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Minimising fluoride in drinking water: fieldwork in Tanzania, August 2002

Groundwater systems and water quality

Internal Report IR/02/160R

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INTERNAL REPORT IR/02/160N

Minimising fluoride in drinking water: fieldwork in Tanzania, August 2002

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Key words

Hydrogeology; geochemistry; Africa.

Front cover

Collecting water from a shallow dugout in Ikungi village, central Tanzania

Bibliographical reference

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1 Introduction

This short report summarises activities from a visit to Tanzania by Alan MacDonald and Richeldis Tyler-Whittle (30 July – 17 August 2002). This visit formed part of the DFID KaR project "Minimising Fluoride in drinking water in problem aquifers". In Tanzania we were joined by Hudson Nkotagu and Radhia Ideva from the University of Dar es Salaam. The objectives of the visit were:

1. To collect representative water samples from drinking water sources throughout the Singida/Igunga area.
2. To collect relevant hydrogeological information at the sample sites.
3. Provide additional observations on the problem that fluoride poses people in the area.

To meet these objectives an 18 day visit to Tanzania was undertaken. An earlier visit by David Kinniburgh and Richeldis Tyler-Whittle in March 2002 had helped to set up the fieldwork; some samples were also collected at this time. Itineraries for both visits are given in Appendix 1.

2 Introduction to the study area

The study area is in central Tanzania, straddling the Singida and Tabora regions (see Figure 1). It comprises 3 districts: Iramba, Singida (Urban and Rural) and Igunga. People living in these areas have stained teeth and therefore show evidence of fluorosis. However, the problem of fluoride in drinking water has not been seriously addressed in this area before this project; most scientific research on fluoride in Tanzania has focussed on the Arusha area.

Figure 1 shows the broad hydrogeological conditions in Tanzania. Much of the country is underlain by Precambrian basement rocks – granite, gabbro and meta-sediments. Sedimentary basins to the south of the country are mainly of Karroo age. Volcanic rocks are associated with the east African Rift which splits in two in Tanzania. The western limb passes through Lake Tanganyika and the Eastern limb from Arusha to Morogoro. Young, mainly unconsolidated sediments are present across the country and comprise alluvium and lacustrine deposits. These often infill depressions and grabens associated with the rifting.

The study area can be split into two main geomorphological units (see Figure 1).

A *high plateau* in the southeast (approximately 1500 m) underlain by basement rocks, both granites and metasediments. Rock is often close to surface and there are many weathered granite boulders and tors. The plateau also has rolling countryside where the granite is more weathered. The soil is generally sandy, although ferrecrete is occasionally present on hill sides and mbuga clays in valleys.

A *flat plain* in the northwest – underlain by alluvium, lacustrine deposits and some metasediments. This plain is very flat and forms the old surface of the proto Lake Eyasi and possibly proto Lake Victoria. At the edge of the plain are alluvial fan deposits. Much of the plain surface is covered by several metres of Mbuga clay. Rivers dissect the plains (normally entrenched by 3 - 5 m) and are filled with alluvium.

Rainfall is low in the area: annual totals are between 600 and 800 mm. Much of this rainfall occurs between November and April, rainfall records show virtually no rainfall between June and September. (However, several hours of heavy rainfall occurred in Singida during the visit – a sample was taken).

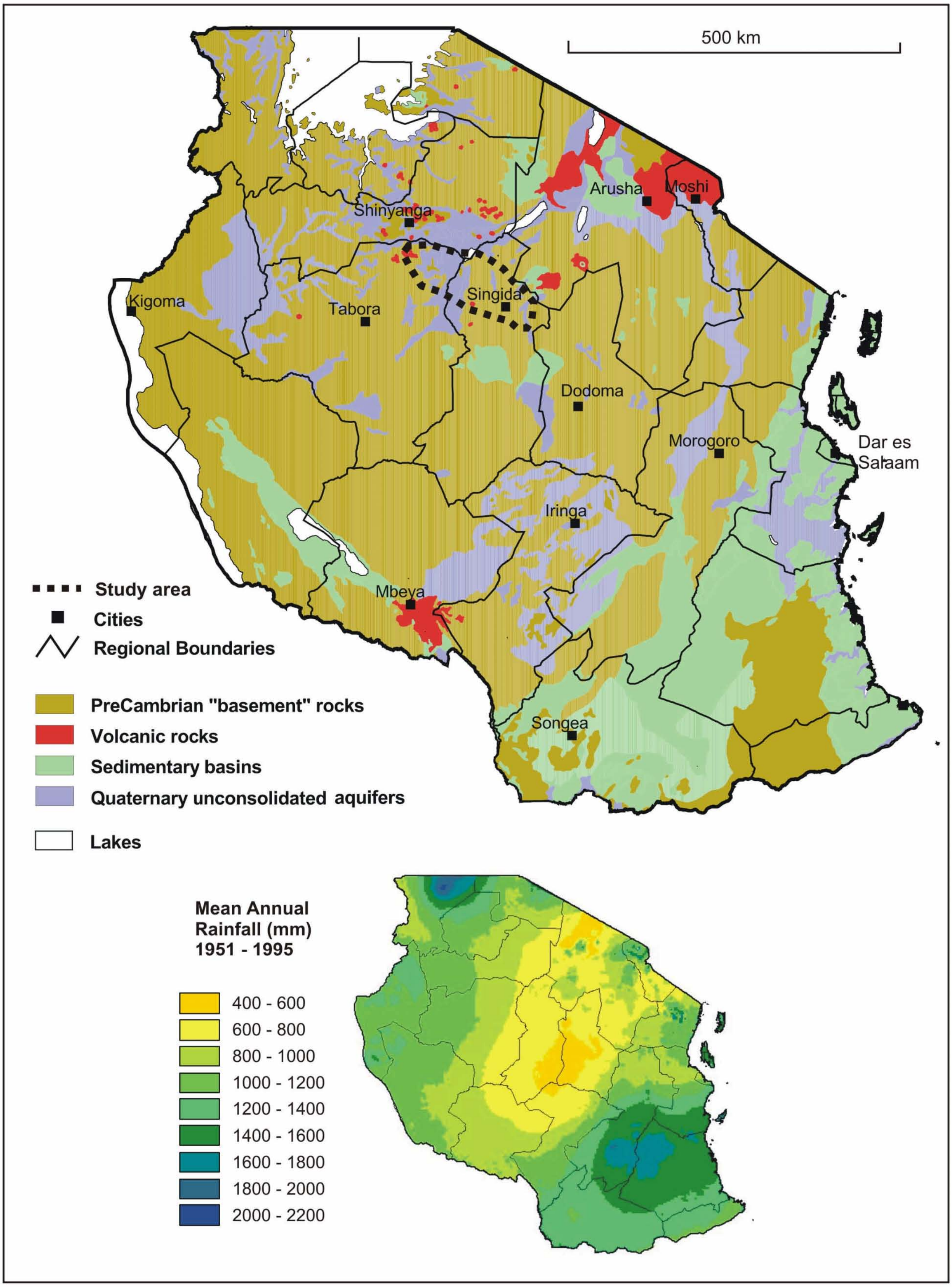

Figure 1 The location of the study area in Tanzania. The hydrogeological map is from MacDonald and Davies (2001) and the rainfall information from New and Hulme (1997).

3 Sampling

Fifty water samples were taken during the visit. A summary of the sample details are given in Appendix 2. Thirty-one boreholes were sampled, six large diameter wells, six dugouts, three river dugouts; one dam, one pond, one river and one sample of rainfall. The distribution of the samples is given in Figure 2. In each district we were accompanied by an engineer from the local water department.

Every effort was made to take samples from different hydrogeological environments in the area. A rough transect was followed moving northwestward from the granite plateau across the metasediments and down onto the plain. At seven of the sites samples were taken from both shallow and deep sources (e.g. boreholes and shallow dugouts).

Stable isotopes were taken at 31 of the sites and CFC samples at 16 sites. For taking CFC samples an airtight connection is required. This was done using an inner tube (see Figure 3). Measurements of dissolved oxygen indicated that the connection was good. Measurements of Eh at the wellhead showed that many of the samples were reducing. CFC samples were not taken where the waters were highly reducing.

A brief survey of the hydrogeological conditions was also taken at each site. This involved getting information on the following:

- depth and nature of the sources (often not a trivial exercise – information from files in the SEMA and water department offices, and also from individual community members),
- the approximate yield of each source, e.g. if it dries or reduces in yield throughout the year
- the geology at each site (from maps and outcrops).

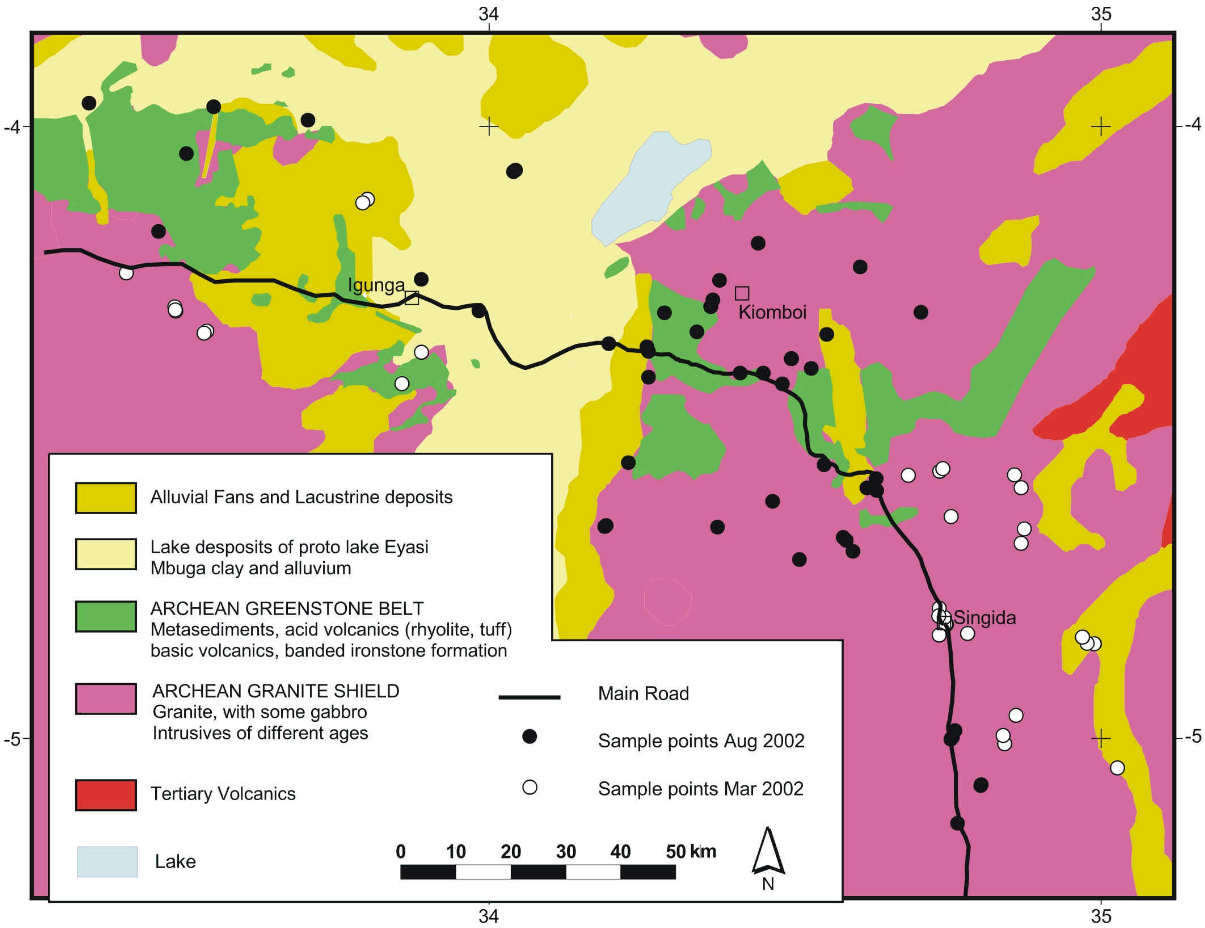

Figure 2 Simplified geological map of the study area and location of sample points.

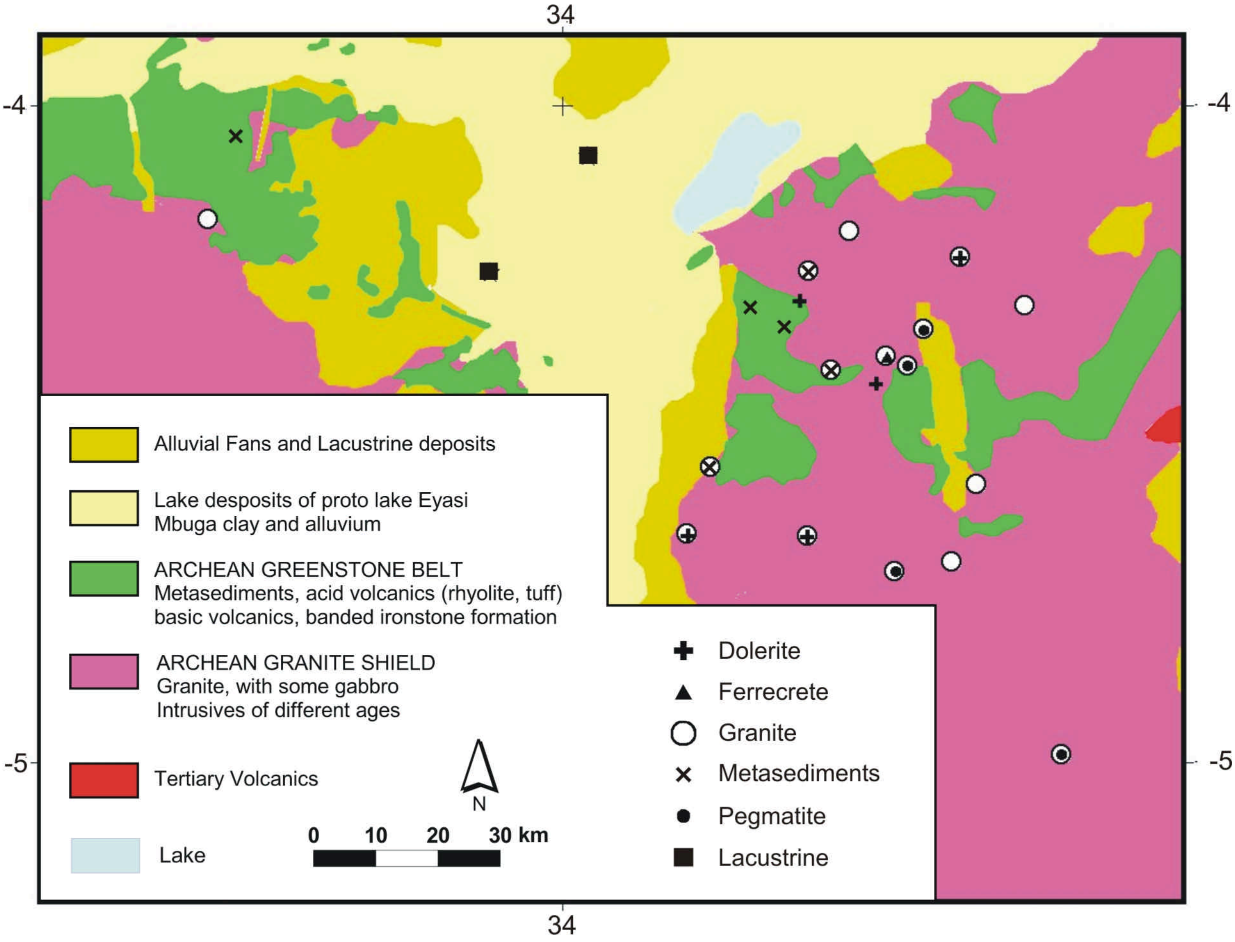

Figure 3 Location of rock samples taken from the study area.

Rock samples were taken from various sites (see Appendix 2 and Figure 3). These were taken from outcrop as close as possible to the sampled water source. In total 35 samples were taken at 23 sites. Seventeen samples of granite were taken, four of pegmatite, six of metasediments, four of dolerite, and one each of tuff, ferrecrete, lacustrine and gabbro. Some additional samples were taken and left in Dar es Salaam.

Some additional hydrogeological information was gathered for some of the samples taken during the March 2002 visit. Unfortunately there was not sufficient time to visit any of the initial sites, although records in the offices in Singida were consulted. This information is given in Appendix 3.

4 A brief summary of geology and hydrogeology

There are four main geological and hydrogeological units in the study area. These are shown in Figures 2 and 3.

Archean granite shield. Much of the study area is underlain by granite. The granite is not homogeneous but varies in grain size and composition. In some areas pegmatite is found with large crystals of biotite mica. The granite has also been intruded by many dolerite dykes and sills. These are of different ages – both Palaeozoic and Proterozoic have been mapped. There appears to be uncertainty with experts as to whether there are also younger (Cenozoic) intrusions.

Figure 4 Sampling procedure for making an airtight connection for taking flow through cell measurements and CFC samples from a Nira handpump.

Groundwater occurs in both the fractured and weathered zones of the granite. From the data available in drilling records, groundwater is often found at the base of the weathered zone – often 20 – 40 m below ground surface. Drilling success rates appear to be around 50-70% with 5 or 6 boreholes being drilled for 3 equipped boreholes. Yields tend to be sufficient for the hand pumps (generally less than 30 m^3/d), and occasionally for higher yielding motorised pumps. Shallow boreholes and wells that only penetrate 10 m of the weathered zone can significantly decline in yield towards the middle of the dry season.

Archean Greenstone Belt. Within the study area the Archean Greenstone Belt comprises a complex mixture of metasediments and acidic and basic volcanics. Exploration for gold is occurring in these areas, and some small scale mining. The metasediments comprise metamorphosed shales greywacke, quartzite and schists. One quartzite unit is easily distinguishable and has been named the Banded Ironstone Formation due to its characteristic iron cementation. Acidic volcanic rocks (such as rhyolite, dacite) and associated tuffs are present along with basic volcanic rocks and tuffs. Some of the basic rocks have been altered to form greenschists – hence the term “Greenstone Belt”.

Lithology and fracturing control the occurrence of groundwater in the Archean Greenstone Belt. However, due to the complexity of the geology and the lack of data it is difficult to make robust generalisations. Weathered and fractured siltstones and quartzite are likely to have the highest potential for groundwater development; fractured lavas may also allow significant groundwater movement.

Cenozoic Lacustrine deposits. The flat plain areas of the study area are thought to have formed the bed of an ancient lake, the forerunner of Lake Eyasi. The deposits that formed on these lake beds as complex and comprise consolidated and unconsolidated sands, gravels, clays, limestones and tuffs. Some evaporite deposits are also thought to be present.

Groundwater is found within the sands and gravels, and is generally exploited at shallow depths (1 – 5 m) via dugouts in river beds or areas of shallow gravel. Some deeper boreholes drilled into these deposits have given saline water. The thick mbuga clays present in much of these areas can give rise to problems developing groundwater.

Holocene alluvial fans and lake deposits. Around the eastern escarpment of plateau, alluvial fans are present. These form shallow slopes at the edge of the plains and comprise poorly sorted cross bedded alluvium. These are likely to be up to 50 m thick, although no detailed logs are available. Mbuga clays can be present at depth within these sequences. Mapped as the same unit are the lake deposits of the forerunner of Lake Victoria. These are present in the Igunga area and comprise cemented limestone sandstone and conglomerate.

Where thick, the alluvial deposits form a good aquifer. Boreholes drilled at the foot of the escarpment have good sustainable yields and low salinity water. However in some of the smaller alluvial aquifers (for example to the southeast of Kiombio) the alluvium can be thin and patchy and groundwater is controlled by the underlying bedrock geology.

Little data was available on the hydrogeology of the lacustrine deposits of the proto Lake Victoria in this area. However, they are likely to be similar to that of the proto lake Eyasi.

5 Fluoride and socio-economic factors

A rigorous analysis of the socio-economic impact of high fluoride on communities in Tanzania is outwith the scope of this study. The primary concern of the research is to understand the controls on high fluoride in groundwater and develop methods for minimising fluoride in water supplies. However, it is vital that the research is rooted in the socio-economic conditions of Tanzania and that steps are taken to help the uptake of research in the area. The comments in this chapter are from discussions with a diverse range of stakeholders including community members, district commissioners, the Ministry of water and livestock development, the state and district water departments, engineering consultant, WaterAid and SEMA.

5.1 FLUORIDE AND WATER SUPPLY

The WHO recommended limit for fluoride in drinking water is 1.5 $mg.l^{-1}$. The Tanzania interim standard is 8 $mg.l^{-1}$. This recognises the fact that so much of Tanzania's water resources exceed the WHO standard. The standard is "interim" to reflect the desire to move towards the WHO standard.

Much of rural Tanzania suffers from acute water shortage. In the study area (Igunga District [Tabora Region], Singida Rural and Iramba Districts [Singida Region]) there are few working boreholes. People often have to travel large distances for water, carrying the water on ox-carts, bicycles or by head. In some communities informal water markets have developed, the price for a 200 litre drum was commonly 500 TZS (50 US cents). The scarcity of water in some areas has lead to skin and eye infections, since water is used only for drinking and cooking. In communities where water was scarce (most of the communities visited) people told us their main concern was water – the problem with the teeth was perceived as much lower. This was reiterated by most of the Ministry officials, NGOs and district commissioners – water first, quality second.

However, fluoride does pose a considerable problem for those involved in developing water supplies in Tanzania. This is well illustrated by the example of JICA in the Singida region. JICA funded a large groundwater investigation programme in central Tanzania during the mid to late 1990s. This was the preparatory work for a large-scale project to develop water supplies for several hundred communities across four districts. The groundwater investigations involved drilling investigatory boreholes across the area and carrying out hundreds of kilometres of geophysical surveys. The state and district water departments were mobilised and expectations among communities in the districts were high. However, the large-scale RWSS project has not got underway because of concerns over fluoride. Only 8 sources are now to be developed – these are in areas where fluoride is known to be below the WHO standard. This has caused considerable confusion and disillusionment in the communities.

The Water Ministry (including those involved in the new World Bank rural water supply project) and Water Departments expressed considerable interest in knowing the extent of the fluoride problem in central Tanzania. This would help ensure that the JICA experience would not be repeated, where the project had progressed far, and expectations raised high, before the problems of fluoride were considered.

5.2 THE IMPACT OF FLUORISIS IN COMMUNITIES

As mentioned above, most opinions expressed by community members (mainly through village chairmen or executive officers) were that communities would rather have reliable sources of high fluoride water, than unreliable sources of low fluoride water. However, during the sampling it was apparent that fluorosis did impact people's lives.

1. Many people's teeth were badly mottled, some appeared deformed.
2. Within the villages there appeared embarrassment about the teeth colour. Before mentioning the reason for sampling, many children would hide their teeth and smile with their mouths closed.
3. Some middle aged people complained of aching joints.
4. Very few consented to having a photograph taken of their teeth.

Within many communities there is considerable diversity in the conditions of individual's teeth, even although the same water source is used. Several factors could contribute to this including diet (dairy products significantly decrease the effect of high fluoride), migration and physiological susceptibility.

In one community the development of a new (high fluoride) water supply had a considerable effect on the community. Prior to the borehole being constructed, water was taken from dugouts several kilometres way; most people had very good teeth. Mottled teeth were associated with people in Iramba to the north. A borehole was drilled closer to the village in 1990. Children are now developing mottled teeth characteristic of dental fluorosis. Since this had not been seen in this particular village before, the fidelity of women within the village is being called into question. Such misunderstandings are understandable and illustrate the importance of education on the effects of fluoride.

6 Miscellaneous

6.1 WATERAID SAMPLING

During the visit training was given to lab technicians in Singida to enable them to take water samples (Appendix 4). Sufficient acid, filters and sample bottles were left to enable 60 additional samples to be taken. It was agreed that samples would be taken from each of the sources developed by WaterAid in Singida Rural in 2002. This will entail about 30 samples from existing boreholes and 30 from new boreholes.

6.2 DAR ES SALAAM MSC STUDENT

During the visit we were accompanied by Radhia Ideva, an MSc student at the department of geology in the University of Dar es Salaam. She had extensive field training in taking water samples and making well head measurements using the flow through cell. She was also shown how to assess the geology and hydrogeology of a site through field observations and community discussions.

Her MSc project will focus on fluoride in northern Iramba – an area that was not covered during this field visit. She has sufficient equipment, resources and expertise to carry out the field work. While in Dar es Salaam a flight to the U.K. was organised for her for the period 17 November to 9 December. This would allow here to observe the laboratory analysis of water samples, carry out a detailed literature review in the library, and discuss the interpretation of data with scientists at Wallingford.

6.3 DISSEMINATION

The project was discussed with people from various organisations (see the contacts list in Appendix 5). Of particular importance is the start of a large World Bank funded project to improve rural water supplies in central Tanzania. Most wanted to be kept informed of the project progress and were impatient for the results and recommendations.

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NEW, M, HULME, M. 1997. Construction of 3 minute latitude/longitude monthly climate surfaces over Africa for the period 1951 – 1995. Climate research Unit, University of East Anglia, Norwich.

Appendix 1 Itineraries for visits to Tanzania

First Visit: Dave Kinniburgh and Richeldis Tyler-Whittle, 12-29 March 2002

Tuesday 12 March	Leave Heathrow 20:00 on British Airways
Wednesday 13 March	Arrive Dar es Salaam 12:35. Change money. Meet Hudson Nkotagu at the University of Dar es Salaam. Discuss project and plans over next few weeks.
Thursday 14 March	Collected passport photos and arranged transport to Tabora. Visited the Water Laboratories unit in the Ministry of Water and Livestock Department, Dar es Salaam. Met Nadhifa Sadiki (Assistant Director) and introduced the project. They were in the process of digitising some water quality data for us for the Tabora and Singida regions. We returned to the university to meet Professor H.H.Nkunya, Chief academic officer of the Univeristy. Professor Nkunya welcomed us and offered us a Memorandum of Understanding for future work with the university. We then visited the Tanzanian Bureau of Standards (TBS), and met Mrs B. Mutabazi, the Deputy Director. Returning to the University DGK gave a talk in the Geology department on 'Natural Groundwater Problems'. This was followed by discussions with people from several disciplines regarding the problem of fluoride in Tanzania. Met Kezia Mbwambo from TBS who would be joining us in the field.
Friday 15 March.	Collected maps , flight tickets and money in Dar es Salaam. Visited laboratory in TBS. Returned to the Water Laboratories Unit to collect available water quality data and met Mr H.J.Mjengera, the Director. The Tabora data was available but Singida was still in the process of being typed in. Met the Minister for Water as we were leaving for the Tanzania Commission for Science and Technology (COSTECH). Waited until 5:30pm for our Research Permits.
Saturday 16 March	Spent day at the University of Dar es Salaam. Discussed project, sorted out the equipment and decanted acid.
Sunday 17 March	Hudson Nkotagu, Kezia Mbwambo, DGK and Raty flew to Tabora.
Monday 18 March	WaterAid, Tabora. Met Eng. Herbert J. Kashililah, the programme manager. Discussed the project and potential collaboration with WaterAid with their future drilling programme in Singida. Kashi provided letters of introduction for us for Igunga and Singida regions. Photocopied Tabora Water Master plan. Meeting at WaterAid with stakeholders from different fields (A hydrogeologist, water technician, engineer and religious worker. We discussed the project and the extent of the fluoride problem. Visited the hospital in Tabora to meet the regional medical officer. Met the water technician (Mr Bwena), from our morning meeting, in the Urban Water and Sewerage Department to collect some hand-written records of all boreholes drilled between 1950-1981. Arranged transport from Tabora for fieldwork.

Tuesday 19 March	Drove to Igunga, via Nzega. Minor problems with vehicle, but fixed in Nzega. Stayed at the Misana Lodge.
Wednesday 20 March	Visited the Igunga water department and met the district water engineer, Mr Yasin Keye. Discussed the project and learnt which villages would be accessible and appropriate for our fieldwork. Met the District commissioner, Major B.N.Matala, and discussed the Igunga district and the fluoride project. Visited Igunga hospital and met Mr Chacha, a health officer who would help us with in locating villages and carrying out the fieldwork in the district. Began fieldwork in the afternoon.
Thursday 21 March	Fieldwork Igunga.
Friday 22 March	Travel from Igunga to Singida. Visited Regional Water Department and discussed project with district water engineers Mr Lenanda and Mr Mahimbo. Introduced the project to the Regional water engineer, Mr Kamara, who agreed Mr Mahimbo could accompany us to help with the fieldwork. Also discussed the project with Mr Christian, the Director of the Water and Sewerage Department, who is responsible for Singida Urban. Visited WaterAid office to meet Godfrey Mpangala (hydrogeologist) and Rita Chizenga (programme officer). Also introduced to their sister organisation, the Urban Authority Partnership Programme.
Saturday 23 March	Fieldwork Singida
Sunday 24 March	Fieldwork Singida
Monday 25 March	Fieldwork Singida
Tuesday 26 March	Travelled back from Singida to Tabora.
Wednesday 27 March	Flight from Tabora to DAR and DGK left for UK in the evening.

Second Visit: Alan MacDonald & Richeldis Tyler-Whittle 30 July-17 August 2002

Tuesday 30 July	Leave Heathrow 20:00 on Kenyan Airways
Wednesday 31 July	Arrive Dar es Salaam 9:30. Met by Hudson Nkotagu. Arrange 4x4 hire with the University. Meet the MSc student (Radia Ideva). Discuss MoU with the Acting Vice Chancellor at University of Dar es Salaam (Prof J S Mshana). Met Dr Mutakyahwa, head of the geology department, discussed the project and left the MOU with him. Change money. Sort out equipment and decant acid.
.	
Thursday 1 August	Drive to Dodoma. Go to Geological Survey and buy appropriate maps and discuss Singida geology with geologists, Dr J B Kashabanu and Dr P Semkiwa. Discuss the project with Lister R E Kongola (Assistant Director and hydrogeologist in the Water Resources Division of the Ministry of Water). Visited WaterAid, but Dave Mather in the UK and no staff available.
Friday 2 August.	Drive to Singida. To the Water Department to discuss the project with Mr Kamara (Regional Water Engineer). Arranged for Fanuel Mgana to accompany us within Singida Rural district during fieldwork. Discussed the Project with Godfrey Mpangala at WaterAid. Stayed at the Stanley Motel.
Saturday 3 August	Met the District Commissioner. Fieldwork Singida Rural.
Sunday 4 August	Rest day
Monday 5 August	Fieldwork Singida Rural. In the evening met Valerian Makusaro, the SEMA hydrogeologist.
Tuesday 6 August	Visited JICA workshop in Singida. Workshop to discuss water supply in Igunga and Hanang districts (Kiyoko Takamizawa – JICA project engineer). To Kiomboi in Iramba District. Met Ally Msangi (District water engineer) and discussed sites to sample in Iramba. Arranged to be accompanied by Manase Nyankwimba and Zachariah Yunge from the Water Department. Met the District Commissioner. Stayed at the Millenium guest house.
Wednesday 7 August	Fieldwork Iramba
Thursday 8 August	Fieldwork Iramba. Dr Nkotagu returns to Dar es Salaam
Friday 9 August	Fieldwork Iramba
Saturday 10 August	Fieldwork Iramba
Sunday 11 August	To Igunga. Met Engineer Herbert Kashililah, (Programme Manager for Water Aid in the Tabora and Singida regions) and arranged to meet in Dodoma. Also met WorldBank RWSSP team (Gabrial Lwakabare, Ismail Mwaka, Genes Kaduri).
Monday 12 August	To water department. Met Director (Yasin Keye) and planning officer (Mr Kombe). Arranged Peter Ngumzi Kuhenga (Health Officer) to accompany us to the villages. Met the District Commisioner, Major Matala. Fieldwork in Igunga.
Tuesday 13 August	Fieldwork Igunga. Travelled to Singida.

Wednesday 14 August	Meeting with Godfrey Mpangala (hydrogeologist) and Rita Chizenga (programme officer) at WaterAid to discuss the project. Training of laboratory staff (Mr Festo Saron and Mr Shifaya Munisi) to take samples. Data collection at the SEMA office. Power cut in the evening.
Thursday 15 August	Travelled to Dar es Salaam. Stopped in Dodoma for meeting with Engineer Kashililah (acting WaterAid Country representative). Discussed project, drilling costs, future sampling etc. Sorted samples in the evening.
Friday 16 August	Bought ticket for MSc Student. Sent CFC samples by DHL. Paid for Car Hire. Sorted out funds for MSc for future sampling etc. AMM on Flight for UK 16:00.
Saturday 17 August	Samples picked up at Heathrow Airport 7:00. AMM to Edinburgh.

Appendix 2 Summary of sample details

Field ID	Locality	O/D	13C	CFC	Rocks	Altitude	Source type	Geology
S02-01245	Puma Mission	1	1			1565	Borehole	Coarse grained granite
S02-01246	Puma Dispensary					1579	LD well	Coarse grained granite
S02-01247	Puma Stones				1	1596	LD well	Coarse grained granite/Pegmatite
S02-01248	Ikungi windmill	1	1	1		1529	Borehole	Granite
S02-01249	Dungunyi Deep					1603	Borehole	Granite (no veins)
S02-01250	Dungunyi Shallow					1607	LD well	Granite (no veins)
S02-01251	Kisiluda	1	1	1		1458	Borehole	Granite
S02-01252	Msumbiji	1	1			1460	Borehole	Granite (old chip samples appear more like phylite)
S02-01253	Itigi				1	1480	Dug out	Granite (grey closeby+ pink granite tor - 1 km)
S02-01254	Ilala	1	1	1		1411	Borehole	Weathered granite - dolerite closeby
S02-01255	Msumbiji	1	1			1379	LD well	weathered granite
S02-01256	Iguguno	1	1	1	1	1364	LD well	weathered granite, some intrusions
S02-01257	Mukwajuni	1	1	1		1131	Borehole	alluvial fans including mbuga clays
S02-01258	Mkuyuni					1152	Borehole	alluvial fans including mbuga clays
S02-01259	Shelui	1	1	1		1101	Borehole	lacustrine - also metasediments??
S02-01260	Masagi	1	1			1164	Borehole	alluvium/ lacustrine
S02-01261	Mtekente	1	1		1	1197	Borehole	granite and metasediments (some dolerite)
S02-01262	Urughu Borehole	1	1	1		1169	Borehole	granite (dolerite within 2 km)
S02-01263	Urughu Pond				1	1167	Pond	weathered granite
S02-01264	Ulemo	1	1		1	1474	Borehole	coarse grained granite, basic igneous or metasediments
S02-01265	Usure	1	1	1	1	1408	Borehole	granite, dolerite
S02-01266	Kaselya	1	1	1	1	1484	Borehole	granite - pegmatite
S02-01267	Misuna	1	1			1437	Borehole	possibly meta sediments (schist?) and dolerite
S02-01268	Nduwa	1	1	1	1	1525	Borehole	medium grained granite
S02-01269	Tumuli dugouts					1489	Dugouts	
S02-01270	Mgundu	1	1			1480	Borehole	metasediments or pyroclastics
S02-01271	Itinku Borehole	1	1		1	1535	Borehole	granite - quartz veining
S02-01272	Itinku Dugout					1551	Dugout	weathered granite, ferrecrete
S02-01273	Mwamboa	1	1		1	1562	Borehole	Coarse grained granite
S02-01274	Mkusi	1	1	1	1	1282	Borehole	Fine grained granite and pegmatite
S02-01275	Gumanga	1			1	1463	Borehole	Pink granite, intrusions and dolerite
S02-01276	Kitima	1	1		1	1549	Borehole	Coarse grained granite, some pink granite
S02-01277	Wembere Spring	1	1		1	1371	River	Dolerite, basalts, metasediments
S02-01278	Mampanda	1	1	1	1	1533	Borehole	Meta sediments or basic tuffs, intrusions
S02-01279	Salala				1	1518	Borehole	Probably granite, some dolerite within 2 km
S02-01280	Salala	1	1			1518	Borehole	Probably granite, some dolerite within 2 km
S02-01281	Salala, Old Kiomboi	1	1	1		1526	Borehole	Granite (coarse grained)
S02-01282	Old Kiomboi windmill	1	1		1	1547	Borehole	granite, ash
S02-01283	Kisiriri	1	1	1	1	1656	Borehole	pink granite
S02-01284	Ngulu	1	1	1	1	1254	LD well	weathered coarse grained granite
S02-01285	Matingo dam				1	1151	Dam	ash, quartzite, metaseds
S02-01286	Chibiso					1107	Dugout	mbuga/alluvium/ lacustrine
S02-01287	Kinungu					1105	River Dugouts	mbuga clay / lacustrine
S02-01288	Igurubi					1094	River Dugouts	mbuga clay / alluvium
S02-01289	Makoromelo					1054	Borehole	mbuga clays / alluvium / lacustrine
S02-01290	Makoromolo	1	1	1		1061	Dugouts	mbuga clays / alluvium / lacustrine
S02-01291	Mbutu				1	1074	River Dugouts	alluvium / ash
S02-01292	Isakakalina dugout				1	1063	Dugouts	Ash
S02-01293	Isakakalina borehole					1064	Borehole	Ash
S02-01294	Singida Motel Rainfall						Rainfall	
S02-01295	Acid Blank							

Appendix 3 Additional data for Mar 2002 samples

Feld ID	name	Source description March 2002	Pump description Mar 2002	Depth Mar 2002	Source type Aug 2002	Depth Aug 2002
S02-00730	Imalanguzu	STW	Hand pump	110 m	Borehole	
S02-00731	Imalanguzu	Charco dam	Surface		Dam	
S02-00732	Nguvumoja	STW	Hand pump	30 m	Borehole	
S02-00733	Mwanzugi	lake	Surface of dam		Lake	
S02-00734	Ussongo	DTW		Deep	Borehole	
S02-00735	Ussongo	STW	Hand pump	Shallow	?LD Well	
S02-00736	Ussongo	STW	Hand pump	Approx.10m	?LD Well	
S02-00737	Moyofuke	HTW	Hand pump	Approx. 30m.	?Borehole	
S02-00738	Moyofuke	Dugwell	Dug well	346 m	?LD Well	
S02-00739	Ziba	STW		Shallow.	?	
S02-00741	Igunga	Rain	Rainfall	Surface	Rain	
S02-00742	Igunga	Rain	Rainfall	Surface	Rain	
S02-00743	Igunga	Rain	Rainfall		Rain	
S02-00744	Mgori	Pit	Pit hole at surface		Dugout	
S02-00745	Mgori	STW	Nira	6 m	Borehole	184 m
S02-00746	Mnkhola	Water hole	Water hole	Surface	Dugout	
S02-00747	Mnkhola	Water hole	Water hole	1.5	Dugout	
S02-00748	Unyaghumpi	STW	Windmill	54 m	Borehole	54 m
S02-00749	Kimbwi	STW	Pump at 6m	7m	?LD Well	
S02-00750	Unyangongo	STW		7m	?LD Well	
S02-00751	Midaani	STW	Artesian bh		Borehole	93 m
S02-00752	Ilongero	STW artesian	Artesian bh		Borehole	
S02-00753	Ilongero	STW	Nira	shallow	Borehole	
S02-00754	Kijota Asili	STW		10	?	
S02-00755	Elimu	DTW	Afridev pump.	Approx. 60m	Borehole	54 m
S02-00756	Laghanida	STW	Afridev pump.	Approx. 60m	Borehole	35 m
S02-00757	Amani	STW	Afridev pump.	Approx. 60m	?Borehole	
S02-00758	Senenemfuru	STW	Afridev pump.	Approx. 60m	Borehole	60 m
S02-00759	Kijota	STW	Diesel pump		Borehole	29 - 65 m
S02-00760	Singida Motel I	Blank			?	
S02-00761	Singida Motel II	Blank			?	
S02-00762	Kititimo	DTW	submercible	Deep	Borehole	58 m
S02-00763	Utemini	DTW			Borehole	53 - 62 m
S02-00764	Lake Singidan	Lake			Lake	
S02-00765	Njuki	DTW			Borehole	80 m
S02-00766	Uhasibu	DTW			Borehole	43 - 55 m
S02-00767	Kindai Lake	Lake			Lake	

Appendix 4 Training for water sampling

BGS training on the collection of water samples was given to the water laboratory technicians (Mr Festo Saron and Mr Shifaya Munisi) at the Water Department Laboratory in Singida. WaterAid intends to construct or rehabilitate up to 60 boreholes/wells in the Singida Urban area over the next 3-4 months and will employ and train Mr Festo Saron and Mr Shifaya Munisi to collect samples from each site and test for fluoride. It was therefore agreed that the technicians would collect two extra samples (FA & FUA) from each site for analysis at BGS. The instructions below were demonstrated and left with the technicians, together with a spreadsheet requiring specific information from each site. The instructions, table and equipment were also left at the WaterAid office in Singida.

Data requested in the spreadsheet included:

> Sample number, location, date, well number, GPS, Altitude, Well depth, Well type, new/ existing well, Samples collected (FA, FUA, F) and notes.

The equipment left at Water Aid included:

> Sterilin tubes (120+), 75 x 0.47 µm filter papers, 1 Swinnex holder, 1 spare O ring for Swinnex filter holder, 5 x 20 ml syringes, HCL and HNO_3 acid, plastic disposable pipettes, indelible pen and labels.

Methodology for collecting samples during WaterAid drilling programme in Singida 2002

1. Fill in the spreadsheet provided (ie: Location, Date, GPS well depth, etc.). Please include as much information on the site as possible in the notes (ie: Land use, soil, geology (surroundings and borehole), topography, any problems with teeth?). Add notes on the back of the sheet if necessary.
2. When collecting the water sample rinse a container out with water from the well you are sampling and ensure your hands are clean. If any contamination occurs use distilled water to wash off the equipment and start again.
3. Three samples will be needed: One for fluoride analysis at the water laboratory in Singida and two samples for analysis at the British Geological Survey (one labeled FA and one FUA). All samples need to be filtered on site.
4. For filtering you will need the filter holder, filter papers and a syringe. It is important that your hands do not touch the water sample, the inside of the filter holder or the filter paper.
5. Unscrew the filter holder.
6. Carefully open a filter paper and lay it onto the flat side of the filter holder with the blue paper on the top. Only the blue side of the paper can be touched during this process and should be removed once the filter paper is in place.
7. Close the filter holder with the white filter paper remaining inside.
8. Collect some water from the container using the syringe without touching the water with your hands.
9. Insert the syringe into the top of the filter holder and push some water through the filter to waste.

10. Each bottle should then be rinsed three times with some filtered water.
11. Fill each bottle with filtered water, refilling the syringe and replacing the filter paper as necessary.
12. Two samples (FUA and Fluoride) should be filled to the top of the bottle so no air is present in the sample. For the FA sample, a gap should remain at the top of the bottle (approximately 1 cm depth).
13. Close samples securely and label the bottles accordingly:

- Date
- Location
- Sample type (ie: FUA/ FA/ F)

14. Remove the filter paper from the filter holder, again without touching the inside of the filter holder.

Back at the laboratory:

15. Open the FA sample and add 0.3 ml of Nitric Acid to each FA bottle in an aerated place. It is important to **use goggles and gloves when handling the acid**.
16. Keep all samples refrigerated/ cool.

Appendix 5 Contact details

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