ENVIRONMENTAL QUALITY DIVISION

RESEARCH PROPOSAL FOR THE DEVELOPMENT OF SMALL SCALE SYSTEMS FOR IRON REMOVAL FROM GROUNDWATERS

DEPARTMENT OF CIVIL ENGINEERING
UNIVERSITY OF SCIENCE AND TECHNOLOGY
KUMASI.GHANA

ENVIRONMENTAL QUALITY DIVISION
(Civil Engineering Department)

RESEARCH PROPOSAL

FOR

THE DEVELOPMENT OF SMALL SCALE SYSTEM FOR IRON REMOVAL FROM GROUNDWATER

---------------oo0oo---------------

Submitted to

THE INTERNATIONAL DEVELOPMENT RESEARCH CENTRE,
OTTAWA, CANADA

By

THE CIVIL ENGINEERING DEPARTMENT
UNIVERSITY OF SCIENCE AND TECHNOLOGY
KUMASI, GHANA

A RESEARCH PROPOSAL FOR THE DEVELOPMENT OF SMALL SCALE SYSTEM FOR IRON REMOVAL FROM GROUNDWATERS

1. BACKGROUND

1.1 Groundwater Source

Groundwater constitutes a major source of cheap water supply for domestic and industrial purposes. A recent study has indicated that the cost of groundwater supplies in Ghana can be as little as 10% the cost of surface water supplies. One possible reason for the lower cost of groundwater is that in most cases, no treatment is normally required for groundwaters other than disinfection. It is therefore not surprising that most governments, especially in developing countries, have embarked on extensive programmes of rural water supply based on groundwaters.

Since about 80% of population in Africa lives in the rural areas, it stands to reason that a great majority of the rural people will have to depend on groundwater sources, Unfortunately, certain chemical substances (constituents), notably iron and manganese, are sometimes present in various concentrations up to say 30mg/1 in groundwaters. When these constituents are present in excessive amounts, objections are raised by consumers on the gounds of staining effects on laundry, cooking utensils and containers, and plumbing fixtures resulting in the rejection of water supplies. It is known that groundwaters in many countries contain these undesirable constituents far in excess in maximum permissible concentrations recommended by the WHO whose International Standards for Drinking Water (1971) give both the "Highest desinable" and Maximum permissible "levels as follows:-

Chemical substance	Highest Desirable level (mg/1)	Maximum Permissible level. (mg/1)
Iron	0. 1	1.0
Manganese	0.05	0.5

Iron is usually present in solution in the ferrous (Fe II) form but other forms,such as organic complexes or polymers may also be present. Such groundwater, which may be clear and bright initially on exposure to air, becomes discoloured opalescent due to oxidation of the ferrous iron to insoluble or colloidal ferric hydroxide. Manganese generally behaves like iron in that soluble manganese results in insoluble manganese oxides. As mentioned above, objections raised by consumers to the presence of iron and manganese in water is due to the production of discolouration, turbidity, deposit and bitter or metallic taste. Such waters are therefore unsuitable for domestic use.

A preliminary study of the Drinking Water Quality of Boreholes in the Rural Areas of Ghana recently completed by Water Recources Research Unit (W.R.R.U.) shows that over 30% of the boreholes have water in which iron concentration exceeds 1.0 mg/1 - the maximum permissible concentration, while 25% have manganese concentration exceeding 0.5 mg/1 - the maximum permissible concentration. The range of concentration reported is , for iron,zero to 20.5 mg/1 and, for manganese, zero to 4.5 mg/1.

1.2 Need for Research:

For a considerable length of time the Ghana Government has embarked on extentive programmes of rural water supplies through the Rural Water Supplies Division (R.W.S.D) of the Public Works

Department (P.W.D.). The Division's operations centred mainly on drilling boreholes and subsequent mechanisation, including hand pump installations. Functions of the R.W.S.D. have been taken over by the Drilling Section of Ghana Water and Sewerage Corporation. In the 1968/69 Fiscal Year, the Government presented what was code-named "Water Budget" to the nation. In that year alone, the target set was to increase the supply of potable water from about 33% to 40% of the population which was then about 8 million. Attempts are still being made for extension of potable water to the rest of the population.

The W.H.O. of the United Nations, acting as executing agency for the United Nations Development Programme (UNDP), is currently undertaking a Rural Water Supply and Environmental Health Programme in collaboration with the Ghana Water and Sewerage Corporation and the Ministry of Health respectively. In the Upper Region, the Canadian Government, through C.I.D.A., is involved in a project consisting of the sinking over 1,000 boreholes to be equipped with hand pumps for rural water supply, as well as in the programming of improvements in urban water supplies in the region. Apart from this region, the Volta, Eastern, Brong-Ahafo, Northern and Western regions derive their sources of supplies mainly from groundwater. Given that 30% of the groundwater supplies have excessive iron content and considering that thousands of wells are envisaged in the government rural water supply projects, the availability of a simple low cost system for iron removal would make an invaluable contribution to the success of the Government's rural water supply programme. Since such problems are related to lateritic nature of the soils and Fe and Mn. bearing minerals in the aquifers, many developing countries are reported to have similar groundwater quality problems. Hence, solutions provided by this study would also be of great value elsewhere.

The Indian N.E.E.R.I. (National Environmental Engineering Research Institute) has developed a unit for iron and manganese removal suitable for rural water supplies but little is known of its success in being accepted and maintained in rural areas. Likewise there are several industrial units available which, although simple in process design are very complex mechanically and far beyong the capability of the villager either to afford or maintain. There is no source which provides information on all the existing units; their merits, demerits, and conditions favouring their use.

This project, therefore, aims at meeting these needs.

2. OBJECTIVES

(1) To review available technology for small scale iron and manganese removal from groundwater in rural areas.

(ii) To improve by adaptation and/or innovation on existing methods of iron removal and make them applicable to the village conditions in Ghana.

(iii) To determine in the laboratory and field the relative effectiveness of the derived systems or units for small scale iron and manganese removal.

(iv) To recommend future activities by which the more promising iron and manganese removal units can be manufactured either at the village or industrial level to meet the demand for such units in Ghana.

(v) To recommend ways by which information on successful technologies can be disseminated at the village level in Ghana and to responsible agencies abroad.

3. METHODOLOGY

The project will be organised through pre-project activities followed by three main phases. Main pre-project activities are project Formulation and mobilisation. A post-project (fourth) phase is also planned for technology propagation and dissemination of information.

3.1 Phase 1 - Review of aVailabe technologies:

This review seeks to identity systems of small scale iron and manganese removal in use in various parts of the world. For each system, the technology of the system will be described in terms of components, principle of operation, materials for design and operation and maintenance, method of operation, associated equipment, cost of installation, operation and maintenance and their adaptability and dependability. Finally the removal efficiencies of the systems will be ascertained. These objectives will be achieved through literature review, correspondence, field visits and desk analysis.

3.1.1 Correspondence and contact with other research institutions:

The objectives of this correspondence will be two-fold; to identify countries having experience with problems of high concentrations of iron and manganese and to obtain information on any iron removal units which may be utilized in the field.

3.1.2 Desk analysis:

A survey of the literature and contact by mail with other workers in the field will be undertaken resulting in a state of the art review. It is likely that, apart from municipal and industrial applications, a few systems appropriate to the Ghanaian village will be identified. It is, therefore, expected that the vast majority of innovative work will have to be accomplished here in Ghana. Following this review of the literature and available materials the experimental design will be again considered and altered where necessary wit in the confines of the objectives stated above and the financial limits of the project. A full progress report will be submitted to ID.R.C. at this stage.

3.1.3 Ghana National survey:

Although some preliminary survey work has been completed (see attached) on iron and manganese levels in Ghanaian waters, the complete picture is not entirely clear. While the literature review is being conducted it is intended that a complete survey of the affected areas be carried out. This will be accomplished by surveys of iron and manganese in waters of existing wells (including those abandoned) in rural areas of Ghana. There may well be considerable difference between the desirable and permissble Fe concentrations of Drinking Water standards and the level at which the Ghanaian villager rejects the water supply either wholly or partly. An investigation of water use and rejection will be undertaken to establish iron and manganese levels at which the Ghanaian rejects his borehole and pump supply or alternatively those levels at which he decides to use other water sources for different purposes (rejection of the borehole supply as a drinking, cooking and/or laundry water source).

In the initial countrywide survey, data will be collected on the forms of iron (divalent, trivalent), pH, alkalinity etc. in order to establish the impact of such characteristics on groundwater rejecttion and the necessary range of conditions which the village iron and manganese removal unit as devised will have to cover. Consideration will have to be given to the increasing expection of the villager for lower levels of iron concentration through modular approach of systems.

3.1.4 Field Visits:

As a result of above activities it will be possible to assess whatever little work conducted elsewhere in rural areas towards removing iron and manganese from groundwaters. It is considered desirable however, that the research engineer involved in this project be given the opportunity of personal contact with people directly involved in such research. The National Environmental Engineering Research Institute (N,E.E.R.I.) in India is mentioned in this regard. Provision, has, therefore, been made for one visit to India which will include other areas having similar critical problems. (Bangladesh, Thailand, Kenya and Tanzania).

3.2 Phase II - Determination of Relative Effectiveness:

The second phase of the project will be aimed at testing the effectiveness of each system under both laboratory and field conditions in terms of (i) raw water characteristics and (ii) operational conditions. It will also aim at determining relative costs of the systems as a function of the two factors listed above, and assessing optimum conditions for operation of each system under both laboratory and field conditions.

These objectives will be achieved through:

(i) fabrication by the University (Project staff) of the various iron removal systems for laboratory studies and field use.

(ii) identification of field testing sites jointly by the University and the Ghana Water and Sewerage Corporation (G.W.S.C.)

(iii) installation of laboratory units in the field for further adaptation and preparation for Phase III. This work will be undertaken by U.S.T. and G.W.S.C.

3.2.1 Laboratory development of test units:

Processes used in industrial and municipal plants for removal of iron and manganese include the following:-

(i) aeration followed by sedimentation and filtration

(ii) use of special filters e.g. contact beds,

(iii) chemical treatment using lime e.g. in the Water softening process.

The first approach does not require the use of chemicals and it is one that might be applicable to Ghanaian rural areas. In some of the special filters, coke is used (as it is in the case of the unit developed in India at the N.E.E.R.I.). Since coke is unavailable in this country, manganese or bauxite ores which occur naturally in Ghana will be considered for use as filter media in the laboratory studies using raw water collected from boreholes. Other sources of filter media may be tailings of ore processing and river bed sand. Variables to be considered in this study will include:

(i) filtration rate

(ii) filter run lengths

(iii) filter washing needs and methods

(iv) removal efficiencies

(v) cost effectiveness.

Results obtained from the laboratory investigations will be tested under field conditions using laboratory test units. Experience gained will be used for planning purposes for Phase III. This aspect of the project will be undertaken by the U.S.T. (Project Staff) and Ghana Water and Sewerage Corporation.

3.3 Phase III - Field Testing

Based on results obtained from Phase II, prototype units will be designed, constructed and installed in selected rural areas throughout the country. This phase will involve studies aimed at selecting the best systems from standpoint of

(i) cost effectiveness

(ii) efficiency of iron and manganese removal

(iii) simplicity of operation and maintenance, and

adapting them or modifying them further for use under Ghanaian conditions. These units will be installed by the Ghana Water and Sewerage Corporation under the supervision of the project engineer. Staff from the Corporation will be expected to supervise with the assistance of the Project Engineer the operation of pilot plant systems. Any training of operators required will be organised to ensure good operation and monitoring of performance of pilot plants. In addition there will be periodic visits by the Project Engineer to evaluate progress. Data Analysis will be performed by U.S.T. (Project Staff). Successful units will be recommended for use in the country and elsewhere under specified conditions such as range of raw water iron concentrations etc.

3.4 Phase IV - Technology Dissemination

The objective of this phase of the project is two-fold. It is aimed at reviewing the findings of the project and at planning an effective method of dissemination of the findings. These two objective will be met partly through international workshops and partly through the activities of the local Project Committee and research personnel.

3.4.1 International Workshops

The International Workshops are aimed at bringing together people who have been working on similar problems. It is therefore aimed at providing a forum for sharing experiences in both successes and failures. The workshops would also provide a forum for a critical review of the research methodology and findings, thereby, stimulating interest in the research findings. Finally, the workshops will be used as a medium for discussing methods for propagating successful technologies which may arise from the research project.

The International workshops will be arranged in countries selected on the basis of their experience, interest, and potential contribution to the objectives of the workshops.

3.4.2 Technology Dissemination Planning

The recommendations of the Internation Workshops will be used as the basis for the formulation of a programme for the propagation and implementation of successful findings that may arise from the research. Methods of developing local capabilities for the production, installation and maintenance of successful systems will be developed, making use of the Project Committee members and such other agencies and people as may appear appropriate.

4. PERSONNEL

This project will be administered by the Head of the Department of Civil Engineering, Professor Albert Wright, who will ensure its continued smooth operation. Professor Wright is an Environmental Engineer and will provide technical guidance to the project as its Director.

The Principal Investigator will be Dr. K.Y. Baliga, a W.H.O. Sanitary Engineer with considerable research experience in the chemistry of iron in water. Dr. Baliga has recently joined U.S.T. after an assignment at University of Nairobi's Environmental Engineering Division. Dr. Baliga will provide most of the technical and innovative skills to this project and be responsible for its day-to-day operation. His involvement will amount to one-third of his time. He will be supported by a research assistant who is to be employed full-time and responsible for the laboratory and the field work. Facilities and personnel associated with construction of models for the laboratory experimentation will be provided through the Civil Engineering workshop.

Communications and co-ordination between the institutions involved in the research and later implementation of results will be enhanced through regular meetings of a Project Committee. This Committee will be made up of representatives of the U.S.T. and the G.W.S.C. and will act to review progress and guide the research as it progresses.

5. PROJECT INSTITUTIONS

This project is to be undertaken by the Environmental Quality Division of the Department of Civil Engineering, Faculty of Engineering, U.S.T., Kumasi in collaboration with the Ghana Water & Sewerage Corporation of Ghana.

5.1 The University of Science and Technology

The U.S.T. was established in 1961 in succession to the Kumasi College of Technology which was established in 1951. It is situated on an eighteen square kilometer campus located about 6.5 km away from Kumasi.

The University has faculties of Engineering, Architecture, Agriculture, Art, Science, Pharmacy, and Social Science. It has just started a school of Medical

Sciences. The Faculty of Engineering has six departments, namely, Civil Engineering, Mechanical Engineering, Electrical and Electronic Engineering, Geodetic Engineering, Mining and Mineral Engineering and Chemical Engineering.

5.2 Environmental Quality Engineering Division

The Environmental Quality Engineering Division has undertaken research in the past on water filtration, oxidation ponds, or an oxidation ditch. Its current projects are:

(i) A study of the performance of oxidation pond in Kumasi

& (ii) Slow Sand Filtration.

The Division is expected to provide the engineering in-put, supported by its laboratories and workshops.

5.3 G.W. & S.C.

It is anticipated that this organisation will be called upon to collaborate in field studies, particularly in operation of units and in chemical analysis of raw and treated waters.

6. WORK PLAN

The Plan of Work is proposed as follows:

(i) Pre-Project activities
(ii) Phase I - state of the Art Review of available technology
(iii) Phase II - Determination of Relative Effectiveness of a selected systems. Laboratory and limited field work.
(iv) Phase III - Field Testing of successful systems.
(v) Phase IV - Technology propagation and dissemination of information.

Table 1 of Appendix I provides information on the duration of each phase together with associated objectives and personnel requirements. A chronogram can be found at Appendix III.

7. FUNDING

Appendix II lists the estimated costs of various activities involved.

8. CAVEAT TO RESEARCH PROPOSAL

It has been assumed that many of the resources necessary in small part to this project will be derived from the Excreta Management Project being proposed to the I.D.R.C. These resources, although small, will be essential to the functioning of the Iron and Manganese removal project. These resources include services of a typist, draughtsman, driver/mechanic and vehicle. The vehicle use will be coordinated by Director of the Projects. The major transport requirement will come during the third phase in which the field units are installed. Allowance has been made for using the University vehicle hiring system during this phase. As a condition of this proposal it is requisite that the Excreta Management proposal be accepted.

9. FUNCTIONAL USE OF RESULTS

The final results will be used in developing countries by Local Governments and Water Authorities (or Corporations) in reactivating boreholes abandoned as a result of high or excessive iron and manganese concentrations or in developing boreholes in areas known to have high concentrations of iron and manganese generally for rural water supplies. This will no doubt, offer a way of increasing water resources use in areas concerned.

To facilitate dissemination it is proposed that meetings be arranged to be attended by Ghanaian agencies to discuss the study findings upon completion of the project and consider methods by which the selected technologies would best be propagated (Phase IV). Copies of project reports will also be made available to interested persons and organisations through international centres such as I.R.C. at the Hague.

APPENDIX I

TABLE I

IRON AND MANGANESE REMOVAL PROJECT

Timing and Resources Requirements

Phase	Description	Activities	Duration (m)	Personnel
	Pre-Project Activities	Project formulation and Mobilisation	3	Principal Investigator & Director.
I	Review of available technology	Literature review Communication with other researchers Desk analysis and report National Fe & Mn Survey Village rejection level survey Visits abroad	7 4 2 9+ 9+ 1	Principal Investigator & Director Research Assistant
II	Laboratory. Determination of Relative effectiveness.	Laboratory development construction of test units Lab. units assessment Initial field test of lab. units Evaluation of results Selection of villages	3 3 2 2 2	Principal Investigator & Director Research Assistant G.W. & S.C.
III	Field testing	Design of prototype units Construction of prototype units Field Installations and testing Evaluation & Analysing Data Recommendation	6 11 4 3	- ditto -
IV	Technology Dissemination	Planning strategies for technology propagation. Blueprint for commercial production of prototypes	2 1 1	Principal Investigator & Director Research Assistant, All agencies of interest.

APPENDIX II

IRON PROJECT

COST ESTIMATES (CEDIS)

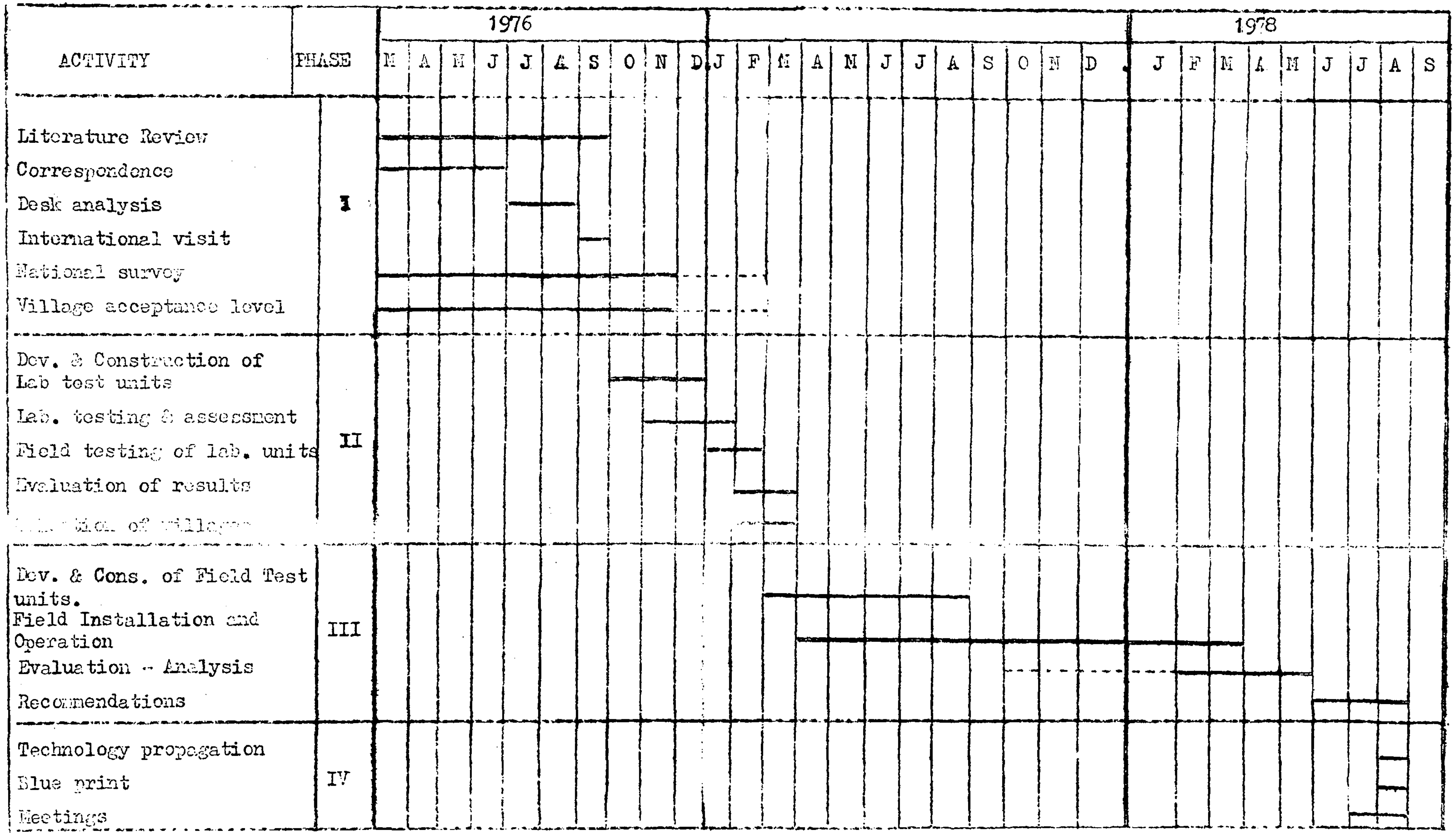
ACTIVITY	UST			IDRC			TOTAL	
	1	2	3	1	2	3	UST	IDRC
PERSONNEL								
Project Director (Admin) 2½ yrs. 10% time	1,322	1,388	728	-	-	-	3,438	-
Principal Investigator/Project Engineer 2½yrs. ⅓ time	3,845	4,037	2,119	-	-	-	10,001	
Research Assistant (full time)				3,450	3,622	1,901		8,973
INTERNATIONAL TRAVEL								
Ghana-Bangladesh-India-Tanzania-Kenya (1)				2,000*	-	-		2,000
Per diem 28 days @ ₵37/d & local transport @ ₵13/d				1,400				1,400
LOCAL TRANSPORT								
UST Vehicle Rental @ 30p/m 3m at 1500m/m					700	650		1,350
Fuel and oil for project vehicle 8000m @ 8p/m				120	360	160		640
Per diem: Project Director @ ₵10/d 20d = 200 Prin. Invest. @ ₵10/d 100 = 1000 Res. Asst. @ ₵ 4/d 300 = 1200 Foreman @ ₵ 4/d 50 = 200 Driver/Mech. @ ₵ 4/d 200 = 800 3400				1,300	1,300	800		3,400

...../2

	UST			IDRC			TOTAL	
	1	2	3	1	2	3	UST	IDRC
MATERIALS & SUPPLIES								
Laboratory								
Chemicals				200	200	200		600
Glassware				500	100	100		700
Misc plumbing				600	300			900
Stationary				100	100	100		300
Workshop								
5 Experimental Units @ ¢400				2,000				2,000
20 Prototype Units @ ¢200					4,000			4,000
20 modification of existing handpumps @ ¢100					2,000			2,000
EQUIPMENT								
Field Testkit for Iron and other analysis				600				600
Lab pumps. peristaltic				1,500				1,500
Library & Documentation				400	400 / 200	300 / 100		1,100 / 500
COMMUNICATIONS								
Mail and Telex				200	100	100		400
Reports Preparation and Printing				200	200	200		600
INTERNATIONAL WORKSHOPS					9000			9000
GRAND TOTAL	5,167	5,425	2,847	14,570	13,382	13,511	13,439	41,463

APPENDIX III

CHRONOGRAM



ACTIVITY	PHASE	1976										1977												1978								
		M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
Project Committee Meetings	I–IV	x				x					x					x					x				x						x	
Progress Report							x						x						x						x						x	
Interim/Final Report									x						x																	x

APPENDIX IV

IRON AND MANGANESE CONCENTRATIONS

IN SOME GROUND-WATERS IN GHANA

TOWN	DISTRICT	Fe, mg/l	Mn, mg/l
AIYINASI	NZIMA	11.0	0.4
BONYERE	"	4.0	0
ESSIAMA	"	15.0	0.06
ABOFOUR	NORTH KUMASI	6.0	0
EFFIDUASI	"	1.7	0.14
JUASO	"	0.6	0.8
AGONA	CAPE COAST	3.1	0.9
FOSO	ASSIN	1.1	1.9
SUHUM	AKIM ABUAKWA	1.5	-
SERIPE	GONJA	11.0	Trace
WAGAWAGA	"	3.5	1.1

With Reference to Section 3.1.3. (Extract from G.W. & S.C. Data)