries resources downstream	0.8	0.8	0.8	−10	8	8	8
7	Poaching of game animals	0	0	0	−2.0	0	0	0
8	Reservoir-induced seismicity	0	0	0	−9.8	10	10	10
9	Houses destroyed	0	0	0	−9.8	0	0	0
10	Increased demand for proper houses	0	0	0	−9.8	0	0	0
11	Flood control	1.0	1.0	1.0	+5.5	10	10	10
12	Safety to life and/or property	1.0	1.0	1.0	+5.5	10	10	10
13	Suitability for proliferation of macrophytes, e.g. *Pistia*	0	0	0	−6.3	0	0	0
14	Proliferation of water-associated diseases (a health hazard)	0.03	0.12	0.01	−9.5	0.4	1.4	0.2
15	Discharge of effluents/wastewater downstream	1.0	1.0	1.0	−4.5	10	10	10
16	Downstream water quality affected	0.1	0.0	0.4	−9.0	1.4	0	9
17	High demand for potable water	1.0	1.0	1.0	−6.5	10	10	10
18	High government expenditure on rural water supply	0.95	0.95	0.95	−95	10	10	10
19	Community tax	0.05	0.05	0.05	−5	10	10	10
20	Backwashing of clogged filters	0.2	0.2	0.2	−10	10	10	10
21	Colour of downstream water affected	0.2	0.2	0.2	−10	10	10	10
22	Turbidity of downstream water affected	0.2	0.2	0.2	−10	10	10	10
Expected environmental impacts (EEIs): $\sum_{i=1}^{n} P_i$ (impact score for branch i)						−129	−144	−209

B: Barekuma; A: Aninkroma; HB: Hiawo Besease.

2.2.2.1. Features of the model

The mathematical model in Rau and Wooten [7] used for total impact evaluation in a network diagram is given by:

$$\sum_{i=1}^{n} P_i(\text{impact score for branch } i) \qquad (1)$$

where P_i is the probability that events on branch i occur (impact frequency) for $i = 1, 2, 3, \ldots n$, where n is the total number of branches in a network diagram. The model also makes use of:

(i) Environmental change between the initial and final states of environmental conditions.

(ii) Impact descriptors [7, 16, 17] that include the following:

- Magnitude (M), which is the intensity (size) or severity of an impact on the environmental elements (i.e., the level at which the effect impinges upon the environment).
- Importance (I), which is the extent of an impact or spread (distribution over space or number of people affected).
- Direction of impact [i.e., whether the impact is beneficial (+) or adverse (−)].
- Duration (i.e., whether the impact is short or long term, recurring impacts, their frequency, etc.).
- Directness (i.e., whether the impact is direct or higher-order impact).

(iii) A weighting system [7].

This transforms Ms and Is of all the qualitative and quantitative data direct and indirect, primary and higher-order impacts in a network diagram into weights and common quantitative denominator [7, 8] for incorporation into the model. The inherent subjectivity in the estimation of weights is minimised using the Delphi technique [11–13, 18].

2.2.2.2. Estimation of total project impact by the model

The calculation of the impact score using equation (1) for any one branch in a network diagram is given by [7]:

$$\sum M(X)I(X) \qquad (2)$$

where X = each impact identified in the network (i.e., directness), $M(X)$ = (±) intensity of impact X (i.e., magnitude), whether it is beneficial (+) or adverse (−) (i.e., direction), and $I(X)$ = importance/significance (extent) of impact X (i.e., its spread).

The product of the probability of occurrence (P_i) of the events of a branch and its corresponding impact score gives the impact of a particular branch expressed as quantitative weighted impact scores [7, 8]. The summation of the weighted impact scores of all the individual branches is the expected environmental impacts (EEIs) representing the total impact evaluation of a project on the environment [7].

2.2.2.3. Model application

In its application, the primary data obtained for all direct and indirect impacts (directness) in Figure 2 were transformed into weights (Ms–intensity of impacts and Is–spread of impacts) based on a weighting system developed by Tetteh [12] and Tetteh et al. [13, 18]. The probability P_i [19, 20] that events on branch i occur (duration), i.e., the impact frequencies (Table 2), were estimated from the results obtained from the primary data. The direction of impacts (whether beneficial or adverse) was also estimated from the results obtained from the primary data as well as information obtained from extensive literature reviews and case studies [5, 21].

2.3. Regression analysis

A multiple linear regression model was formulated to analyse environmental quality of the communities as a function of distance from the dam and their water sources (Table 1). The model is given by:

$$E_q = \beta_0 + \beta_1 D_d + \beta_2 D_w + U$$

where E_q is the environmental quality, β_0, β_1 and β_2 are the parameter coefficients, D_d is the distance of the communities from the dam, D_w is the distance of the communities from their water sources and U is the error term.

3. Results and discussion

The network diagram and the model estimated positive, negative and zero impacts resulting from the post-project actions (Figure 2) on the communities. The multiple linear regression analysis also showed a direct relationship between the post-operational impacts of the dam and the variations in the environmental quality of the communities with respect to their relative distances from the dam and the river.

3.1. Impact identification and expected environmental impacts of the communities

The network diagram (Figure 2) established 14 branches and identified the following impacts in the riparian communities:

- Positive impact: branch 7 for all the communities.

- Negative impacts: branches 1, 2, 4 and 11–14 at Aninkroma; branches 1, 2, 4 and 9–14 at Barekuma and Hiawo Besease.
- No impact (zero impact): branches 3 and 5–10 at Aninkroma and branches 3 and 5–8 at Barekuma and Hiawo Besease.

Table 2 shows the impact frequencies (probabilities of occurrence), EEIs, Ms and Is estimations resulting from the post-operational actions of the dam. Barekuma, Aninkroma and Hiawo Besease registered respective EEIs of −129, −144 and −209 weighted impact scores, the negative values indicative of the adverse impacts of the dam. The EEIs of the communities rather increased with relative distances away from the dam and their water sources (R^2 = 0.987; adjusted R^2 = 0.974; $P < 0.01$), which are in contrast to spatial distribution of environmental change that experiences attenuation with distance away from the impact source [8, 22]. These observations are suggestive of cumulative impacts transmitted downstream [23]. The regression analysis furthermore suggested a strong association between the post-operational impacts of the dam and the environmental quality of the communities.

3.1.1. Health problems

Previous studies in the communities indicated that health problems endemic and also water-related were five diseases, namely, malaria, urinary schistosomiasis, diarrhoeal diseases, infectious hepatitis and scabies [12, 13]. The EEIs of the health problems with reference to these diseases at Barekuma, Aninkroma and Hiawo Besease were −0.1, −1.6 and −0.02 weighted impact scores, respectively. Downstream, the deterioration in health status was severe at Barekuma, the closest community to the dam (Figure 1), peaking at Aninkroma and improving at Hiawo Besease, the farthest community. The observed pattern in health problems along the river basin could be explained in terms of community risk factors and herd immunity [13, 24].

3.1.2. Impact of the wastewater on the downstream water quality and its implications

The impact of the wastewater discharge/occasional backwashing of clogged filters and its associated effluents on the quality of the downstream water and their implications identified by branches 9–14 resulted in EEIs of −50.2, −28.6 and −185.5 weighted impact scores for Barekuma, Aninkroma and Hiawo Besease, respectively. The downstream water quality parameters that appeared to have been affected by the two actions/activities (Figure 2) were as follows:

(i) At Barekuma: TDS, colour and turbidity.

(ii) At Aninkroma: colour and turbidity.

(iii) At Hiawo Besease: TDS, colour, turbidity and total aluminium.

The decline in the impact of the two actions in the deterioration of water quality from Barekuma to Aninkroma is in consonance with the theory of spatial distribution of environmental change, which declines with distance away from the impact source [8, 22]. However, the most serious deterioration registered at Hiawo Besease, the farthest community, rejects the theory [8, 22] in favour of cumulative impacts [23] that appeared to have resulted from the generation of effluents from the two reservoirs (Figure 1). Inferential analysis with reference to the general effluents quality guidelines for discharges into natural water bodies [15] and the communities' visual pollution indices therefore suggests that in the absence of infrastructural development such as the dam, the baseline water quality downstream would have maintained its natural quality with time. This further implied that had we had the opportunity of measuring the downstream pre-impoundment water quality, all the parameters investigated would have been below the guidelines, suggesting that the existing natural riverine systems had suffered no environmental pollution and, in that case, the EEIs without project actions would have been zero for all the communities.

In view of the deterioration in the downstream water quality, the communities were all demanding for potable water from the government as compensation. However, their high expectation would be tied to a community tax of 5% in a move by the government to supply potable water to rural areas in the country [25]. This measure apparently will overburden these communities, which are already deprived.

3.1.3. Impact of the embankment on fish and fisheries resources and livelihood of communities dependent on fishing

The EEIs resulting from the presence of the embankment in branch 2 (Figure 2) yielded −188.5, −224.1 and −133.0 weighted impact scores for Barekuma, Aninkroma and Hiawo Besease, respectively. The study further revealed that River Offin was very rich in fish and fisheries resources in pre-impoundment period. The dominant species included, among others, *Malapterurus electricus*, *Hepsetus odoe*, *Heterobranchus*/*Clarias* species, *Chrysichthys* species, *Channa obscura*, *Mastacembelus* species, *Synodontis* species, *Heterotis niloticus* and various cichlids, cyprinids and characids, freshwater crabs and prawns.

About three decades of operation of the dam, there has been a significant reduction in the fish and fisheries resources in the downstream communities. According to the study, the dominant species downstream in the post-operational phase were *Channa obscura*, *Mastacembelus* species and cichlids. On the other hand, freshwater crabs and prawns are now rare or extinct. This problem has arisen apparently due to their disappearance and has seriously affected households whose livelihood depends on fishing. The survey further indicated that the proportion of households in the communities that had at least a member engaged in active fishing used to be 85%, 78%

and 75.5% in the pre-impoundment phase for Barekuma, Aninkroma and Hiawo Besease, respectively. But this has now declined substantially to 5.6%, 0.0% and 11.1%, respectively, in the communities because of poor catch and disappearance of species. Consequently, fish protein intake of members of families engaged in fishing could be seriously affected. However, poaching of game as an alternative is not a characteristic of the communities. In a similar observation, the number of households dependent on fisheries upstream of the Pak Mun Dam in Thailand declined from 95.6% to 66.7% after the dam had been formed, and this was attributed to the decline in fish catch and disappearance of species [5]. Also, the construction of the Akosombo Dam has affected the catch downstream as well as the freshwater clam (*Egeria radiata*) fishery in the lower Volta River below Akuse [26].

3.1.4. The dam and induced seismicity

There has not been any evidence of earthquake and/or related phenomena in the vicinity of the dam and its catchment areas since its construction, although the occurrence of reservoir-induced seismicity in river basin development projects is a possibility and may have devastating effects [27, 28]. For instance, it has been reported that the possibility of earthquake occurring in Lake Kariba appears to have increased in the dam area since its construction [5].

3.1.5. Flood control and its impact

Although the initial reason for the construction of the dam was not to moderate floods, the survey indicated that natural floods, which used to be destructive and posed a safety hazard in the riparian communities, have been minimised following the construction of the dam. The positive action of flood control, which yielded EEIs of +110.0 weighted impact scores for each of the riparian communities, compares favourably with other reports [5, 21, 28]. Associated with this action was, however, the slowing down of the flow regime downstream, thus creating suitable habitats for the growth of macrophytes such as *Pistia* and proliferation of water-related diseases especially urinary schistosomiasis in the communities [12, 13].

3.2. Strategic measures for improving environmental quality

Since quality of life depends on the quality of the environment, it is imperative to embark on strategies that seek to improve environmental quality of the affected communities. The following measures are therefore recommended:

(i) Waste management

- The effluents can be treated before their final disposal with activated charcoal produced from coconut shell wastes that is known to be highly efficient in reducing substantially the levels of pollutants in heavily polluted waters [29].

(ii) Health management

- Provision of potable water will wipe about 75% of all parasitic diseases [30] in the communities.
- Provision of health centres at the community level for prompt treatment of the diseases is very important in disease control.
- Periodic health education and disease surveillance are also very vital in disease control [31, 32].
- Adapting environmental management methods [33, 34] for effective control of the diseases.

(iii) Fish and fisheries development

- Development of downstream fish and fisheries will help in the restoration and preservation of their biodiversity with other added advantages of increasing fish protein and offering employment opportunities for the affected communities.

Acknowledgements

We are thankful to the chiefs, elders and community leaders for granting us permission to carry out this piece of work. We also appreciate the full cooperation of the community members. We thank the health personnel at Abuakwa Health Post for providing information on endemic water-related diseases in the district. Finally, we express our sincere gratitude to Mr. Gerald Forkuo of the Department of Geodetic Engineering, Kwame Nkrumah University of Science and Technology, for designing the map.

References

[1] A. Gilpin, *Environmental impact assessment (EIA): cutting edge for the twenty-first century* (Cambridge University Press, Cambridge, 1995).
[2] L. Caldwell, *Science and the National Environment Policy Act* (University of Alabama Press, 1982).
[3] P.J. Culhane, Post-EIS environmental auditing: a first step to making rational environmental assessment a reality, Environ. Prof. 15(1) (1993) 66–75.
[4] L. Ortolano and A. Shepherd, Environmental impact assessment: challenges and opportunities, Impact Assessment. IAIA 13(1) (1995) 8, Spring.
[5] WCD, World Commission on Dams Report, available at http://www.dams.org (2000).
[6] E.P.A. Ghana, *Environmental Protection Agency Act* (Government of Ghana, 1994).
[7] J.K. Rau and D.C. Wooten (eds.), *Environmental Impact Analysis Handbook* (McGraw-Hill Book Company, New York, 1980) pp. 8-6–8-24.
[8] B. Julien, Current and future directions for structured impact assessments, Impact Assessment, IAIA 13(4) (1995) 403–432.

[9] GISD, Ghana Information Services Department, *GHANA – A Brief Guide* (1994).

[10] K. Boafo-Arthur, The political economy of Ghana's foreign policy. Past, present and the future, Ghana Soc. Sci. J. 1(1) (2000) 1–30, January.

[11] L.W. Canter, *Environmental Impact Assessment*, 2nd edn. (McGraw-Hill, Inc., New York, 1996) pp. 550–552.

[12] I.K. Tetteh, An assessment of the health and socio-economic impacts of the Barekese Dam on human communities downstream. M.Sc. Thesis, Department of Biological Sciences, KNUST, Kumasi, Ghana (1999) p.194.

[13] I.K. Tetteh, E. Frempong and E., Awuah, An analysis of the environmental health impact of the Barekese Dam in Kumasi, Ghana J. Environ. Manag. 72 (2004) 189–194.

[14] American Public Health Association/American Water Works Association/Water Environment Federation (1995), *Standard Methods for the Examination of Water and Wastewater* (18th edn.), eds. A.D Eaton, L.S. Clesceri and A.E. Greenberg (Washington, DC 20005, 1995) pp. 10–157.

[15] Ghana EPA, *General Effluents Quality Guidelines for Discharges into Natural Bodies of Water* (1999).

[16] B.D. Clark, K. Chapman, R. Bisset and P. Wathern, Methods of environmental impact analysis, Built Environ. 4(2) (1978) 111–121.

[17] J. Shopley and R. Fuggle, A comprehensive review of current environmental Impact assessment methods and techniques, J. Environ. Manag. 18 (1984) 25–47.

[18] I.K. Tetteh, E. Awuah and E. Frempong, Development of a weighting system for use in Environmental Health Impact Assessment associated with water impoundment projects in Ghana and its application 1, Journal of the Ghana Science Association 6(2) (2004) 59–69.

[19] D.H. Sanders, *Statistics – A Fresh Approach* 4th edn. (McGraw Hill Publishing Company, New York, 1990) pp. 253–288.

[20] D. Freedman, R. Pisani and R. Purves, *Statistics* (W. W. Norton and Company, New York, 1978) pp. 203–230.

[21] C. Harinasuta, S. Sornmani, T. Bunnag and P. Vivatanasesth, Investigation on socio-economic status, health and nutritional problems in connection with water resource development in south-east Asia. Tropical Medicine and Public Health Projects. TROPMED/pp-08 SEAMEO (1978) p.240.

[22] L. Changming and Z. Dakang, Environmental issues of the Three-Gorges project: an overview. In: *UNESCO/UNEP. The Impact of Large Water Projects on the Environment*. Proceedings of an International Symposium, UNESCO, UNEP, IIASA and IAHS, 21–31 October (1990) pp. 249–260.

[23] US-CEQ, United States Council on Environmental Quality. Regulations Implementing the National Environmental Policy Act. 40 CFR 1508.7, 1508.8, 1508.25 (1978).

[24] A.M. Lilienfeld and D.E. Lilienfeld, *Foundations of Epidemiology* 2nd edn. (Oxford University Press, Oxford, 1980) pp. 61–62.

[25] Daily Graphic, Rural people to pay for water supply, Ghana Newspaper. Tuesday, 21 October (1997) pp. 12–13.

[26] B. Moss, *Ecology of Freshwater*, 2nd edn. (Blackwell Scientific Publications, Oxford, 1988) pp. 258–272.

[27] R.C.S. Walters, *Dam Geology*, 2nd edn. (Wiley, Texas, 1971) pp. 50–62.

[28] N.K. Sarma, Environmental impacts of water resources projects: the Indian experience, in *UNESCO/UNEP. Impacts of Large Water Projects on the Environment*. UNEP, EMINWA, UNESCO. Proceedings of an International Symposium, UNESCO, UNEP, IIASA and IAHS 21–31 October (1990) pp. 239–248.

[29] I.K. Tetteh and K. Okyere-Kumah, Waste recycling: the potential of coconut shell wastes, *Technocrat* 2(3) (2004) 6–7.

[30] F.M.A. Ukoli, *Introduction to Parasitology in Tropical Africa* (Wiley, Great Britain, 1984) pp. 1–16, 52–89, 399–432.

[31] K. Tones and S. Tilford, *Health Education – Effectiveness, Efficiency and Equity*, 2nd edn. (Chapman and Hall, London, 1994) p. 462.

[32] W.H. Greene and B.G. Simons-Morton, *Introduction to Health Education* (Waveland Press, Inc., Illinois, 1984) p. 462.

[33] World Health Organisation, Environmental management for vector control. Fourth report of the WHO Expert Committee on Vector Biology and Control", WHO Technical Report Series no. 649 (WHO, Geneva, 1980).

[34] World Health Organisation, Manual on environmental management for mosquito control, WHO Offset Publication no. 66 (WHO, Geneva, 1982).

View publication stats