KTH Land and Water Resources Engineering

CONTAMINATION OF WATER RESOURCES IN TARKWA MINING AREA OF GHANA: LINKING TECHNICAL, SOCIAL-ECONOMIC AND GENDER DIMENSIONS

Diarienummer: SWE-2003-245

Scientific Report (2004-2006)

Berit Balfors, Gunnar Jacks, Nandita Singh, Prosun Bhattacharya
Department of Land and Water Resources Engineering,
Royal Institute of Technology, (KTH), SE-100 44 Stockholm, Sweden

John E. Koku
Department of Geography and Development, University of Ghana at Legon
Accra, Ghana

July 2007

TRITA-LWR REPORT 3016
ISSN 1650-8610
ISRN KTH/LWR/REPORT 3016-SE
ISBN 978-91-7178-759-0

Table of Contents

SUMMARY

Ghana is Africa's second largest producer of gold with gold deposits in western part of the country. There are seven large-scale mines and 168 small-scale mining concessions valid in the region. Wassa West District is an important mining area, with Tarkwa as administrative capital. In recent years, the area has been exposed to lead, cadmium, arsenic, mercury and cyanide. Both small and large-scale mining industries have reportedly contaminated rivers, streams, dug wells and boreholes with heavy metals such as lead, cadmium, arsenic, mercury and cyanide. There has been significant adverse impact upon health, economy, and social life that may be felt differently by women and men, raising the question of sustainable access to safe water as a millennium development goal (MDG) in the area.

A multi-disciplinary approach was adopted in the project with distinct work components on the technical as well as on social, gender and policy aspects. It also aimed to suggest integrated strategies to address the problem so as to ensure achievement of the MDGs. Based upon a field study in 37 local communities coupled with water and sediment analysis from the area, the research indicated the existence of not only higher levels of metal contaminants in local water resources in Tarkwa area, particularly manganese and iron, but also arsenic and aluminium in some wells. However, water resources, particularly groundwater is currently safe for human consumption but the spillages of cyanide and other effluents into surface streams have health and ecological implications. Levels of mercury in stream sediments are high with a clear risk of methylation of the mercury and transfer in the food chain via fish to humans.

Regarding the impact of mining, it was found that for women who are the primary domestic water managers, contamination of local water sources has forced them to fetch water from greater distances, and livelihoods are hampered due to the fish loss through cyanide spillages in streams. Another finding was the lack of trust and rising water conflicts between mining authorities and the local communities. Regarding the policy aspects underlying the problem, it was found that there is a lack of coordination between the 3 policy areas, namely, rural water supply, mining, and environmental impact assessment (EIA) and environmental protection to the detriment of women as water users and domestic water managers. While impact of mining is increasingly seen as an issue of human rights violation, little is being done to strengthen participatory approaches especially involving women in rural water supply programs. The detailed analysis of the EIA regulations reveals that most mining have not undertaken any comprehensive EIA guiding their operations.

A number of recommendations have emerged from the integrated perspective attempted to be developed through this research. These include a need for further in-depth explorations on the situation of contamination in groundwater and surface waters as well as stream sediments in the area; the need to resolve the situations of water conflicts between the local communities and the mining authorities by promoting greater public participation; and the need to minimize the gaps between the three related policy frameworks. Also, there is a necessity to strengthen environmental compliance on part of the mining companies so as to uphold the quality of water resources in the area.

Key words: mining, water supply, metals, arsenic, cyanide, women, participation, Ghana

SAMMANFATTNING

Ghana är Afrikas andra guldproducent med guldfyndigheter i västra delen av landet. Det finns sju större gruvor och 168 mindre licencierade gruvkoncessioner. Wassa West District är ett viktigt gruvdistrikt med Tarkwa som administrativt centrum. På senare år har området utsatts för bly, kadmium, arsenik, kvicksilver och cyanid. Både den småskaliga gruvverksamheten och de stora gruvorna har rapporterats förorena vattendrag, grävda brunnar och borrbrunnar med tungmetaller som by, kadmium, arsenik. Eftersom de nämnda källorna utgör huvudsakliga vattentäkter för människor i området har det uppstått avsevärda effekter på hälsa, ekonomi och socialt liv, något som kan drabba kvinnor på annat sätt än män. Förhållandet ifrågasätter möjligheten att uppnå milleniemålet för tillgång till säkert vatten i området.

Ett tvärvetenskapligt tillvägagångssätt har tillämpats i projektet med beaktande av såväl tekniska som sociala, gender och policy aspekter. Arbetet syftade också till att föreslå strategier för att uppnå milleniemålet gällande tillgång till ett säkert vatten. Baserad på en fältstudie in 37 lokalsamhällen länkade till vatten och sediment analyser från området, erhölls indikationer på förekomsten av metallföroreningar i lokala vattenförekomster i Tarkwaområdet, i synnerhet järn och mangan men också arsenik och aluminium i några brunnar. För närvarande är dock vattnet av tillfredställande kvalitet som dricksvatten men utsläppen av cyanid och andra föroreningar är både hälsomässigt och ekologiskt problematiska. Halterna av kvicksilver i bäcksediment är mycket höga och det föreligger en uppenbar risk för metylering av kvicksilvret och transport via fisk till människor.

Beträffande påverkan på lokalsamhället av gruvverksamheten befanns det att kvinnor, de huvudsakliga vattenanvändarna, påverkas negativt genom att de tvingas hämta vatten längre bort samt att försörjningen försämrats genom fiskdöden orsakad av cyanidutsläpp. Ett annat viktigt fynd var bristen på förtroende och ökande konflikter mellan gruvföreträdare och den lokala befolkningen. Problemen beror på bristande koordination mellan de tre verksamheterna vattenförsörjning av lokalbefolkningen, gruvbrytning samt utförandet av miljökonsekvensbeskrivning (MKB) av miljöpåverkan. Bristande omsorg av miljön påverkar kvinnorna som är de huvudsakliga vattenanvändarna. Medan påverkan av gruvbrytningen alltmer ses som ett hot mot de mänskliga rättigheterna görs litet för att stärka medinflytandet för speciellt kvinnor vad gäller vattenförsörjningsprogram i gruvpåverkade områden. En detaljerad analys av reglerna för MKB visar att de flesta gruvföretagen inte gjort någon mera omfattande MKB i syfte att styra verksamheten.

Ett antal rekommendationer har framkommit genom det tvärvetenskapliga tillvägagångssättet som tillämpats i detta projekt. Dessa omfattar ytterligare undersökningar av grund- och ytvatten samt bäcksediment i området, nödvändigheten att lösa konflikter mellan lokalbefolkningen och gruvföretag genom ett vidgat medinflytande samt att minska klyftorna mellan de tre relaterade miljöramverken nämnda ovan. Det är också nödvändigt att stärka gruvföretagens efterföljd av miljökrav för att bibehålla vattenkvaliteten i området.

Nyckelord: gruvbrytning, vattenförsörjning, metaller, arsenik, cyanid, kvinnor, medinflytande, Ghana

1. INTRODUCTION

Ghana is Africa's second largest producer of gold with prospective gold deposits localized in western part of the country (Akabzaa and Darimani 2001). Wassa West District is an important mining area of the country, with Tarkwa as its administrative capital. While mining has been an important economic activity in Ghana for centuries, gold industry has actually flourished after 1983 with launching of the Economic Recovery Program (ERP) by government under guidance of IMF (Aryee 2001, Hilson 2002a). By adopting a new minerals policy through new mining laws, the government handed over mine operations, management and ownership to the private sector, along with legalization of small-scale gold mining as an industry (Addy 1998, Hilson 2002a). As a result, many large and small-scale projects have developed in the area since 1990s, with large-scale investments by foreign companies. There are seven large-scale mines and 168 small-scale mining concessions presently valid in the region.

In recent years, Tarkwa has tended to be the most discussed area in west-Africa with mining-related pollutants, notably heavy metals like lead, cadmium, arsenic, mercury and cyanide being identified as key public health problems (Hilson 2002b). In most parts of the district, studies have shown that gold mining operations have resulted in significant localized surface water and atmospheric arsenic pollution (Smedley 1996). A recent work showed arsenic concentrations in groundwater from some of the mining communities to vary from <1-64 μg/L (Smedley 1996). Many of these exceed revised WHO guideline maximum for drinking water (10 μg/L). Apart from groundwater, studies also report arsenic, cyanide and mercury contamination in surface waters (Hilson 2001). Thus, the phenomenal growth of the industry over the last two decades facilitated by the new legal framework has had several unfavorable impacts, with local communities feeling the toll. Both small and large-scale mining industry that use local water resources have reportedly caused contamination of rivers, streams, dug wells and boreholes with heavy metals such as lead, cadmium, arsenic, mercury and cyanide. It was hypothesized that since these constitute the major sources of water for people living in the area, there has been significant adverse impact upon health, economy, and social life that may be felt differently by women and men. On the whole, it can be said that the degradation of water resources in the area, set in by the development of the mining sector, raise significant issues in water resources management.

Considering the global policy framework on water, the problem of study was conceptualized in terms of two integral aspects: first, the problem of contamination of the water resources – an ongoing process under the present mining policy framework; and second, that of ensuring supply of safe water for the women, men and children of the affected communities for fulfillment of their basic water needs. Both the aspects were seen as having significant policy dimensions that were incorporated within the scope of the project so that sustainable access to safe water can be ensured for the people as the UN Millennium Development Goal (MDG).

2. MINING IN GHANA

In Ghana there are both small-scale miners and large-scale mining. The general processing techniques are handpicking, amalgamation, cyanidation, flotation, electrowinning and roasting of ore (Akosa et al. 2002). The technique differs between large- and small-scale mining and also varies depending on the type of deposit and its location (Ntibery et al. 2003). The area has three main gold deposits (Kortatsi 2004):

- Placer or alluvial deposit,

- Non-sulphidic paleplacer or free milling ore, and
- Oxidized ore

At present there are totally about 237 companies (154 Ghanaian and 83 foreign) prospecting for gold and another 18 are operating gold mines in Ghana (Hilson 2002a).

2.1 Large-scale mining

Large-scale mining in the area is today conducted as surface mining. Cyanidation is the most common technique in the study area and is used for non-sulphidic paleplacer ore (Akosa and Adimado 2002, Kortatsi 2004). Non-sulphidic paleplacer ore occurs mainly in hard rock. It is particularly associated with the Banket conglomerates of the Tarkwa formation (Kortatsi 2004). This technology is typically conducted as drilling, blasting, haulage of the ore, crushing and screening, agglomeration, haulage and stacking. Lime (CaO) is now applied to the ore to raise the pH to between 10.5 and 11.0. Sodium cyanide solution (NaCN) is used for dissolution of the gold. The prepared ore is heaped into plastic lined pads but between 45-450 l/day of sodium cyanide solution per hectare possibly leaks out into the environment (Kuma and Younger 2004). Finally gold is recovered through electro winning (Akosa et al. 2002, Kortatsi 2004).

Oxidized ore occurs in weathered rocks and is derived from sulphides, arsenopyrite, realgar (AsS), opiment (As_2S_3), pyrite etc. Roasting is used as a preferable method for the recovery of metals from the ores (Kortatsi 2004). In the Wassa west district there are in this moment seven large-scale mines which extract and process two metals, gold (six mines) and manganese (one mine). A number of these are located in the study area namely; Ghana Australian Goldfields (GAG), Teberebie Goldfields Limited (TGL), Goldfields Ghana limited (GGL) (Kuma and Younger 2004), Ghana Manganese Company in Nsuta (Kortatsi 2004) and also Abosso Goldfield at Damang (Nankara, T. 2004, pers. comm., 16 Sep. 2005).

2.2 Small-scale mining

Small-scale mining in Ghana is defined as "mining by any method not involving substantial expenditure by any individual or group of persons not exceeding nine in number or by a co-operative society made up of ten or more persons" (Government of Ghana 1989). They are estimated to number over 150,000 in Ghana, of which many operate illegally on concessions belonging to large scale operators, or in restricted areas (Ghana academy of arts and sciences 2003). The illegal small-scale miners account for approximately 10% of the gold production in Ghana (Ntibery, B. 2004, pers. comm., 9 Sep.). These are locally referred to as galamsey (Hilson 2002c). The technique mostly used for small-scale mining is amalgamation (Akosa 2002). In this process mercury is mixed with gold concentrate to form gold amalgam, which is heated to separate the gold (Ntibery et al. 2003). Both legal and illegal small scale mining is practised in the district (Avotri et al. 2002). Small-scale mining is found all around, both in the forest and along the rivers in the Tarkwa region. It is practised all year around and at present the total number of such small scale mines were more than 20 000 in the Wassa West district. Of these small-scale mines about 90 % are illegal. At the moment 168 small-scale mining concessions are valid in the region (Ntibery, B. 2004, pers. comm., 9 Sep.).

2.3 Impact of mining and environmental degradation

Large- and small-scale mining cause somewhat different environmental concerns. The major concerns on the environmental degradation due to Akosa et al. (2002). The main environmental problems arising due to amalgamation mostly used by the small scale miners (Ntibery et al. 2003).

2.3.1 Large-scale mining

The major concerns observed in this area are:

- Land degradation, for example removal of vegetative cover and destruction of flora and fauna.
- Impact due to processing technique includes contamination of water bodies and soil by release of cyanide (see below), arsenic, sulphates, and heavy metals as Pb, Cu, Zn and Fe.
- Cyanide spillage. There have been a number of accidental cyanide spillages in Ghana. The major spillages occurred in 1989, 1991, 1994, 1996, 1999 and 2001.
- Roasting of ore containing pyrite gives a rise to the production of SO_2 in the atmosphere which produces acid rain. The acid water then releases high levels of toxic ions from the rock matrix in the groundwater. This has been the main mode of extraction for the Prestea mine during the last decade. SO_2 could also been transported with north-eastern winds from the Ashanti Goldfields in the northeast (Kortatsi 2004)
- Noise and vibrations
- Dust from blasting operations
- AMD (Acid Mine Drainage) from solid waste from sulphidic ore leaching heavy metal and acidity into water and soil
- Siltation of surface waters
- Grease and oils from various activities in the mine

The management of waste from large scale mining is done in accordance to approved environmental plans. The spent heap and waste rock heaps are stabilized and re-vegetated. Tailing slurries are channeled into tailing dams that also are re-vegetated. Reagent containers and packing materials are sold out to contractors who dispose of them. The monitoring of these contractors is poor. Spent oil and grease are sold to end-users.

2.3.2 Small-scale mining

Illegal miners account for the most significant part of the environmental damage of the small-scale miners. Legal small-scale miners must have environmental permits and are monitored regularly by field officers (Ntibery et al. 2003).

- Land degradation
- Pollution of rivers and streams by mercury
- Atmospheric impacts from mercury fumes during gold recovery and dust
- Mercury in groundwater from accidental spillage during gold processing (Akosa et al. 2002)
- AMD from solid waste from sulphidic ore leaching heavy metal and acidity into water and soil (Akosa et al. 2002)
- Siltation of surface waters (Akosa et al. 2002)
- • Deforestation due to wood used for stabilizing mining shafts (Ntibery, B., pers. comm., 9 sep. 2004)
- • Damage to infrastructure due to undermining of roads and houses

The management of waste on small-scale mines particularly illegal ones does not have a waste management plan but simply leave the waste.

Estimated 5 tonnes mercury is released from small-scale mining operations in Ghana each year (Hilson 2001). High concentrations of mercury have been found in sediments and fish in the vicinity of small-scale mining activities using amalgamation as their main technique. The concentration in most fish fillets in these areas exceeds the recommendations of the United States Food and Drug Agency (Babut et al. 2003).

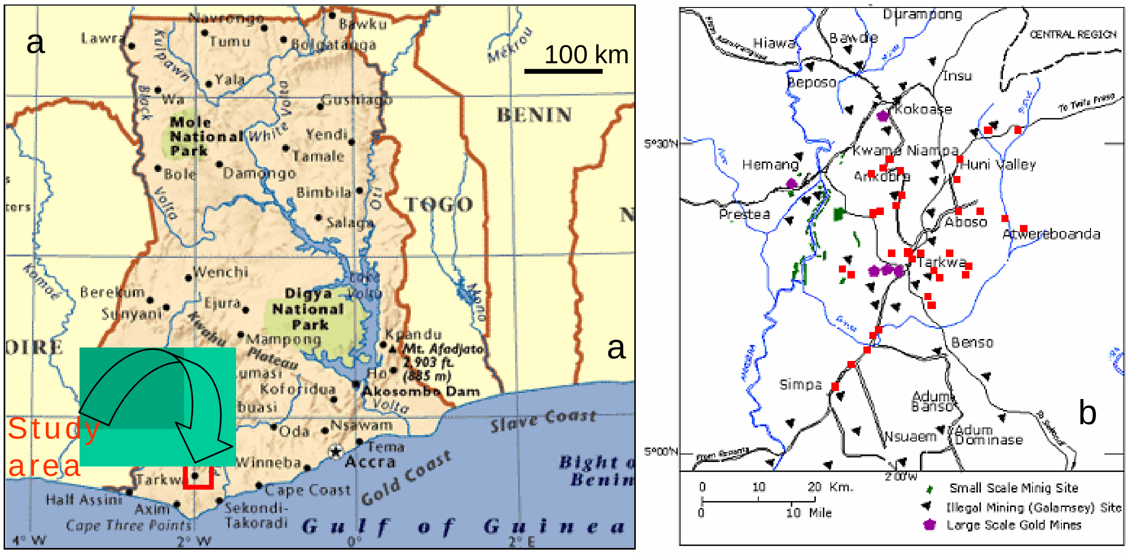


Figure 1. *a) Map of Ghana showing the study area near Tarkwa; b) location map of the sampling sites points. Number mark sampling number (Reproduced from Asklund & Eldvall 2005)*

3. Aims and Objectives

The aim of the research was develop an integrated perspective on the problem of contamination of water resources in Tarkwa mining region as a problem of sustainable water resources management in the area, by linking technical dimensions of the problem with socio-economic and gender issues, examined against the policy framework. It also aims to suggest integrated strategies to address the problem so as to ensure achievement of the MDGs in the area. The following objectives have been further specified:

- Investigate the metal pollution in water resources (both ground- and surface water) in selected communities in the proposed study area.
- Assess the social impact of & responses to contamination of local water resources.
- Evaluate the effectiveness of the initiatives of different actor agencies in management of the contamination, at levels of policy as well as action.
- To suggest interventions at technical as well as policy levels that are socio-culturally appropriate for addressing the problem of water contamination in the local communities.

4. Methodology

4.1 The Study Area

This study was carried out in the Tarkwa and its environs in the Wassa west District of Ghana. The choice of this location is considered appropriate and timely as it tends out to be the most discussed area in west-Africa in recent years, as far as the link between mining, health environment and water resources is concerned (Lassey 1999, Akabzaa & Darimani 2001). Mining-related pollutants, notably the heavy metals such as lead, cadmium arsenic, mercury and cyanide have been identified as key public health problems in the Tarkwa gold mining area (Fig. 1) where the main prospects occur in Ghana (Amonoo-Neizer & Amekor 1993, Armah et al. 1998, Hilson 2002a).

4.2 Geology and Hydrogeology

Ghana is underlain partly by what is known as the Basement Complex. It comprises a wide variety of Precambrian igneous and metamorphic rock and covers about 54% of the country, mainly the southern western parts of the country (Fig. 2). It consists mainly of gneiss, phyllites, schists, migmatites, granite-gneiss and quartites. The rest of the country is underlain by Palaeozoic consolidated sedimentary rocks referred to as the Voltaian Formation consisting mainly of sandstones, shale, mudstone, sandy and pebbly beds and lime stones (Gyau-Boakye & Dapaah-Siakwan 1999).

In the Tarkwa-Prestea area groundwater occurrence is associated with the development of secondary porosity through fissuring and weathering. The rock underlying the area lacks primary porosity since they are consolidated. The weathering depth is greatest in the Birimian system where depths between 90m and 120 m have been reached. Also in granites, porhyrites, felsites and other intrusive rock the weathering depth is great. In the Tarkwa system though, and especially in the Banket series quartzites, grits, conglomerates and Tarkwa phyllite the weathering depth rarely exceed 20 m. Clay, silts, sandy clays and clayey sands are mostly the result of the weathering. In this area two types of aquifers occurs. The weathered aquifer occurs mainly above the transition zone between fresh and

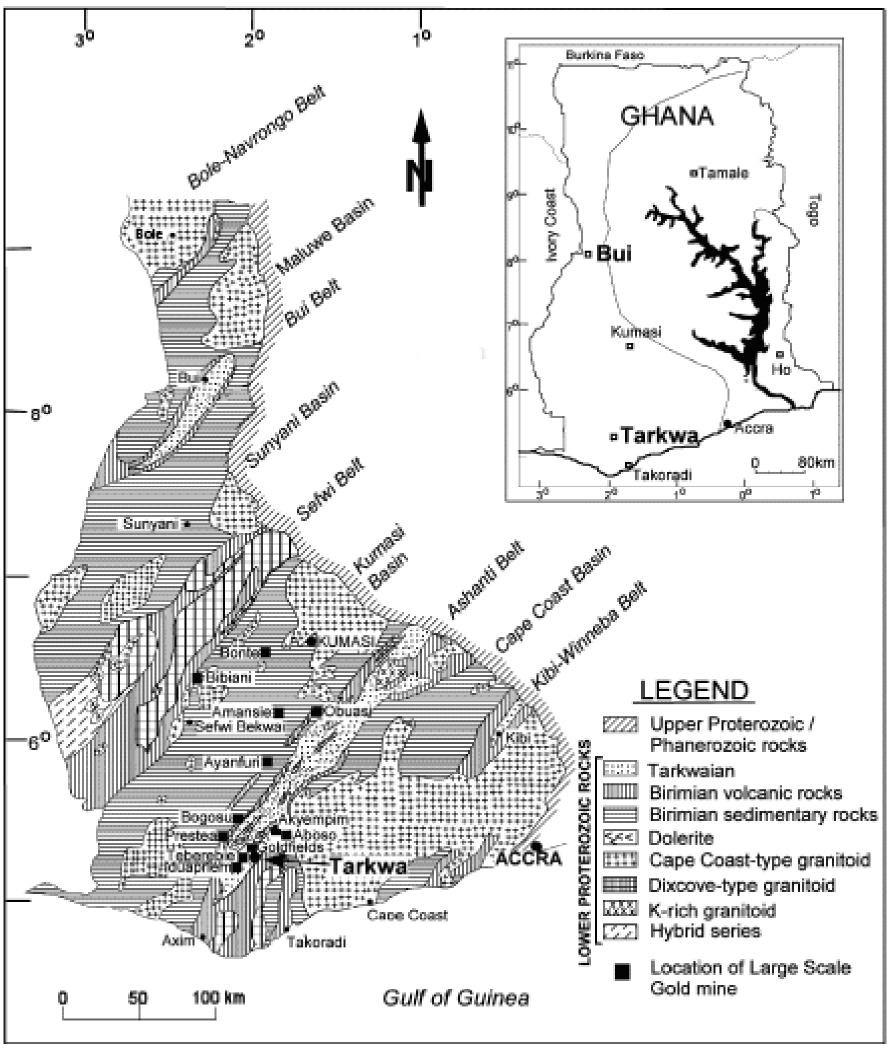


Figure 2. *Simplified geological map of southwest Ghana (modified from Kuma 2004)*

weathered rock. Due to the soils content of clay and silt in these aquifers have high porosity and storage but low permeability. The fractured/fissured zone aquifer occurs below the transitions zone. They have relatively high transmissivity but low storage (Kortatsi 2004). Groundwater is the main source of water supply in the Tarkwa-Prestea area. Most major towns in the area except from Tarkwa rely solely on groundwater. To match the demand for potable water the number of boreholes and hand dug wells keeps increase rapidly (Kortatsi 2004). Surface water taken from the Bonsa River at Bonsaso is treated and distributed to Tarkwa town. Some villages between Bonsaso and Tarkwa are also connected to the pipe (Tim 2004). The borehole yields of the area varies between 1-9 m^3/h (Dapaah-Siakwan & Gyau-Boakye 2000).The depth varies between 18m to 75m with an average of 35.4m. Yield varies from 0.4-18 m^3h^{-1} with an average of 2.4 m^3h^{-1}. The depth has little or no effect on borehole yields.

4.3 Study Approach

A multi-disciplinary approach was adopted in the project with distinct work components identified in relation to the research objectives. To ensure logical links between various components of the project, different aspects of project activities were localized within the same communities.

4.3.1 Technical components

4.3.1.1. Hydrogeochemical investigations

On the technical side, particularly in relation to the first objective, data on hydrogeology, groundwater level fluctuations and groundwater chemistry were collected from government and local agencies. This was followed by systematic hydrochemical investigations on the water samples from saturated and unsaturated zones carried out in different phases. 40 groundwater samples were collected from Tarkwa-Prestea area during the period September 2004 (Fig. 1b). The field investigations included Measured field parameters are Eh, conductivity, pH and temperature using Ecoscan pH 6, Ecoscan Con 5 and Hach Sension 2. A flowcell was used for measuring the Eh value. Measurements were made until stable values were achieved. The sample sites were positioned with a Cobra GPS100 to get their exact location. Methodology of groundwater sampling involved collection of water samples: (i) filtered samples (0.45µm, for anion analyses), (ii) filtered and acidified samples (with concentrated HNO_3, for cation and trace element analyses), (iii) sampling for DOC analyses (Bhattacharya et al. 2002, 2007 in prep.). Determination of carbonate alkalinity was measured on acified water with Radiometer Copenhagen automatic titration equipment comprising ABU 80 Autoburette, PHM 82 Standard pH meter and TTT80 Titrator. Major anions such as Cl^-, NO_3^- and SO_4^{2-} were analysed on Dionex DX-120 Ion Chromatograph. PO_4^{3-}-P and NH_4^+-N were determined using Aquatec 5400 Analyser and 5027 Sampler, Tecator following application notes ASN 140-01/90 and ASN 146-01/90. Dissolved organic carbon (DOC) was determined as NPOC, using a TOC-5000 Shimadzu Total Organic Carbon Analyser These analyses were performed at the laboratory of the Department of Land and Water Resource Engineering at Royal Institute of Technology, Stockholm, Sweden. Trace elements were analysed at the Department of Geology and Geochemistry at Stockholm University, Sweden. Element concentrations were measured on Varian Vista Ax Pro ICP-OES (Optical Emission Spectroscopy) equipped with a CCD camera) and an axial mounted torch. The typical precision in analyses based on measurements of certified standards was typically better than 4%.

4.3.1.2. Sediment sampling and analyses

A number of sediment samples were later taken from streams where small-scale mining takes place. The samples were taken in sections with slow flow to obtain samples, which were more fine-grained and contained more organic matter, both factors that would enhance mercury accumulation (Boszke et al. 2004). Two samples were analysed using ICP-MS instrument at ACME Analytical Laboratories Ltd. at Vancouver, Canada.

4.3.2 Social Components

With respect to the social component, research was undertaken in relation to the second and third research objectives. Different actor agencies actively associated with genesis and perpetuation of the problem as also the connected policy issues were selected and their representatives interviewed. These included the concerned government ministries like Works and Housing, and Mines and Energy; government agencies like Community Water and Sanitation Agency (CWSA), and Environmental Protection Agency (EPA); two large-scale mining companies and two small-scale miners with permits. Secondary literature concerning the problem was also reviewed and an EIA-based analysis was also carried out. Further, 37 local communities whose members – both women and men – that participate in mining activities for small earnings and also largely suffer the consequences of the contamination – were sampled for study. A general socio-economic survey was undertaken in 18 out of these 37 communities. Of these, 6 were taken up later for in-depth study. Data collection primarily rested upon qualitative techniques like key-informant and household level interviews based largely upon open-ended questions, and observation. Case studies were explored to gain more specific and detailed information on related events, while for facilitating community-level opinions on issues of common interest, participatory techniques, notably focus group discussion were blended.
Data analysis with respect to the socio-economic and gender components was done using the SPSS[1] program. Analytical tools like GIA[2] and EIA[3] with respect to water resources were utilized to analyze the impact of the underlying policy as well as policy outcomes at the level of local communities. With regard to the applied component (objective 4), recommendations were made for effective problem resolution with respect to water and policy support in relation to drinking water supply in the area under study, integrating the findings from the technical and social dimensions.

5. Results and Discussion

5.1 Technical Dimensions

5.1.1 Hydrogeochemistry and metal contamination

Average groundwater temperature was measured to 26.6 C° ranging from 25.4-28.5 C°. The pH varies between 4.19 to 6.92 with an average of 5.38. The redox potential was measured within a range of 192-523 mV with an average of 357 mV. Electric conductivity ranges between 11.0 and 780 µS/cm with an average of 301 µS/cm. Table 1 shows a statistical summary of groundwater analyses for all the wells.
The present study clearly indicates the existence of elevated levels of metal contaminants in local water resources of the Tarkwa area that were of major concern. The principal contaminants were M and iron but arsenic and aluminium are also present in concentrations exceeding the WHO guidelines in some wells (detailed in Asklund & Eldvall 2005).
In a later study, Kusimi (2007) integrated the facets of groundwater chemical data for studying the long term variations in the concentration of trace elements as well nitrate within five settlements (Simpa, Odumase, Nsuaem, Aboso, and Huni Valley) within the Waasa West district over a period of five years

[1] Statistical Package for the Social Sciences

[2] Gender Impact Assessment

[3] Environmental Impact Assessment

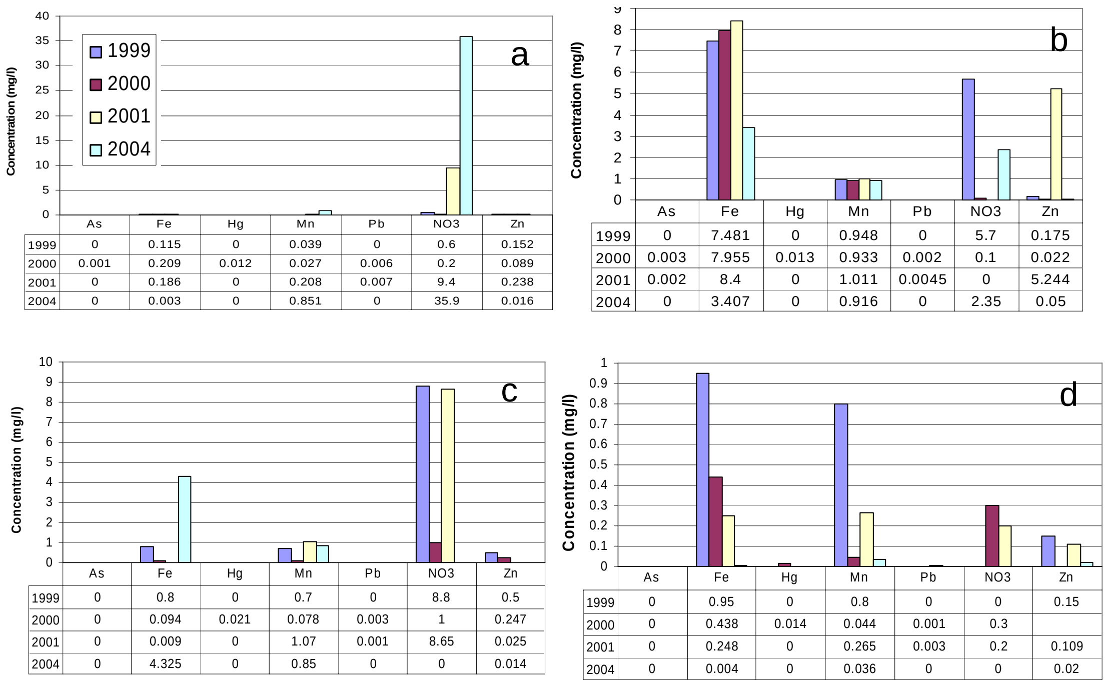
Table 1: *Statistical summary of groundwater chemistry (values exceeding WHO:s guidelines for drinking water are marked bold).*

Parameter	Unit	Min	Max	Average	Median	St. Dev.
pH		4.19	6.92	6.00	6.07	0.631
Eh	mV	192	523	357	344	103
Cond	µS/cm	11.0	780	301	276	197
Temp	C°	25.4	28.5	26.6	26.5	0.654
DOC	mg/L	0.636	3.89	1.09	0.940	0.590
HCO_3^-	mg/L	bld	378	139	107	103
NO_3^-	mg/L	bdl	**146**	9.70	0.230	26.0
SO_4^{2-}	mg/L	0.220	68.5	10.3	2.73	16.2
PO_4^{3-}	mg/L	bdl	0.352	0.061	0.034	0.072
Cl^-	mg/L	3.160	117	20.1	8.55	25.7
NH_4^+	mg/L	bdl	0.262	0.0107	bld	0.0422
Na^+	mg/L	2.19	69.7	17.1	12.1	12.6
K^+	mg/L	0.266	22.7	2.28	0.912	3.98
Ca^{2+}	mg/L	1.27	111.	34.1	27.3	25.9
Mg^{2+}	mg/L	0.583	22.4	7.48	5.77	5.91
Al	µg/L	3.49	**2180**	80.8	8.35	352
As(tot)	µg/L	bdl	**69.4**	2.26	bdl	11.2
B	µg/L	bdl	53.1	10.4	9.08	10.5
Ba	µg/L	7.24	469	89.0	39.6	101
Cd	µg/L	bdl	0.704	bdl	bdl	0.163
Cr	µg/L	bdl	2.00	bdl	bdl	0.415
Cu	µg/L	bdl	17.0	2.68	bdl	5.25
Fe	µg/L	1.16	**10800**	1160	102	2350
Li	µg/L	bdl	28.2	6.72	5.73	5.99
Mn	µg/L	5.50	**2040**	432	303	403
Ni	µg/L	bdl	19.0	3.39	bdl	5.10
Pb	µg/L	bdl	4.11	bdl	bdl	0.650
Si	µg/L	2940	26000	14200	15800	6350
Sr	µg/L	32.5	3260	398	198	625
Zn	µg/L	5.95	650	56.9	19.9	124

(1999 to 2004). The choice of the settlements was based on the availability of groundwater data as well the socioeconomic situation of the communities (see following discussion in section 3.2).

Detailed scrutiny of the hydrochemical data based on the previous studies by Asklund & Eldvall (2005) as well as the previous studies by Kortatsi (2004) did not reveal any spectacular differences. The are plotted is presented in Figure 3a-e. In general, concentrations of metals such as Fe, As, Pb, Mn, Zn and Hg and nitrate have been low, that is within the WHO drinking water guideline value.

Concentrations of Fe are higher than the acceptable limits in all stations except Nsuaem and Aboso. Levels are highest at Simpa with a mean of 6.81 mg/L and are lowest at Nsuaem with a mean value of 0.13 mg/L. Elevated levels of Fe are strongly influenced by the oxidation of pyrite and arsenopyrite (sulfidic ore minerals) in the bed rocks. Arsenic (below detection limit to 69.4 µg/L) and Pb (below detection limit to 4.1 µg/L) levels have been consistently low and within WHO limits for safe drinking water. Arsenic was below detection limits in all localities except Odumase. The presence of As was found in mineralized areas mostly associated with the oxidation of pyrite and arsenopyrite minerals, while Pb also present as sulphide ores in the Birrimian Formation was less mobilized in

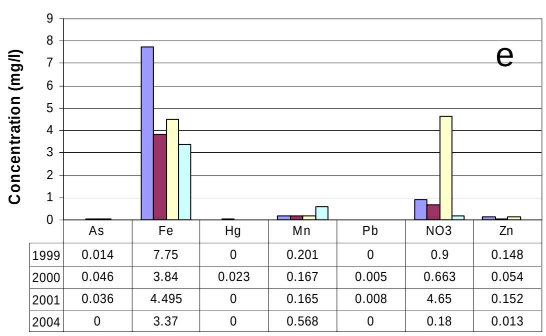


a	As	Fe	Hg	Mn	Pb	NO3	Zn
1999	0	0.115	0	0.039	0	0.6	0.152
2000	0.001	0.209	0.012	0.027	0.006	0.2	0.089
2001	0	0.186	0	0.208	0.007	9.4	0.238
2004	0	0.003	0	0.851	0	35.9	0.016

b	As	Fe	Hg	Mn	Pb	NO3	Zn
1999	0	7.481	0	0.948	0	5.7	0.175
2000	0.003	7.955	0.013	0.933	0.002	0.1	0.022
2001	0.002	8.4	0	1.011	0.0045	0	5.244
2004	0	3.407	0	0.916	0	2.35	0.05

c	As	Fe	Hg	Mn	Pb	NO3	Zn
1999	0	0.8	0	0.7	0	8.8	0.5
2000	0	0.094	0.021	0.078	0.003	1	0.247
2001	0	0.009	0	1.07	0.001	8.65	0.025
2004	0	4.325	0	0.85	0	0	0.014

d	As	Fe	Hg	Mn	Pb	NO3	Zn
1999	0	0.95	0	0.8	0	0	0.15
2000	0	0.438	0.014	0.044	0.001	0.3	
2001	0	0.248	0	0.265	0.003	0.2	0.109
2004	0	0.004	0	0.036	0	0	0.02



e	As	Fe	Hg	Mn	Pb	NO3	Zn
1999	0.014	7.75	0	0.201	0	0.9	0.148
2000	0.046	3.84	0.023	0.167	0.005	0.663	0.054
2001	0.036	4.495	0	0.165	0.008	4.65	0.152
2004	0	3.37	0	0.568	0	0.18	0.013

Figure 3*. Trends in variations in the concentrations of metals such as Fe, As, Pb, Mn, Zn and Hg and nitrate in groundwater at five communities: a) Nsuaem, b)Simpa, c) Aboso, d) Huni Valley, and e) Odumase.(Based on the data from Kortatsi 2004; Asklund &Eldval 2005)*

groundwater. The maximum level for both metals was detected within the Lower Birrimian at Odumase. It was also detected that concentration levels had a positive correlation with residence time (Kortatsi 2004).

Zinc concentration in groundwater was also in general low except at Simpa where levels exceeded WHO (1993) limit of 3 mg/L as 5.24 mg/L in 2001. Its occurrence is also associated with sulphide ore in the Prestea mine. Like others, manganese levels were generally low with isolated higher levels in certain settlements. The highest concentration was found at Simpa with a mean value of 0.95 mg/L where the elevated concentrations are related to the presence of Mn-rich bedrocks comprising manganiferous oxide minerals particularly in Birimian rock terrains in the Tarkwa-Prestea area (Kortatsi 2004).

Mercury is commonly used for small scale mining in the area (and the amalgamation process is locally called as '*galamsey*', see Fig. 4). Mercury is however not present in the underlying geology, hence its occurrence has been attributed to activities of small scale mining. Although Asklund & Eldvall (2005) did not analyse Hg in groundwater, but earlier studies have shown that the levels of Hg in the water resources fluctuated seasonally, low during dry seasons and high during rainy seasons (Kortatsi 2004, Kusimi 2007).

Concentration levels of nitrate in groundwater were also found to be low. Based on the

***Figure 4**. a) Blanket washing of milled ore. The concentrate from this gravity method is repeatedly washed and b) gold amalgam is formed when mercury has been added. (Reproduced after Asklund &Eldval 2005).*

groundwater investigations, it can therefore be said that inspite of the intense mining activities, concentrations of the heavy metals are low and thereby appear to have less impact on metal contamination in the groundwater resources in the Wassa-West District. However, it was deduced that the distance of the sampling sites from the main mining sites could be a reason for presence of trace metals in groundwater in boreholes and wells within the international limits prescribed by WHO. On the other hand, spillage of cyanide and other effluents into surface streams due to the local mining practices might have much health and ecological implications (Kusimi 2007). Although the groundwater resource does not pose immediate threat, it is important to carry out more detailed study to advocate for long-term sustainability of these resources for safe drinking purposes.

4.1.2 Scenario for sediment contamination

Regarding the sediment samples, the two samples sent for ICP-MS analysis contained 27 respectively >100 mg/kg of mercury. Both are extremely high values as Swedish Environmental Board consider 5 mg/kg as "very highly polluted". The main worry is whether the mercury is being methylated and transferred in food chains. Methylation is considered to be done by sulphate reducing bacteria, thus under rather strongly reducing conditions but even abiotically (Celo et al. 2006). Sulphate contents are at sites rather high making sulphate reduction likely (Bhattacharya et al., manuscript in preparation). However even Fe(III)-reducing bacteria are found to methylate (Kerin et al. 2005). Thus methylation is not unlikely in the streams. A key question arising then is whether there exist a fish population consumed by the people. If so, this constitutes a very serious threat to the population and especially if the fish is consumed by pregnant women. The most vulnerable are the fetuses which can be born with serious neurological aberrations.

Table 2: *Trace element concentrations in selected rive- bed sediment samples from the Wassa West-Tarkwa miming area.*

Parameter	Unit	Concentration range	Parameter	Unit	Concentration range
Mo	mg/kg	0.8-1.1	Ca	%	0.01-0.54
Cu	mg/kg	62.4-96.7	P	%	0.009-0.026
Pb	mg/kg	6.6-51.2	La	mg/kg	15-4
Zn	mg/kg	13-191	Cr	mg/kg	55.0-17.0
Ag	mg/kg	1.0-0.1	Mg	%	0.01-0.02
Ni	mg/kg	6.1-7.6	Ba	mg/kg	9.0-193
Co	mg/kg	6.3-3.9	Ti	%	0.062-0.006
Mn	mg/kg	137-459	B	mg/kg	<1.0-1.0
Fe	%	4.4-3.8	Al	%	0.03-0.34
As	mg/kg	10.0-6.9	Na	%	0.002-0.041
U	mg/kg	1.7-0.4	K	%	<0.01-0.06
Au	mg/kg	>100.0-1.45	W	mg/kg	1.1-0.4
Th	mg/kg	30.1-1.8	Hg	mg/kg	>100.0-26.9
Sr	mg/kg	2.0-34.0	Sc	mg/kg	0.4-0.7
Cd	mg/kg	<0.1-0.3	Tl	mg/kg	<0.01
Sb	mg/kg	0.6-1.4	S	mg/kg	<0.05
Bi	mg/kg	0.2-0.1	Ga	mg/kg	1.0-3.0
V	mg/kg	87.0-210	Se	mg/kg	<0.5-0.8

4.2 Socio-economic, Gender and Policy Dimensions

4.2.1 Socio-economic and gender dimensions and water conflicts

Regarding the impact of mining on the local communities in the area, it was found that while the resultant socio-economic turmoil has been inadvertent, especially with respect to water resources, contamination of rivers and streams has the potential of serious adverse impact upon health, economy, and social life that is being felt differently by women and men. For instance, for women who are the primary domestic water managers, contamination of local water sources adversely influence their efficiency by forcing them to fetch water from greater distances, in turn causing adverse health impact on themselves and their families as well as potential loss of their productivity and capabilities. Livelihoods are also hampered due to the fish toll resulting from cyanide spillages in the local streams. It is feared that contamination of groundwater sources may also have large-scale implications for the agricultural sector, primarily a concern of men since use of contaminated groundwater from agricultural tubewells can lower the prospects of market return from the produce (Koku & Singh 2005).

In the study, informants were asked to indicate perception of the impacts of mining activities on their communities. Although the response was mixed (Fig. 5), the impact of mining on water quality was found to be of

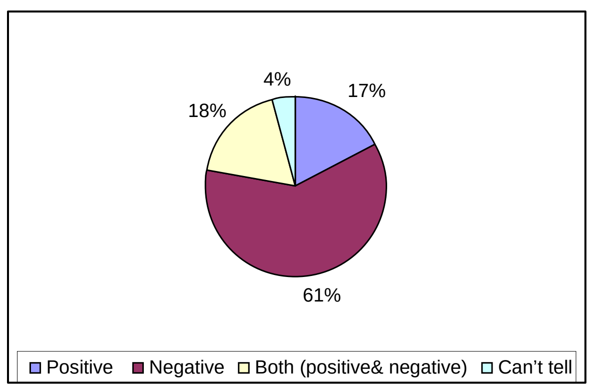


Figure 5. *Perceived impact of mining in communities.*

concern to the local residents. For instance, about sixty percent (60.2%) of the informants claim that mining activities exert a negative impact on the society (Table 3), while only

Table 3: *Perception of impacts on mining in the study area.*

Perception	Frequency	Percent
Positive	29	17.5
Negative	100	60.2
Both (positive& negative)	30	18.1
Can't tell	7	4.2
Total	166	100

Table 4. *Types of impacts related to mining industries in the study area.*

Types of impact	Frequency	Percent
Water Pollution	37	23.1
Land Degradation	22	13.8
Mining Related diseases	18	11.3
Displacement from farmlands	33	20.6
Natives denied employment	6	3.8
Others	10	6.3
N/A	34	21.3
Total	160	100

17.5% considered the impacts to be positive. This represents distinct perceptions of the impacts. However, the third category of responses representing 18.1% presents a more balanced perspective of the operations of the mines in communities as they recognized that the impact has been both positive and negative. To unearth reasons underlying perceptions, informants were further asked to assign reasons. Those who saw the impact of mining as negative identified six major areas of impact. These are: land degradation, water pollution, mining-related illnesses, displacement from farmlands, denial of employment of natives and other negative mining related problems that include increased school drop-out rates, etc. Out of the six categories of impact identified, water pollution (23.1%) stood out as the issue of greatest concern. (Table 4 & Fig. 6).

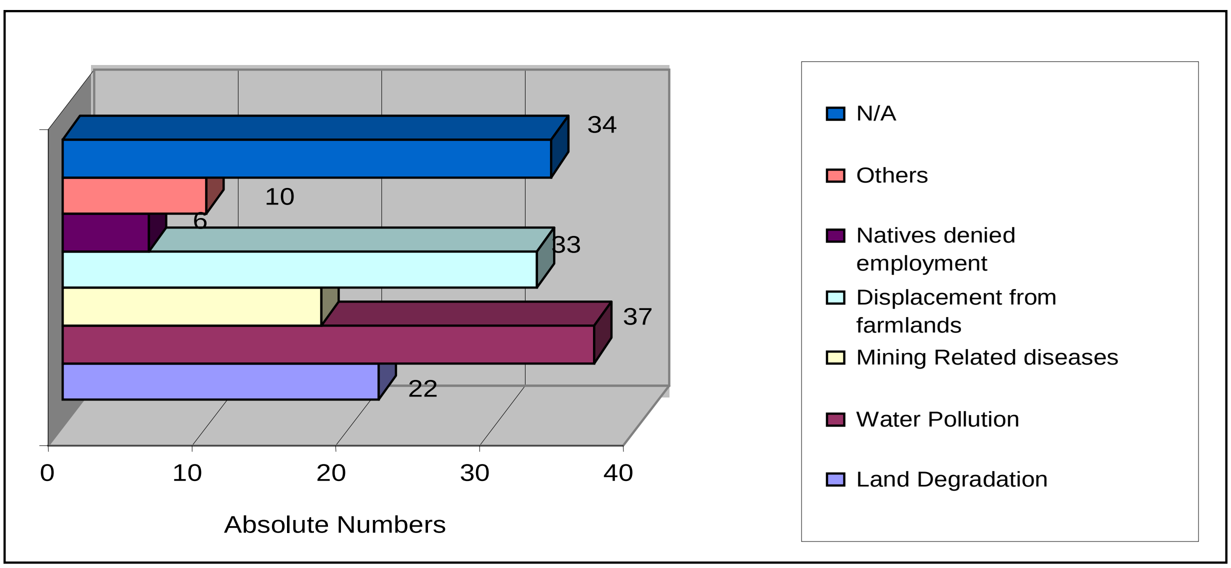


Figure 6. *Perceived areas of negative impact of mining.*

An important finding regarding the impact of mining on local communities was the lack of trust and rising water conflicts between mining authorities and the local water-using communities. while a number of case studies were explored in this regard, the following case unfolds why and how water conflicts are evolving in the mining communities.

Case of the Bogoso Goldfields Ltd. (BGL)-contamination of six rivers in Dumase:

There have been continuing clashes between host communities and BGL as the former perceive operations of the latter to be inimical to their welfare, notably contamination of their water resources. Asumin (2005) reports citing the Executive Director of the Wassa Association of Communities Affected by Mining (WACAM) as having said that 'BGL has destroyed six rivers in Dumase and provided the community with a borehole that turns blackish when plantain is put into it.' He recounted that in 2004, BGL spilled cyanide into River Aprepre at Dumase, the source of drinking water for the inhabitants. This sparked a long-standing misunderstanding between the people of Dumase and the BGL, apparently arising from dissatisfaction with the way of operations of the company.

This was testified at a FGD with residents in the community, when the contention that water from borehole turns blackish on putting plantain into it was demonstrated to the research team. While there appears to be no clear scientific explanations for what the causes of the colour changes are likely to be,

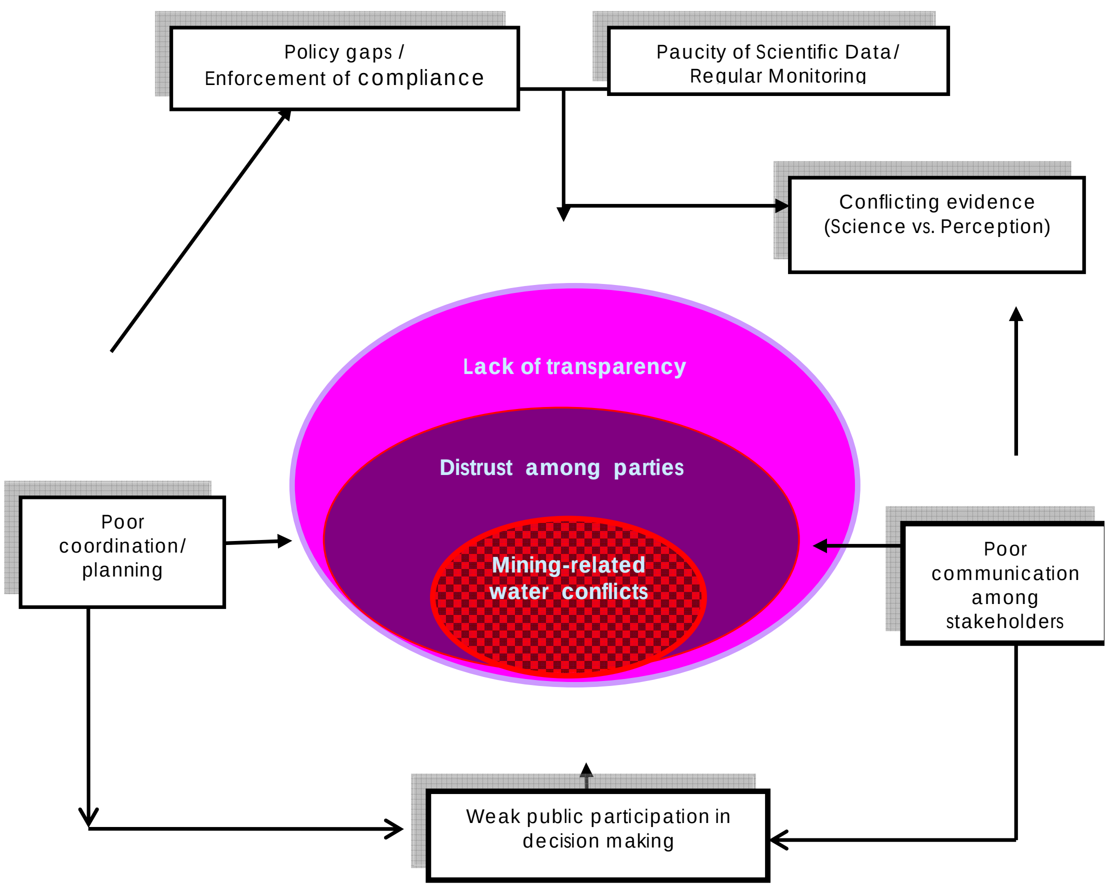


Figure 7. *Conceptual causal factors underlying mining-related water conflicts in the study area.*

local residents attributed the colour changes in the water from the borehole to the operations of the mines that had affected the quality of their water thereby rendering it unsafe for human consumption. However, this view was not shared by the mining authorities that argue that the colour changes might be due to some other reason, or else a hydro-geological reaction.

Analysis of such cases and outcomes of the FGDs bring to the fore the importance of communication in conflict mediation. Scientific evidence needs to be treated or explained in a way that would be acceptable to all parties involved in the conflict. For example using thresholds such as the WHO standards, to ascertain whether pollutions from mining are harmful or not makes much sense only to the educated and technical persons. The study revealed that water conflicts find their greatest expression when the following factors co-exist:

- existing policy gaps /enforcement of compliance; and
- paucity of scientific data/regular monitoring and conflicting evidence.

Other factors which also fuel conflicts include:

- poor co-ordination/planning;
- poor communication among stakeholders; and
- weak public participation in decision making

The interconnections between the various factors are described in fig 7. There is a lack of institutions on behalf of the mining authorities to promote the participation of the water user communities in critical decisions regarding the use of their local water resources for mining purposes.

4.2.2 Mining, corporate social responsibility and water

Corporate Social Responsibility (CSR) means that a corporation should be held accountable for any of its actions that affect people, their communities, and their environment. It implies that negative business impacts on people and society should be acknowledged and corrected if at all possible (Post et al, 1999:58). Inherent in this definition are three cardinal principles—accountability for actions, concern for communities/ environment and the promotion of social good—that must govern and foster good cordial relationship between any corporate body and the society within which they operate.

A range of activities has been undertaken by mining companies nationwide to reflect their commitment to CSR (Ghana Chamber of Mines 2003). Some of these are the provision of schools, potable water, and electricity for host communities. Funds have been committed to the provision of social infrastructure services. However, the study showed that while the activities as above do merit the concern of local residents, the water sector around which most conflicts revolve has received relatively less attention in terms of commitment of funds (Table 5). If, indeed, pollution of water bodies has been a critical issue, attributable to the operations of the company, one would have expected water sector to receive much attention in terms of contributions made in that sector. The study further showed that though CSR has been recognised & is in practice, there is a significant gap concerning the integration of communities' perspective into priority setting and CSR planning.

On the basis of recommendations from participatory research elsewhere in the world, it can be argued that mining companies could build a healthy symbiotic relationship with their host communities and minimize negative sentiments if CSR processes are made participatory with involvement of the local communities. During the study it was found that one of the mining companies - has already initiated a participatory approach in its CSR activities by establishing the 'Damang Mine Community Consultative Committee' (DMCCC) in 2001.

Table 5. *Voluntary CSR contributions to host communities in 2003*

Item	Amount (Cedis)	Estimated Dollar (US) Equiv.
Sanitation	40,269,024.000	4,474.346
Electricity	25,851,501.000	2,872.389
Health	24,546,564.000	2,727.398
Housing	16,385,985.000	1,820.665
Water	7,110,000.000	790.000
Education	3,646,350.000	405.150
Resettlement Action Plan	2,801,772.000	311.308
Roads	1,532,916.000	170.324
Agro-industry	1,289,088.000	143.232
Agriculture	810,666.000	90.074
Alternative Livelihood Projects	18,000.000	2.000
Total	**124,261,866.000**	**13.806.874**

Source: Ghana Chamber of Mines (2003)

The committee is meant to function as a consultation group to channel effective communication between the company and the surrounding communities in relation to its alternate livelihoods programs. At regular quarterly meetings of the DMCCC (usually attended by company management representatives, traditional leaders, youth group leaders, assembly men/women etc.), emerging issues and problems are discussed on the basis of which action plans are formulated. Through consultation with the DMCCC, the company had implemented a number of ALPs. However, due to its mandate on ALP, DMCCC's discussions and planning do not adequately focus on water.

4.2.3 Policy issues

Regarding the policy aspects critical from gender perspective, the questions to be examined were – do the policies concerning water supply and mining – 'fit' together in the mining areas so as to maximize or at least protect the interests of women as domestic water managers? Are their water needs addressed in an efficient, effective and sustainable manner? How well has the policy framework on environmental impact assessment (EIA) and environmental protection in the country, been able to prevent degradation of the water resources so as to safeguard women's water interests in these areas?

Presently Ghana does not have a national water policy document that states the intentions of government regarding management of the country's water resources (Mensah 1999). However, a draft national policy on water has been developed that is in the process of discussion (MoWH 2005). The draft policy recognizes the principle of fundamental right of all people without discrimination to safe and adequate water to meet basic human needs. The policy objectives include first, provision of improved access to potable water, and second, ensuring that water resources are managed and developed in a manner, which as first priority safeguards that the entire population, particularly the poor and vulnerable, will have access to adequate and safe water supply.

Regarding community water and sanitation, the draft policy recognizes gender sensitivity and mainstreaming as vital in such interventions by promoting the decision-making role of women within the concept of 'community ownership and management' (COM). In this area, the policy objective is to ensure sustainable provision of and access to potable water to rural communities that will contribute towards the capital cost and ensure payment for normal operation, maintenance and repair cost of their facilities. Sustainability

Table 6. Salient features of different policy frameworks concerning water supply in mining areas

	Policy on rural water supply	Policy on mining	Policy on EIA and environmental protection
Goal	Aims at ensuring access to safe water for all	Promotes privatization of mining activities	Promotes institutions and mechanisms for protection of environment and natural resources including water
Approach	Draws rationale from participatory approach where implementation of program is based in the concept of COM	Promotes an overall principle of 'minimum government interference' with serious potential implications for issues such as water pollution caused by mining activities	Requires that EIAs be carried out and EIS submitted by mining industries, followed by ensuring of their compliance by EPA
Institutional aspects	Based on partnership between agency and community	Allocates responsibility of safe water provision to mining companies as a CSR	Requires public participation in decisions affecting the environment and granting of water rights
Gender concern	Can be potentially implemented in all mining communities and provides central role to women in decision-making	In relation to neither water provision as a CSR nor mining-related decisions impacting their environment and water resources, is there an explicit provision for promoting participation of local communities in general or that of women in particular	Absence of explicit provisions promoting participation of women in decision-making regarding environment or water resources in affected areas

is to be ensured through effective community ownership and management of the facilities, active participation of women, public sector facilitation, and private sector provision of goods and services. For achieving 'good governance' in relation to rural water supply, women are to be empowered through training at all levels to perform their roles in partnership with their male counterparts.

Rural water supply is organised under the program called Community Water and Sanitation Program (CWSP) that was actually launched earlier in 1990. Under this program, communities are supposed to organize themselves by contributing financial and human resources through the WATSAN committees that are responsible for all operations connected with control and maintenance of the water supplies. Women are given a central role in the design and management of the water facilities.

Ghana's mining policy has been under reform since 1983 as a result of wider structural adjustment policies governing the general economy of the country. In a nutshell, the policy aimed at shifting the focus from direct state investment in the mining sector to promotion and regulation of private companies. The policy and initiatives, basically promoted by the World Bank, include privatization of the state mining interests, enactment of laws affecting the mining sector and the environment, and measures that lifted almost all fiscal burdens from mining companies. The legislation has aimed to reduce risk for investors, ensure access to mining permits and concessions, and protect investors from government interference.

In general, the mineral and mining legislations make provision for environmental protection and pollution prevention (Vormawor & Awuku-Apaw 1996 cited in Boocock 2002). Regulations also restrict mining activities near water bodies, preventing water pollution and stipulate some provisions concerning water supply to both mine employees and the local communities within which the mining activities are taking place. However, while rules and regulatory imperatives exist as far as potable water supply is concerned in mining areas, it is vague as to how their enforcement will be ensured, either from legal persuasion or from morally persuasive alternatives. Also, while responsibilities of mining companies have been fixed, what appears missing from the mining legislation is the scope for involvement of the local communities in relation to either decisions about their water supplies or ownership and management of the same in the mining areas.

The national environmental policy calls for the institution and implementation of an environmental quality control program by requiring prior environmental assessments for all new investments that could affect the environment. The environmental aspects of mining are directly regulated by the Environmental Protection Agency (EPA) Act, 1994 and the new Mining and Environmental Guidelines (MEG 1994). A strategy to address key environmental issues known as the Ghana Environmental Action Plan (GEAP) has been implemented that defines key issues in various sectors followed by recommendations of policy actions and institutional strengthening activities to make Ghana's development more environmentally sustainable. According to GEAP, decisions on the environment should be taken at the lowest appropriate level and the public must be encouraged to participate in decisions that affect the environment.

With respect to the research questions, it was found that the three policy contexts present a number of paradoxes. There is a lack of coordination between to the detriment of women as water users and domestic water managers. These are summarized in Table 6.

The gray areas regarding the three policy frameworks in relation to women's interest in water can be seen in terms of both the contents of these policies as also their practice. **First**, there is multiplicity of options for community water supply in mining areas. While the objective is common, the underlying approach, principles, institutional mechanisms, and delegation of responsibilities are different under the two options. Under the CWSP option, the approach is based on community participation, the essential principle is coded as COM, and the institutional framework is based on WATSAN committees at local level where women are to play a well-defined role. Under the mining policy, water provision is a CSR, essentially promoting a paternalistic approach contributing to the much debated 'dependency syndrome' of the users, having no connections with community-based institutions or involvement of local users in either decision-making, capital contributions or organizing sustainable management of the supplies. The responsibility for installation and maintenance of the water supplies is entirely delegated to the mining company. Multiplicity of options that are basically contradictory in nature can lead to much confusion in the minds of the local users and can deter them from effectively adopting the CWSP that is being increasingly assessed as an effective option to sustainable water supplies in rural areas.

Second, taken together, the policies are paradoxical when viewed in the light of integrated water resources management. While the basic objective under the policy on rural water supply is to ensure sustainable supply of 'safe' and 'adequate' water to local communities, the mining policy aims to maximize mining activities in the potential areas. Given the negative connections between mining and water resources, and hence the regulatory principles under the environmental policy, it appears that water resources in mining communities can become adversely affected in the long run both in terms of quality and quantity, leading to the 'sustainability' question. Though the mining policy promotes the CSR that mining company provide 'safe water supply alternative' to the community, from where will the sustainable source of the safe water be delivered under CSR? Further, and more importantly, if CWSP is implemented in the mining communities, can sustainable delivery of 'safe' and 'adequate' water be really ensured?

Third is the question of gender dimension in the policies. While women's interest with respect to water is explicitly recognized in the rural water supply policy, leading to recognition of the need of their active participation alongside men, gender dimension is completely missing in the mining as well as environmental policy frameworks. While public participation is recognized as an important element in the process of EIA or application for grant of water right, the need to organize such exercises from gender perspective, consulting women and men, is not explicitly recognized. This is a significant lacuna, because the perceived or actual impact of mining on women and their interest in water cannot be adequately known without incorporating a gender perspective and involving them in a systematic manner. This, in turn, can thwart effective participation of women in CWSP when implemented later in the mining areas, particularly because of lack of interest and motivation and other attitudinal barriers that may result from previous experience of non-consultation in public participatory processes (Singh, 2006).

Besides the paradoxes, a detailed analysis of the EIA regulations revealed that most mining companies have not undertaken any comprehensive EIA guiding their operations. Despite the fact that all actively operating mining companies claim to have environmental departments, the corporate will and responsibility towards the environment leaves much to be desired. Further, the Environmental Protection Agency (EPA) does not strictly enforce deterring punitive measures for environmental laws violation (Appiah 2006).

5. Conclusions and Recommendations

A number of recommendations emerge from the integrated perspective attempted to be developed through this research on the problem of contamination of water resources in Tarkwa mining area.

First, there is a need for further in-depth explorations on the situation of contamination in groundwater and surface waters as well as stream sediments in the area. Further, the presence of mercury and especially methyl-mercury in benthic invertebrates and fish should be investigated (Castoldi et al. 2003).

Second, given the extent of possible mercury contamination in the surface waters, the consumption of fish from local streams in the area needs to be inverted to avoid a local catastrophe.

Third, there is a need to resolve the situations of water conflicts between the local communities and the mining authorities. Learning lessons from platforms such as the DMCCC, there is a need to design structures where effective communication regarding water can be affected, hence contributing to resolution of water conflicts. It is proposed that such a structure should first strive to bring on board all possible groups of stakeholders and then establish effective communication channels among them. The key actors that are proposed to be integrated into the process include: The District Assembly[4]; District Resource Management Committee; Community Resource Management Committee; Local Media (local FM stations), Independent Team of Impact Evaluators/Assessors; Environmental Monitoring & Enforcement team; and NGO and Civil Society Groups and the mining authorities (Fig. 8). The incorporation of all of these groups into a mediation plan and the

[4] The District Assembly is the highest political organ in the district, elected by the community and responsible for coordinating all water planning activities.

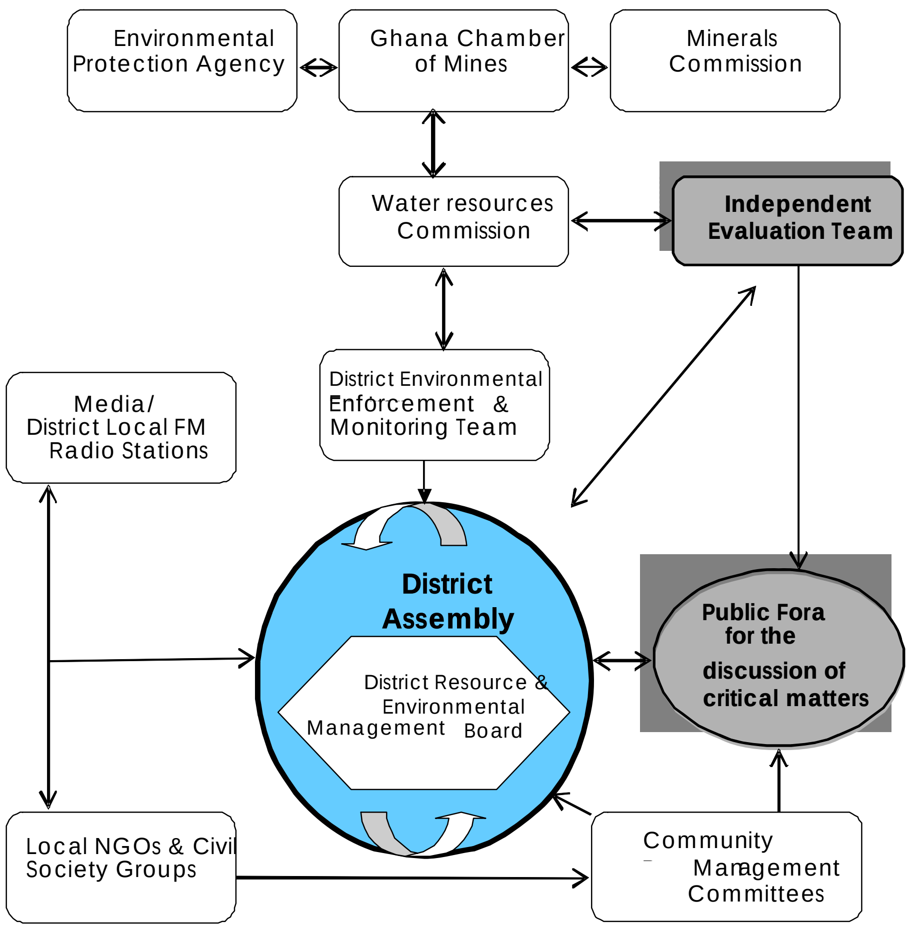


Figure 8. *Strategy for enhancing information flow and co-operation building in mining-related water conflicts.*

roles they play can have a significant impact on ensuring trust and co-operation building in times of conflict.

Also, strategies need to be developed for promoting greater participation of women and men from the local communities in environmental/water planning processes in these communities.

Fourth, if women's interest as domestic water managers is to be safeguarded in the mining areas, the gaps among the three policy frameworks on rural water supply, mining and environmental protection must be overcome. This can be attempted by:

i) Adopting commonality of program approach that will enable removal of the administrative gray-area created by contradictory principles and institutions promoted under different policy frameworks.

ii) Engendering of all policies, programs and actions in relation to the problem.

iii) Designing and ensuring effective implementation of participatory institutions and mechanisms concerning water and environment. While participatory institutions have been defined in relation to management of water supplies in all rural areas in the country, and similar mechanisms exist in the law related to EIA and environmental protection, there is need to extend these under the mining policy as well. The institutions and mechanisms designed for practicing CSR within this policy also need to be based upon effective communication modes that essentially incorporate views of the public from local communities

iv) Promoting greater coordination and cooperation among different government agencies at different levels that are operative in the mining areas. The various agencies would need to work together to develop a way forward for meeting the emerging challenges facing women as domestic water managers in the mining communities. This is essential if the Millennium Development Goals are to be effectively realized in the Ghanaian context.

Fifth, for upholding the quality of water resources in the area, greater environmental compliance on part of the mining companies is essential, for which improved environmental management, along with improved environmental technology is necessary.

6. REFERENCES

Addy, S.N. (1998) Ghana: Revival of the mineral sector. *Resource Policy* 24 (4): 229-239.

Akabzaa, A. & Darimani, M. (2001) Impact of Mining Sector Investment in Ghana: A study of the Tarkwa Mining Region. A report prepared for SAPRI, January 2001.

Akosa AB, Adimado AA, Amegbey NA, Nignpense BE, Carboo D, & Gyasi S (2002) Report submitted by Cyanide investigation committee, Ministry of Environment and Science. June, 2002.

Amonoo-Neizer, E.H & Amekor, E.M.K (1993) Determination of Total Arsenic in Environmental Samples from Kumasi and Obuasi, Ghana. *Environmental Health Perspectives* 101(1), April 1993.

Appiah, D. O. (2006) Environmental impact assessment regulations: the level of compliance by mining companies in the western mining enclave, Ghana. TRITA-LWR Master Thesis LWR-EX-06-11, Stockholm, KTH..

Armah, A.K., Darpaah, G.A. & Carboo, D. (1998) Heavy metal levels and physical parameters of drainage ways and wells in three mining areas in Ghana. *Journal of the Ghana Science Association.* 1(1), July 1998.

Aryee, B.N.A. (2001) Ghana's mining sector: its contribution to the national economy. *Resource Policy* 27: 61-75.

Asklund, R. & Eldvall, B. (2005) Contamination of water resources in Tarkwa mining area of Ghana. *A Minor Field Study for Master of Science Thesis*. Lund University.

Asumin, G. (2005) Negative Impact of Mining, *Ghanaian Chronicle* (Accra). Posted to the web August 30, 2005.

Babut, M., Sekyi, R., Rambaud, A., Potin-Gautier, M., Tellier, S., Bannerman, W. & Beinhoff, C. (2003) Improving the environmental management of small-scale gold mining in Ghana: a case study of Dumasi. *Journal of Cleaner Production* 11: 215-221.

Bhattacharya, P., Jacks, G., Ahmed, K.M., Khan, A.A. & Routh, J. (2002) Arsenic in groundwater of the Bengal Delta Plain aquifers in Bangladesh. *Bull. Env. Cont. Toxicol.* 69: 538-545.

Bhattacharya, P., Eldvall, B., Asklund R., Barmen, G., Sracek, O., Jacks, G., Koku, J., Kusimi, J.M., Gustafsson, J.E., Singh, N. & Balfors, B. (2007) Hydrogeochemical study on the contamination of water resources in a part of Tarkwa mining area, Western Ghana.. *Environmental Geology* (Manuscript under preparation)

Boocock, C.N. (2002). OECD Global forum on international investment: Environmental impact of foreign direct investment in the mining sector in Sub-Saharan Africa. 12-15pp.

Boszke, L., Kowalski, A & Siepak, J. (2004) Grain size partitioning in sediments of the Middle Odra River (Germany/Poland). *Wat. Air Soil Poll.* 159(1-4): 125-138.

Castoldi, A. F., Coccini, T. & Manzo, L. (2003) Neurotoxic and molecular effects of methylmercury in humans. *Rev. Environ. Health* 18(1): 19-31.

Celo, V., Lean, D.R.S. & Scott, S.L. (2006) Abiotic methylation of mercury in the aquatic environment. *Sci. Tot Environ.* 368(1): 126-137.

Dapahh-Siakwan, S. & Gyau-Boakye, P. (2000) Hydrogeologic framework and borehole yields in Ghana. *Hydrogeology Journal* 8: 405-416.

Ghana Chamber of Mines (2003) *Mining and Sustainable Development: Corporate Social Responsibility* . The Ghana Chamber of Mines Annual Report 2003.

Gyau-Boakye, P. & Dpaah-Siakwan, S. (1999) Groundwater: Solution to Ghana's rural water supply industry? The Ghana Engineer, (online), May. Available: http://home.att.net/~africantech/GhIE/ruralwtr.htm (12 mars 2004).

Hilson, G (2001) *A Contextual Review of the Ghanaian Small-Scale Mining Industry*. MMSD Commissioned study. International Institute for Environment and Development (IIED), London.

Hilson, G. (2002a) Harvesting mineral riches: 1000 years of gold mining in Ghana'. *Resource Policy*, 28: 13-26.

Hilson, G. (2002b) Promoting sustainable development in Ghanaian small-scale gold mining operations. *The Environmentalist* 22: 51-57.

Kerin, E.J., Gilmour, C.C., Roden, E., Suzuki, M.T., Coates, J.D. & Mason, R.P. (2006) Mercury methylation by dissimilatory iron-reducing bacteria. *Applied and Environ. Microbiol.* 72(12): 7919-7921.

Kortatsi, B.K. (2004) Hydrochemistry of groundwater in the mining area of Tarwa-Prestea, Ghana. PhD thesis, University of Ghana, Legon-Accra, Ghana.

Lassey, A. (1999). Mining and Community Rights: The Tarkwa Experience. Seminar paper on the Socio-Economic and Environmental Effects of Surface Mining. Environmental Action group, University of Science and Technology, Kumasi Ghana, 28th May 1999.

Mensah, K. (1999). Water Law, Water Rights and Water Supply, Africa. Ghana – study country report. Silsoe: DFID.

MoWH (2005). National Water Policy, Draft for discussion, March 2005. Ministry of Works and Housing, Government of Ghana.

Post, J.E., A.T. Lawrence and J. Weber (1999) *Business and Society: Corporate Strategy, public policy, ethics.* USA: Mc Graw-Hill Companies, Inc.

Ntibery, B.K., Atorkui, E. & Aryee, B.N.A. (2003) Trends in small-scale mining of precious minerals in Ghana: a perspective on its environmental impact. *Journal of Cleaner Production* 11:131-140

Singh, N. (2006) Women's participation in local water governance: Understanding institutional contradictions. *Gender, Technology and Development* 10 (1), 61-76.

Smedley, P.L (1996) Arsenic in Rural Groundwater in Ghana. *Journal of African Earth Sciences* 22(4): 459-470.

Vormawor, D. K. Y and Awuku-Ampaw, J. (1996) "Ghana" International Labour Organization, Geneva, *cited in* Boocock, C. N. (2002) OECD Global forum on international investment: Environmental impact of foreign direct investment in the mining sector in Sub-Saharan Africa.

7. Dissemination of the Project Outcomes

The outcomes of the project have been disseminated through scientific papers as well as through participation in conferences during the project period. The following have been written with the aim of disseminating the findings of research as widely as possible:

7.1 Peer-reviewed Publications

i) Singh, N., Koku, J.E., Balfors, B. (2006a) Resolving water conflicts in mining areas of Ghana: A communication perspective. *Journal of Creative Communication.* (Under publication).

ii) Singh, N., Balfors, B., Koku, J.E., Appiah, D. (2006b) Gender and community water supply: Policy paradoxes in mining areas of Ghana. *Water Policy*. (In review).

iii) Bhattacharya, P., Eldvall, B., Asklund R., Barmen, G., Sracek, O., Jacks, G., Koku, J., Kusimi, J.M., Gustafsson, J.E., Singh, N., Balfors, B. (2007) Hydrogeochemical study on the contamination of water resources in a part of Tarkwa mining area, Western Ghana.. *Environmental Geology* (Manuscript under preparation)

7.2 Conference Presentations

iv) Mining Policy, Water Conflicts and Corporate Social Responsibility in Ghana: Perspectives from the Wassa West District. Presentation made by J. Koku and N. Singh at the Fourth Conference of International Water History Association on "Water and Civilization" at Paris, France, December 2005.

v) A presentation based on findings of the pilot study at Tarkwa was made in May 2004 at an institutional seminar in KTH. Findings emerging from later phase of research have also been discussed on several forums within and outside the institutional setting.

7.3 Master Theses

vi) Asklund, R. and Eldvall, B. (2005) Contamination of water resources in Tarkwa mining area of Ghana. A Minor Field Study for Master of Science Thesis. Lund University. (Supervisors: P. Bhattacharya & J. Koku).

vii) Appiah, D. (2006) Environmental impact assessment regulations: the level of compliance by mining companies in the western mining enclave, Ghana. Master's Thesis, LWR, KTH. (Supervised by B. Balfors)

viii) Kusimi, J. M. (2007) Groundwater hydrogeochemistry and landcover change in the Wassa West district of Ghana. Master's Thesis, LWR, KTH. (Supervisors: P. Bhattacharya & J. Koku)