OPEN ACCESS

African Journal of Environmental Science and Technology

June 2019
ISSN 1996-0786
DOI: 10.5897/AJEST
www.academicjournals.org

ACADEMIC JOURNALS
expand your knowledge

About AJEST

African Journal of Environmental Science and Technology (AJEST) provides rapid publication (monthly) of articles in all areas of the subject such as Biocidal activity of selected plant powders, evaluation of biomass gasifier, green energy, Food technology etc. The Journal welcomes the submission of manuscripts that meet the general criteria of significance and scientific excellence. Papers will be published shortly after acceptance. All articles are peer-reviewed

Indexing

The African Journal of Environmental Science and Technology is indexed in:
CAB Abstracts, CABI's Global Health Database, Chemical Abstracts (CAS Source Index), China National Knowledge Infrastructure (CNKI), Dimensions Database, Google Scholar, Matrix of Information for The Analysis of Journals (MIAR), Microsoft Academic

AJEST has an h5-index of 14 on Google Scholar Metrics

Open Access Policy

Open Access is a publication model that enables the dissemination of research articles to the global community without restriction through the internet. All articles published under open access can be accessed by anyone with internet connection.

The African Journal of Environmental Science and Technology is an Open Access journal. Abstracts and full texts of all articles published in this journal are freely accessible to everyone immediately after publication without any form of restriction.

Article License

Article Copyright

Self-Archiving Policy

The African Journal of Environmental Science and Technology is a RoMEO green journal. This permits authors to archive any version of their article they find most suitable, including the published version on their institutional repository and any other suitable website.
Please see http://www.sherpa.ac.uk/romeo/search.php?issn=1684-5315

Digital Archiving Policy

The African Journal of Environmental Science and Technology is committed to the long-term preservation of its content. All articles published by the journal are preserved by Portico. In addition, the journal encourages authors to archive the published version of their articles on their institutional repositories and as well as other appropriate websites.
https://www.portico.org/publishers/ajournals/

Metadata Harvesting

The African Journal of Environmental Science and Technology encourages metadata harvesting of all its content. The journal fully supports and implement the OAI version 2.0, which comes in a standard XML format. See Harvesting Parameter

Memberships and Standards

Academic Journals strongly supports the Open Access initiative. Abstracts and full texts of all articles published by Academic Journals are freely accessible to everyone immediately after publication.

All articles published by Academic Journals are licensed under the Creative Commons Attribution 4.0 International License (CC BY 4.0). This permits anyone to copy, redistribute, remix, transmit and adapt the work provided the original work and source is appropriately cited.

Crossref is an association of scholarly publishers that developed Digital Object Identification (DOI) system for the unique identification published materials. Academic Journals is a member of Crossref and uses the DOI system. All articles published by Academic Journals are issued DOI.

Similarity Check powered by iThenticate is an initiative started by CrossRef to help its members actively engage in efforts to prevent scholarly and professional plagiarism. Academic Journals is a member of Similarity Check.

CrossRef Cited-by Linking (formerly Forward Linking) is a service that allows you to discover how your publications are being cited and to incorporate that information into your online publication platform. Academic Journals is a member of CrossRef Cited-by.

Academic Journals is a member of the International Digital Publishing Forum (IDPF). The

IDPF is the global trade and standards organization dedicated to the development and promotion of electronic publishing and content consumption.

Contact

Editorial Office: ajest@academicjournals.org

Help Desk: helpdesk@academicjournals.org

Website: http://www.academicjournals.org/journal/AJEST

Submit manuscript online http://ms.academicjournals.org

Academic Journals
73023 Victoria Island, Lagos, Nigeria
ICEA Building, 17th Floor,
Kenyatta Avenue, Nairobi, Kenya.

Table of Content

Vol. 13(6), pp. 220-227, June 2019
DOI: 10.5897/AJEST2018.2597
Article Number: 112075160865
ISSN: 1996-0786

http://www.academicjournals.org/AJEST

ACADEMIC JOURNALS
expand your knowledge

African Journal of Environmental Science and Technology

Review

A 50-year review on heavy metal pollution in the environment: Bivalves as bio-monitors

Fred A. Otchere

Department of Environment and Development Studies, Central University, P. O. Box 2305, Tema, Ghana.

Received 8 October, 2018; Accepted 27 November, 2018

There has been a steady increase in the quantity and diversity of discharges that reach aquatic environment, both organic and inorganic, either synthesized or mobilized by man as a result of high population growth and development activities. This has led to the appearance of several types of pollution. Inland and coastal waters have been the most affected, since most major cities are located near water bodies. Monitoring programs and research for metals in the environment have become widely established because of concerns over accumulation and toxic effects, particularly in aquatic organisms. Quantifying metal concentrations in water and sediments may have limited value in this respect, particularly in circumstances in which it is difficult to define biologically relevant fractions. Therefore, the analysis of aquatic organisms have been used increasingly as a direct measure of the abundance and availability of metals and micro-pollutants in the environment and has led to the adoption of the bio-indicator (bio-monitor, sentinel organism) concept 50 years ago. All heavy metals (trace elements) are potentially toxic, even the essential ones if accumulated above (or below) levels needed by the organism. Temperature and salinity are the two major factors to be considered when considering abundance, availability, bioaccumulation and excretion of these metals in the aquatic environment. Almost all developed countries are found in the temperate region while the developing ones are located or/and found in the tropics where these factors are at the extreme. Hot spots for heavy metal pollution are found both in the developed and developing world.

Key words: Heavy metals, aquatic environment, bivalves, bio-indicator/monitors, seasonal variation, accumulation.

INTRODUCTION

High population growth accompanied by intensive urbanization, increased industrial activity and higher exploitation of natural resources; as a result, there has been a steady increase in the quantity and diversity of discharges that reach aquatic environments, both organic and inorganic, either synthesized or mobilized by man. This has led to the appearance of several types of pollution. Inland and coastal waters have been the most

E-mail: faotchere8@yahoo.ca. Tel: 233 (0)555246302.

affected, since most major cities are located near them. Three main sources of pollution are recognized: urban development, industrial waste and agricultural use of pesticides. Urban pollution is mainly organic in origin and stems from domestic wastes, particularly sewage and garbage. Such wastes mainly originate from residential, commercial and recreational areas, offices and institutions. Most urban areas in developing countries still lack adequate waste collection; hence treatment and disposal facilities and wastes are therefore discharged untreated into natural water bodies. Industrial wastes are very diverse in nature and include chemicals, mine wastes, ferrous and non-ferrous metals and dust particles. Discharges may be either gas, liquid or solid that may finally reach the aquatic environment. These may include wastes from breweries, food processing plants, tanneries, textiles, paper pulp mills, manufacturing and use of paints, pesticides and fertilizers, mining operations, refining and burning of fossil fuels. The magnitude of waste varies with different industries. Extensive use of pesticides is considered necessary to increase production and improve food storage as well as vector control campaigns to curb endemic diseases such as malaria, onchocerciasis, schistosomiasis and trypanosomiasis. One of the strategies to increase crop production is effective pest management, because more than 30% of the world annual food production is lost through pest infestation (Pimentel, 1992; Kibuthu et al., 2016; Li and Jennings, 2018). In the tropical countries, crop loss is even more severe, because the prevailing high temperature and humidity are highly conducive to rapid multiplication of pests. Thus, the application of a wide variety of pesticides on crop plants is necessary to combat pests and diseases. The continuous production and use of these chemicals load the environment with xenobiotic substances and create complex ecological problems in the environment (Jennings and Li, 2014; Kibuthu *e*t al., 2016).

The term 'heavy metals' is used in this text synonymously with 'trace metals' and includes both the essential (e.g. Fe, Cu, and Zn) and non-essential (Cd, Pb, and Hg) ones. All of these have the potential to be toxic to living organisms if present and available above (or below; for essential metals) a certain threshold which varies between taxa (Bleeker et al., 1992; Mouneyrac et al., 1998). Essential metals are required in small amounts (e.g. Zn: 0.75-2 mg/l and Cu: 0.06-0.16 mg/l for bivalves) (Watling, 1981) by organisms as component of proteins and enzymes (Underwood, 1974; Simkiss et al., 1982; Bleeker et al., 1992). Most animals can regulate the body concentration of these metals up to a certain ambient water concentration, above which accumulation starts and toxic effects may occur. Non-essential metals are considered not to play any biological role and cannot be regulated. These metals can be toxic at low concentration (that is, close to the ppt levels or ng/l) (Amiard et al., 1987; Fowler, 1990; Rainbow, 1995; Laporte et al., 1997; Otchere et al., 2003).

TRACE ELEMENTS

At present, 14 elements are known to be essential to animal life and regulated at trace concentrations: Fe, Zn, Cu, Mn, Co, I, Mo, Se, Cr, Sn Ni, F, Si, and V. The non-essential ones including: Hg, Pb, Cd, As, Au, Ag, etc., are considered not to play any biological role and cannot be regulated. A further trace element, boron, is essential for plant life. In addition, 20 to 30 other elements occur, more or less constantly in low but variable concentrations in living tissues. The presence of these elements is believed to reflect the contact of the organism with its environment. Indeed Sn, F, Si, Ni and V, often referred to as the 'newer trace elements', only emerged as essential recently as an outcome of the use of purified diet and plastic isolator techniques. A few trace elements are referred to as toxic because they are toxic at relatively low concentrations (close to the ppt level or ng/l); however, this statement can be misleading because all the elements are toxic if ingested at sufficiently high levels and for long enough periods. With some, notably fluorine in man and Cu in sheep, the margins between beneficial and toxic intakes, that is, between needs and tolerance are small. With others such as Zn and Mn, tolerance is high and wide margins exist between minimum essential intake and those resulting in toxic effects (Underwood, 1974; Fowler, 1990; Bleeker et al., 1992; Laporte et al., 1997; Otchere, 2003; Obirikorang et al., 2011). Concentrations of heavy metals in aquatic environments have two phases: dissolved and particulate. The comparison of metal levels between different years in the same environment or between different environments should be considered very carefully, taking into accounts the seasonal variability which can be very important in estuaries. In these environments, concentrations may depend very much on salinity, apart from the seasonal variability (Baeyens, 1998; Baeyens et al., 1998a).

BIO-MONITORS

Monitoring programs and research for trace metals in environmental samples have become widely established because of concerns over accumulation and toxic effects, particularly in aquatic organisms and to humans consuming these organisms. The criteria by which organisms are accepted as biological indicators for the assessment of contamination were proposed about fifty (50) years ago since 1970 and remain unchanged (Butler et al., 1971; Boyden, 1974; Phillips, 1976; Fowler and Oregioni, 1976; Otchere, 2003). Bivalves are widely used as bio-indicators of heavy metals pollution in coastal areas because of their abundance and known to concentrate these elements, providing a time integrated indication of environmental contamination. Bivalves are chosen because they are ideal indicators of heavy metal pollution, if and when pollution is present, and they facilitate analysis by this natural process of metal preconcentration. This bioaccumulation also gives a good idea of the amount of metal that is available for uptake in the system as metal concentrations in seawater or sediment alone do not give a true indication of what is actually available for uptake (Obirikorang et al., 2011). Bivalves are generally consumed by waterfowl and fish and so are sources of heavy metals to higher trophic levels. In comparison to fish and crustaceans, bivalves have a very low level of activity of enzyme systems capable of metabolizing persistent organic pollutants (POPs), such as aromatic hydrocarbons and polychlorinated biphenyls (Otchere, 2005). Therefore, contaminants concentrations in the tissues of bivalves more accurately reflect the magnitude of environmental contamination (Phillips, 1977a, b, 1980, 1990). Factors known to influence metal concentrations and accumulation in these organisms include metal bioavailability, season of sampling, hydrodynamics of the environment, size, sex, changes in tissue composition and reproductive cycle (Boyden and Phillips, 1986). Seasonal variations have been related to a great extent to seasonal changes in flesh weight during the development of gonadic tissues (Joiris et al., 1998, 2000). Element concentrations in mollusks at the same location differ between different species and individuals due to species-specific ability/capacity to regulate or accumulate trace metals (Reinfelder et al., 1997; Otchere et al., 2003). Different animals in the same community at the same trophic level could accumulate pollutants differently due to differences in habitat/niche's physical and chemical properties (Otchere, 2003, 2005).

The smallest individuals of shellfish often show the highest concentrations of trace metals on a weight specific basis. In such situations it is very difficult to assess whether observed differences in tissue levels between populations reflect real differences in environmental trace element constitution, or are merely due to variations in body size. This problem can be avoided by determining element concentration over a range of body sizes and reference made to a specific size (or size range) for comparative purposes. However, environmental metal levels are not the only factor affecting the metal content of molluscs, as both the size and season markedly affect this parameter in order to avoid the problem of cases where it is difficult to assess whether observed differences in tissue level/burden between these bivalves reflect real differences in environmental heavy metal constitution, or are merely due to variations in body size. Boyden (1974: 77) proposed model relating metal content to body weight; metabolic power function: $Y = aW^b$; where Y = burden/content, W = dry weight, a = intercept and b = the slope co-efficient. He showed that the regression coefficient of the relationship between metal content and body weight was generally constant for a given metal and species. Thus, the intercept can be used to compare environmental metal levels from different locations (Otchere, 2003).

Once in the organism, metals are stored or eliminated in different ways. Cd, Cu, Hg, Ag, Au, Bi and Zn can be complexed to cystein-rich heat stable, low molecular weight proteins called metallothioneins (MT), in different tissues of the organism (Langston and Zhou, 1986; Bouquegneau and Joiris, 1988; Bebiano and Langston, 1991; Bordin et al., 1992, 1997). The metal binding affinity for the protein order is Zn - Cd - Cu - Hg, suggesting that toxic metals such as Cd and Hg are able to displace essential metals (Bouquegneau and Joiris, 1988). Metal-binding proteins similar to MT have been recently identified in different tissues of *Mytilus edulis* and other bivalves (*Macoma balthica*) exposed to Cd, Cu, Zn, Hg and Ag (Roesijadi, 1982; Bebiano and Langston, 1991; Bordin et al., 1992, 1997). The functions attributed to MT included detoxification, storage and regulation of heavy metals. Moreover, it has been shown that metals such as Cd, Zn and Cu can induce MT synthesis in aquatic animals. Thus, MT has been proposed as indicators of trace metal pollution (Bouquegneau and Joiris, 1988; George and Olsson, 1994; Roesijadi, 1992; Bordin et al., 1997).

SEASONAL VARIATIONS

The influence of season on the concentration of trace metals in bivalves has also been investigated (Dare and Edwards, 1975; Cossa et al., 1980; Boyden and Phillips, 1986; Cossa and Rondeau, 1985; Bordin et al., 1992; Otchere, 2003). Bryan (1973) gave a more detailed seasonal profile for the concentration of Zn, Pb, Cu, Co, Fe, Mn and Ni in tissues of *Pecten maximus* and *Chlamys operacularis* from the English Channel. In general, the concentrations of metals in these scallops were greatest in autumn and winter and it was suggested that metal concentrations were inversely related to phytoplankton production. However, Fowler and Oregioni (1976) in their studies of the variation in the concentration of ten metals in *Mytilus galloprovincialis*, suggested that the seasonal maximum (Cd: 4.0 µg/g dw; Pb: 12 µg/g dw; these are 2 and 3-fold respectively more than that of summer concentrations) seen in the samples collected in March (spring) was due to the reproductive state of the animals and to the winter run-offs increasing the amount of available metals. Phillips (1976) reached a similar conclusion concerning the seasonal variations of Zn, Cd, Pb and Cu in *M. edulis.* The seasonal fluctuations of trace metal concentrations were inversely linked to the seasonal changes in tissue weights of individual animals. Weight changes were related to the sexual cycle, with a minimum in late winter or early spring. Bordin et al. (1992) found similar seasonal fluctuations (in *M. balthica,* from Netherland and Belgian coasts) for four metals with higher concentrations in winter and lower in summer, ranging from 17 to 32. µg/g for Cu, 0.2 to 1.1 µg/g for Cd;

377 to 690 µg/g for Zn and 500 to 2000 µg/g for Fe (all in dw). Joiris et al. (1998) working with the cockle *Anadara (Senilia) senilis* from West Africa found a seasonal maximum of Hg in the dry season (0.4 µg/g) and a minimum in the wet season (0.1 µg/g dw), partly attributed this to the seasonal fluctuation of phytoplankton production, seasonal abiotic factors (such as temperature and salinity) and the spawning/physiology of the cockles.

SOURCES OF METAL POLLUTION

Generally, the sources for trace metals in aquatic systems are through natural and anthropogenic. In the marine ecosystem, the natural source has been categorized into:

i) Coastal supply, including inputs from rivers and from erosion produced by wave action and glaciers.
ii) Deep sea supply, including metals released from deep sea volcanism and those removed from particles or sediments by chemical processes.
iii) Supply which bypasses the near-shore environment; in particular, metals transportation through the atmosphere as dust particles or as aerosols and also material produced by glacial erosion in polar regions which is then transported elsewhere by floating ice.

The two main routes of anthropogenic inputs into the sea are the atmosphere and rivers. Metal particles released into the air at ground level are mixed vertically and consequently, contaminants may be transported many thousands of kilometers from where they were first released. Differences in global climate also results in uneven deposition of trace metals. For example, the net accumulation of Hg, Cd, V and Mn in Arctic biota and ice has been attributed to the relative absence of precipitation, scavenging and strong atmospheric inversions. The emission source of these metals is thought to have come from industrialized temperate zones and thus considerable directional transport has occurred. In reviewing the aquatic transport of chemical, Goldberg (1989) concluded that organic compounds in the sea play a key role in trace metal transport. Comparisons of atmospheric and riverine input of trace metals in the sea indicates that only 2% of the Pb, for instance, which eventually dissolves in seawater enters the global ocean via rivers. The primary source of most of the dissolved Cd, Cu, Fe and Zn is also the atmosphere. At a regional level, it is thought that for the trace metals Cd, Hg, Cu, Pb and Zn, 40 to 60% of the input into the North Sea is via atmospheric deposition. Domestic effluent and urban storm water runoff have also been identified as significant sources of trace metal input into coastal waters. Concentrations in the milligram per liter range can be found in domestic effluent; metabolic waste, corrosion of water pipes (Cu, Pb, Zn and Cd) and consumer products (e.g. Detergents formulations containing Fe, Mn, Cr, Ni, Co, Zn, B and As) all contribute appreciable amounts. Finally, it should be remembered that metals are indestructible (unlike organic compounds); they are retained and accumulated within ecosystem because reactive forms bind to sediments and non-reactive forms occur as insoluble oxides and salts. Thus, ecotoxicological effects of metals can persist for decades after pollution incidents and also when sediments and mine waste are disturbed (Connell and Miller, 1984).

FINDINGS

Mercury levels from literature around the world generally, are the same order of magnitude to those reported in Table 1. Biney (1991) found mean concentrations in oysters: 0.06 µg/g fw, cockles: 0.055 µg/g fw and mussels: 0.06 µg/g fw (fw = fresh weight). These were equivalent to 0.48, 0.37 and 0.46 µg/g dw, respectively similar to concentrations reported in Table 1. Average Hg concentration from Ivory Coast using the same species of oysters was 0.125 µg/g fw; this high value may be due to higher urbanization at Abidjan (Metongo, 1991), and while Mbome (1988) recorded a mean value of 0.083 µg/g fw in Cameroon waters with *Crassostrea tulipa*. These were within the range of 0.034-0.13 µg/g fw for western and central Africa sub regions reported by Biney et al. (1994).

Metal concentrations in bivalves from West Africa and elsewhere in Africa were not exceptional when compared with those reported for other coastal areas throughout the world. For example, Cu, Fe and Mn levels in the oysters, cockles and mussels have the same order of magnitude as in literature (Table 2); while Cd levels recorded in Africa were similar or lower than concentrations in other studies. In the case of oysters, the Zn level reported in Ghana (175 µg/g fw) was much lower than the levels from other studies in West Africa (e.g. Côte d'Ivoire -1200 and Nigeria - 630 µg/g fw). Metal concentrations in mussels from Oman and India compared to those from African and European coastal waters are similar.

The comparison

Differences in Zn, Fe and Cu, essential elements for cockles, mussels and oysters, could be due to specific internal regulatory processes. Since these three elements are essential to life, we may expect a stronger influence of specific species than the variations in Mn. Higher wet season concentrations in Zn, Fe and Mn in the bivalves were similar to levels recorded in the mussel *Perna viridis* from India by Rivonker and Parulekar (1998); they attributed this observation to higher content of organic matter brought in by monsoon rains. Joiris and Azokwu (1999) reported higher concentrations (Cu, Fe and Zn) in

Table 1. Total and organic Hg (µg/g dw) and percent MeHg reported in bivalves by different authors: median and range where appropriate.

Species	Place	∑Hg	MeHg	%MeHg	References
Anadara (S) senilis	Ghana	0.19	0.10	46	Otchere et al. (2003)
Anadara tuberculosa	Costa Rica	0.16	0.08	51	De la Cruz (1994)
Anadara granosa	Malaysian Coast	0.03 - 0.6	-	-	Jothy et al. (1983)
Anadara (S) senilis	Nigeria	0.18	0.06	32	Joiris et al. (1998)
Cerastoderma glaucum	France	0.55	-	-	Szefer et al. (1999)
Venerupis galactites	Australia	0.71	0.13	18	Francesconi and Lenenton (1992)
Crassostrea tulipa	Ghana	0.17	0.08	52	Otchere et al (2003)
Crassostrea virginica	Georgia USA	1.60	0.27	17	Gardner et al. (1978)
Crassostrea virginica	Indian coast	0.10	-	-	Sanzgiri et al. (1988)
Saccostrea echinata	N. Australia	0.27	-	-	Peerzada et al. (1993)
Macoma phenax	Georgia USA	1.7	0.03	2	Gardner et al. (1978)
Katelysia scalarina	W. Australia	0.49-2.7	0.19-0.45	30	Jackson et al. (1986)
Perna perna	Ghana	0.26	0.10	37	Otchere et al. (2003)
Perna viridis	Indian coast	0.46	-	-	Sanzgiri et al. (1988)
Mytilus galloprovincialis	N. Adriatic Sea	2.0	0.5	25	Mikac et al. (1985)
Mytilus edulis	Belgian coast	0.17 - 0.23	0.02 - 0.05	-	Gurney (1992)
Mytilus edulis	Canada	0.07-0.38	-	-	Cossa and Rondeau (1985)
Mytilus edulis	W. Danish coast	7.5	0.3	4	Riisgard et al. (1985)
Mercenaria mercenaria	Georgia USA	0.80	0.28	35	Gardner et al. (1978)

dw: Dry weight.

Table 2. Average metal concentrations (µg/g fw) reported in bivalves by different authors for other coastal areas throughout the world.

Parameter	Cu	Zn	Fe	Mn	Cd	Reference
Oysters						
Ghana	4.4	175	56	1.84	0.06	Otchere (2003)
Ghana	3.1	460	76	2.95	-	Biney (1991)
Nigeria	5.8	630	-	-	0.17	Okoye (1991a)
Cameroon	8.5	410	-	-	0.25	Mbome (1988)
Côte d'Ivoire	24.5	1200	-	-	0.65	Metongo (1991)
Venezuela	3.9	0.14	-	-	0.09	Jaffé et al. (1998)
Oman	27.6	140	48	0.64	1.96	Fowler et al. (1993)
Cockles						
Ghana	0.90	7.3	110	1.98	0.05	Otchere (2003)
Ghana	1.01	13	11	1.59	-	Biney (1991)
Nigeria	1.0	15	62	-	0.03	Joiris and Azokwu (1999)
Belgium	3.6	74	198	-	0.13	Bordin et al. (1992)
Costa Rica	0.83	10	90	-	0.63	De la Cruz (1994)
France	1.6	11	130	1.2	0.19	Szefer et al. (1999)
Saudi Arabia	1.2	15	71	9.8	0.12	Fowler et al. (1993)
Mussels						
Ghana	1.58	5.2	130	1.74	0.13	Otchere (2003)
Ghana	1.96	18	65		-	Biney (1991)
Oman	0.91	5.2	10	0.53	3.6	Fowler et al. (1993)
India	3.1	64	340	17.7	-	Rivonker and Parulekar (1998)
WHO limits	30.0	1000	-	-	2.0	Moraes et al. (1997)

fw: Fresh weight.

wet season in the cockle (*Anadara senilis*) from Nigeria and they ascribed this variation to increased run-off water with possible increase in pollutants load. Likewise, Joseph and Srivastava (1993), Mitra and Choudhury (1993) and Pillai and Valsala (1995) observed increased concentrations of heavy metals during the monsoon season.

Elevated levels of Zn in both (wet and dry) seasons (2400 and 2800 µg/g dw for dry and wet seasons) in oysters from Ghana, Fe in cockles and mussels might be due to treated wood used in boat construction (e.g. marine paints, etc.) and anthropogenic flux of metallic contaminants (Weis et al., 1993; Ferreira and Vale, 1995; Szefer et al., 1999). These high levels might also reflect the presence of blood systems or transport medium with these metals as essential components; for example, hemoglobin in cockles (high Fe content) and haemocyte in oysters (high in Cu and Zn). Similarly, Rivonker and Parulekar (1998) reported high levels of Fe in mussels from India (ranged: 200 - 4000 µg/g dw) and attributed these levels to the high uptake capacity of mussels towards this particular metal. While Boyden and Phillips (1981) working on *Crassostrea gigas* found similar trends of high concentrations (Cu ranged: 100 - 7000 µg/g dw; Zn ranged: 2 - 16 mg/g dw), they concluded that inherent variability of elements in a bivalve population depended on the particular species-metal pair considered, and also on the degree of contamination involved. Other studies with these species-metal pairs are shown in Table 2.

Manganese levels in cockles and mussels do not seem to follow any specific trend in variations; and may reflect which of the two bivalves could efficiently regulate this metal. On the other hand in oysters, concentrations were more variable. Frazier (1975, 1976) found high turnover of Mn in soft tissue of *Crassostrea virginica* during the period of shell growth and the amount of Mn incorporated into the shell in one day was twice the total Mn burden of the whole soft parts. Boyden and Phillips (1981) observed a similar phenomenon; they inferred that seasonal changes in the concentration and body burden of Mn in oysters depended primarily on factors other than the cyclic changes of tissue weight associated with gametogenesis and spawning. Levels reported in this review might reflect over-riding influence of shell deposition, even though the data are also suggestive of significant losses of Mn in gametes at spawning. No other plausible explanation for Mn variations in this review has been found. Results presented in this review showed that from a practical point of view when using bivalves as a quantitative indicator of metal pollution, influence of the size of molluscs must be taken into account even when the shell length has been classified. For example, Cossa and Rondeau (1985) found that the Hg load of mussels of 3 and 4 cm in length differ by 100% due to size. In addition, changes in weight during a season may cause a 300% difference in Hg content of the mussels.

Expressing results in terms of metal concentration in the soft tissue circumvents the major bias due to size. Neglecting to take into account the influence of length and/or weight could have more drastic consequences, as noted above and by other authors (Joiris and Azokwu, 1999; Joiris et al., 1998, 2000; Otchere, 2003).

CONCLUSION

Fluctuations in trace metal concentrations have been related to changes in metal bioavailability. Not only this but also several biological variables such as size, sex or changes in tissue composition and reproductive cycle as well as the season of sampling and the hydrodynamics of the environment have to be considered (Boyden and Phillips, 1981; Phillips and Segar, 1986; Joiris et al., 1998, 2000; Szefer et al., 1999). Many authors writing on seasonal variations have reported higher concentration in soft tissue during winter than in summer (Cossa et al., 1980; Cossa and Rondeau, 1985; Bordin et al., 1992; Regoli and Orlando, 1993, 1994; Soto et al., 1995; Regoli, 1998; Szefer et al., 1999). These seasonal variations have been related to a great extent to seasonal changes in flesh weight during development of gonadic tissues (Regoli and Orlando, 1994; Joiris et al., 1998; Szefer et al., 1999; Bordin et al., 1997). However, even if the effects of these parameters were eliminated by the use of specific sampling procedures, element concentrations will still differ between different species due to species specific ability/capacity to regulate and/or accumulate trace metals (Tanabe et al., 1987; Reinfelder et al., 1997; Otchere, 2003).

Concluding, the wet season/winter-spring maxima in Zn, Fe and Mn observed should reflect a higher metal availability during this season (through 'import'). This could not be reproducible (due to differential ability of some species to regulate more efficiently than others) and would allow one to infer that temporal variability in metal concentration from sites to sites are irregular; nevertheless, it could have also depended on the amount of rainfall/precipitation at each location during the season. This irregularity might also be due to varying gut content since bivalves were neither depurated nor drained prior to storage. The essential metals which were reviewed, were present in similar respective concentrations to those found around the world and exhibited similar seasonal pattern in terms of their concentrations although of different magnitudes. In order to remove the variability due to seasonally changing body weight, the use of metal content (absolute value) instead of metal concentration in tissue against weight or size has been proposed by several authors (Boyden, 1974; Cossa et al., 1980; Boyden and Phillips, 1981; Cossa and Rondeau, 1985). Considering metal load or content instead of metal concentration provides more information on metal behavior. While temporal variations in element concentration were mainly caused by changes in the tissue weight of bivalves according to the sexual cycle, body burden of elements alter only a little throughout the year. Hence data expressed both as metal concentration and load/content could be integrated for a better assessment of differences in the bioavailability of these metals as a function of site and time of collection.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

REFERENCES

Amiard JC, Amiard-Triquet C, Berthet B, Metayer. (1987). Comparative study of the pattern of bioaccumulation of essential (Cu. Zn) and non-essential (Cd. Pb) trace metals in various estuarine and coastal organism. Journal of Experimental Marine Ecology 106:73-89.

Baeyens W (1998). Evolution of trace metal concentrations in the Scheldt estuary (1978-1995). A comparison with estuarine and ocean levels. Hydrobiologia, 366:157-167.

Baeyens W, Elskens M, Gillain G and Goeyens L (1998a). Biogeochemical behaviour of Cd, Cu, Pb and Zn in the Scheldt estuary during the period 1981-1983. Hydrobiologia 366:15-44.

Bebianno MJ, Langston WJ (1991). Metallothionein induction in Mytilus edulis exposed to cadmium. Marine Biology 108:91-96.

Biney CA (1991). A method for characterizing natural and waste waters using plant seeds. Environmental Monitoring and Assessment 18:123-128.

Biney CA, Amuzu AT, Calamari D, Kaba N, Mbome IL, Naeve H, Ochumba PBO, Osibanjo O, Radegonde V, Saad MAH (1994). Review of heavy metals in the African aquatic environment. Ecotoxicology and Environmental Safety 28:134-159.

Bleeker EAJ, Kraak MHS, Davids C (1992). Ecotoxicity of lead to the zebra mussel *Dreissna polymorpha*. Hybrobiology Bulletin 25(3):233-236.

Bordin G, McCourt J, Rodriguez A (1992). Trace metals in the marine bivalve *Macoma balthica* in the Westerschelde estuary (The Netherlands). Part 1: Analysis of total copper, cadmium, zinc and iron concentrations-locational and seasonal variations. The Science of Total Environment 127:255-280.

Bordin G, McCourt J, Cordeiro Raposo F, Rodriguez AR (1997). Metallothionein-like metalloproteins in the Baltic clam *Macoma balthica*: seasonal variations and induction upon metal exposure. Marine Biology 129:453-463.

Bouquegneau J-M, Joiris CR (1988). The fate of stable pollutants: heavy metals and organochlorines. In: Advances in Comparative and Environmental Physiology 2:218-219.

Boyden CR (1974). Trace element content and body size in molluscs. Nature 251:311-314.

Boyden CR (1977). Effect of size upon metal content of shellfish. Journal of the Marine Biological Association UK. 57:675-714.

Boyden CR, Phillips DJH (1981). Seasonal variation and inherent variability of trace elements in oysters and their implications for indicator studies. Marine Ecological Programme Service 5:29-40.

Bryan GW (1973). Occurrence and seasonal variation of trace metals in the scallops *Pecten maximus* (L) and *Chlamys opercularis* (L) Journal of the Marine Biological Association UK. 53:145-166.

Butler PA, Andren L, Bonde GJ, Jernelöv A, Reisch DJ (1971). Monitoring organisms. In F.A.O. Technical conference on Marine Pollution and its Effects on Living Resources and Fishing, Rome, 1970. Supplement 1: Methods of detection, measurement and monitoring of pollutants in the marine environment, ed. M. Ruivo, 101-112. London, Fishing News (Books) Ltd.

Cossa D, Rondeau JG (1985). Seasonal, geographical and size induced variability in mercury content of *Mytilus edulis* in an estuarine environment: a re-assessment of mercury pollution level in the Estuary and Gulf of St. Lawrence. Marine Biology 88:43-49.

Cossa D, Bourget E, Pouliot D, Chamut JP (1980). Geographical and size variations in the relationship between trace metal content and body weight in *Mytilus edulis*. Marine Biology 58:7-14.

Dare PJ, Edwards DB (1975). Seasonal changes in flesh weight and biochemical composition of mussels (*Mytilus edulis*) in the Conway estuary, North Wales. Journal of Experimental Marine Biology and Ecology 18:89-97.

De la Cruz EM (1994). Stable pollutants in the bivalve *Anadara tuberculosa* from the Nicoya Gulf Costa Rica -organochlorines and metals- Ph. D. thesis, Free University of Brussels (VUB).

Ferreira AM, Vale C (1995). The importance of runoff to DDT and PCB inputs to the Sado estuary and Ria, Formosa. Netherland Journal of Aquatic Ecology 29(3-4):211-216.

Fowler SW, Oregioni B (1976). Trace metals in mussels from the N.W. Mediterranean. Marine Pollution Bulletin 7(2):26-29.

Fowler SW (1990). Critical review of selected heavy metals and chlorinated hydrocarbon concentrations in the marine environment. Marine Environmental Research 29:1-64.

Fowler SW, Readman JW, Oregioni B, Villeneuve J-P, McKay K (1993). Petroleum hydrocarbons and trace metals in Nearshow Gulf sediments and biota before and after the 1991 War: An assessment of temporal and spatial trends. Marine Pollution Bulletin 27:171-182.

Francesconi KA, Lenanton RCJ (1992). Mercury contamination in semi-enclosed marine embayment/ Organic and inorganic mercury content of biota, and factors influencing mercury levels in fish. Marine Environmental Research, 33:189-212**.**

Frazier JM (1975). Dynamics of metals in the American oyster, *Crassostrea virginica*, I. Seasonal effect. Chesapeake Science 16:162-171.

Frazier JM (1976). Dynamics of metal in the American oyster, *Crassostrea virginica,* II. Seasonal effect. Chesapeake Science 17:188-197.

Gardner WS, Kendall DR, Odom RP, Widom HL, Stephens JA (1978). The distribution of methylmercury in a contaminated salt marsh ecosystem. Environmental Pollution 15:243-251.

Goldberg ED (1989). Synthetic organohalides in the sea. Proc. R. Soc. Lond. B. 189:277-289.

Gurney J (1992). Stable pollutants in *Mytilus edulis* along the Belgium coast. M. Sc. thesis, University College of North Wales.

Jaffé R, Leal I, Alvarado J, Gardinali PR, Sericano JL (1998). Baseline study on the levels of organic pollutants and heavy metals in the bivalves from the Morrocoy National Park, Venezuela. Marine Pollution Bulletin 36(11):925-929

Jennings AA, Li Z (2014). Scope of the worldwide effort to regulate pesticide contamination in surface soils**.** Journal of Environmental Management 146:420-443.

Joiris CR, Azokwu MI, Otchere FA, Ali IB (1998). Mercury in the bivalve *Anadara (Senilia) senilis* from Ghana and Nigeria. Science of the total environment 224:181-188.

Joiris CR, Azokwu MI (1999). Heavy metals in the bivalve *Anadara (Senilia) senilis* from Nigeria. Marine Pollution Bulletin 40(5):457-460.

Joiris CR, Holsbeek L, Otchere FA (2000). Mercury in the bivalves *Crassostrea tulipa* and *Perna perna* from Ghana. Marine Pollution Bulletin 38(7):618-622.

Jothy AA, Husschenbeth E, Harms U (1983). On the detection of heavy metals, organochlorine pesticides and polychlorinated biphenyls in fish and shellfish from coastal waters of Peninsular Malaysia. Archiv Fur Fischereiwissenschaft 33(3):161-206.

Joseph KO, Srivastava JP (1993). Heavy metal load in edible oysters *Crassostrea madrasensis* (Preston) from the Ennore Estuary in Madras (India). Journal of Environmental Management 14:121-127

Kibuthu TW, Njenga SM, Mbugua AK, Muturi EJ (2016). Agricultural chemicals: life changer for mosquito vectors in agricultural landscapes. Parasites and Vectors 9(1):500.

Laporte, JM, Truchot JP, Ribeyre F, Boudou A (1997). Combined effect of water pH and salinity on the bioaccumulation of inorganic mercury and methylmercury in the shore crab *Carcinus maenas*. Marine Pollution Bulletin 33(11):880-893.

Langston WJ, Zhou M (1986). Evaluation of the significance of metal-binding proteins in the gastropod *Littorina littorea*. Marine Biology92:505-515.

Li Z, Jennings AA (2018). Global variations in pesticide regulations and health risk assessment of maximum concentration levels in drinking water. Journal of Environmental Management 212:384-394.

Mbome IL (1988). Heavy metals in marine organisms from Limbé and Douala. Report presented to 2nd workshop of participants in the joint FAO/IOC/WHO/IAEA/UNEP Project on pollution in marine environment for the west and central African region (WACAF/2- First Phase), Accra, Ghana, 13-17 June 1988. IOC of Unesco, Paris.

Metongo BS (1991). Concentration en métaux toxiques chez *Crassostrea gasar* (huitre de mangrove) en zone urbaine lagunaire d'Abidjan (Côte d'Ivoire). Journal Côte d'Ivoire Océanology Limnology 1(1):1-8.

Mikac N, Picer M, Stegnar P, Znidaric M (1985). Mercury distribution in polluted marine area, ratio of total mercury, methylmercury and selenium in sediments, mussels and fish. Water Research 19:1387-1392.

Mitra A, Choudhury A (1993). Metal content in the gastropod *Nerita articulata* (Gould) Indian Journal of Environmental Health 35: 31-35.

Moraes LAF de, Lenzi E, Luchese EB (1997). Mercury in two fish species from the Paranà River floodplain, Paranà, Brazil Environmental Pollution 98(1):123-127

Mouneyrac C, Amiard JC, Amiard-Triquet C 1998). Effect of natural factors (salinity and body weight) on cadmium, copper, zinc and metallothionein-like protein levels in resident populations of oysters *Crassostrea gigas* from a polluted estuary. Marine Ecological Programme Service 162:125-135.

Obirikorang KA, Adjei Boateng D, Otchere FA, Amisah S, Madkour HA (2011). Relationship between Heavy Metal Concentrations in Bottom Sediments and the Clam, *Galatea paradoxa* (Born 1778) from the Volta Estuary, Ghana. Journal of Environmental Protection 2:720-728.

Okoye BCO (1991a). Heavy metals and organisms in the Lagos lagoon. International Journal of Environmental Studies 37:285-292.

Otchere FA (2003). Heavy metals concentration and burden in the bivalves (*Anadara (S.) senilis*, *Perna perna* and *Crassostrea tulipa*) from lagoons of Ghana: model to describe mechanism of accumulation /excretion. African Journal of Biotechnology 2(9):280-287.

Otchere FA, Joiris CR, Holsbeek L (2003). Mercury in the bivalves *Anadara (Senilis) senilis, Perna perna* and *Crassostrea tulipa* from Ghana. Science and Total Environment 304:369-375.

Otchere FA (2005). Organochlorines (PCBs and Pesticides) in the bivalves: *Anadara (Senilis) senilis, Perna perna* and *Crassostrea tulipa* from the lagoons of Ghana. The Science of Total Environment 348(1-3):102-114.

Phillips DJH (1976). The common mussel *Mytilus edulis* as an indicator of pollution by zinc, cadmium, lead and copper. I. Effect of environmental variations on uptake of metals. Marine Biology 38:56-69.

Philips DJH (1977a). The use of biological indicator organisms to monitor trace metal pollution in the marine environments - A review: Environmental Pollution 13:281-317.

Phillips DJH (1977b). Effects of salinity on the net uptake of Zinc by the common mussel *Mytilus edulis*. Marine Biology 41:79-88.

Phillips DJH (1980). Quantitative Aquatic Biological Indicators: Their use to monitor trace metal and organochlorine pollution. Applied Science Publishers Ltd. UK.

Phillips DJH, Segar DA (1986). Use of bio-indicator to monitor conservative contaminants: programme design imperatives. Marine Pollution Bulletin 17:10-17.

Phillips DJH (1990). In: Furness RW and Rainbow PS (eds) Heavy metals in the marine environment. CRC Press, Florida pp. 81-99.

Pillai VK, Valsala KK (1995). Seasonal variation of some metals in bivalve mollusc *Sunetta scripta* from the Cochin coastal waters. Indian Journal of Marine Science 24:113-115.

Pimentel D (1992). Pesticides and world food supply. In: Dunnette, D.A., O'Brien, R.J. (eds) The Science of Global Change. ACS Symp. Ser.483. American Chemical Society, Washington DC. pp. 309-323.

Rainbow PS (1995). Bio-monitoring of heavy metals available in the marine environment. Marine Pollution Bulletin 31:183-192.

Regoli F, Orlando E (1993). *Mytilus galloprovincialis* as a bio-indicator of lead pollution: biological variables and cellular response. The Science of Total Environment 2:1283-1292.

Regoli F, Orlando E (1994). Seasonal variation of trace metals concentrations (Cu, Fe, Mn, Pb and Zn) in the digestive gland of the Mediterranean mussel *Mytilus galloprovincialis* Comparison between a polluted and non-polluted sites. Archives of Environmental Contamination and Toxicology 27:36-43.

Regoli F (1998). Trace metals and Antioxidant enzymes in gills and digestive gland of the Mediterranean mussel *Mytilus galloprovincialis*. Archives of Environmental Contamination and Toxicology 34:48-63.

Reinfelder JR, Wang W-X, Luoma SN, Fisher NS (1997). Assimilation efficiencies and turnover rate of trace elements in marine bivalves: a comparison of oysters, clams and mussels. Marine Biology 129:443-452.

Riisgard HU, Kiorboe T, Mohlenberg F, Drabaek Z, Madsen PPh (1985). Accumulation, elimination and speciation of mercury in the bivalves *Mytilus edulis* and *Macoma baltica* Marine Biology 86:52-55.

Rivonker CU, Paruleker AH (1998). Seasonal variation of major elements (Ca, Mg) and trace metals (Fe, Cu, Zn, Mn) in cultured mussels *Perna viridis* L. and seawater in the Dona Paula Bay, Goa. Indian Journal of Marine Science 27:411-415.

Roesijadi G (1982). Uptake and incorporation of mercury into mercury-binding protein of gills of *Mytilus edulis* as a function of time. Marine Biology 66:151-157.

Sanzgire S, Mesquita A, Kureishy TW (1988). Total mercury in water, sediments and animals along the Indian coast. Marine Pollution Bulletin.

Simkiss K, Taylor M, Mason AZ (1982). Metal detoxification and bioaccumulation in molluscs. Marine Biological Letters 3:187-201.

Soto M, Kortabitarte M, Marigòmez I (1995). Bioavailable heavy metals in esturine waters as assessed by metal/shell-weight indices in sentinel mussels *Mytilus galloprovincialis* Marine Ecological Programme Service 125:127-136.

Szefer P, Wolowicz M, Kusak A, Deslous-Paoli JM, Czamowski W, Frelek K, Belzunce M-J (1999). Distribution of mercury and other trace metals in the cockle *Cerastoderma glaucum* from the Mediterranean lagoon Etang de Thau. Archives of Environmental Contamination and Toxicology 36:56-63.

Tanabe S, Kannan N, Wakimoto T, Tatsukawa R (1987). Method for the determination of three toxic non-ortho chlorine substituted coplanar PCBs in environmental samples at parts per trillion levels. Journal of Environmental Analysis and Chemistry 29:199-213.

Underwood EJ (1974). Factor influencing trace metal needs and tolerances in Man. Marine Pollution Bulletin 5(5): 86-88.

Watling J (1981). The effect of metals on mollusc filtering rates. Transvaal Royal Society of South Africa 44:441-451.

Weis P, Weis JS, Lores E (1993). Uptake of metals from Chromated-Copper-Arsenate (CCA) - treated lumber by Epibiota. Marine Pollution Bulletin 26(8):428-430.

World Health Organization (WHO) (1976). Environmental Health Criteria. 1. Mercury. Geneva, WHO, 131 p.

Vol. 13(6), pp. 228-240, June 2019
DOI: 10.5897/AJEST2019.2675
Article Number: 2F9F68160866
ISSN: 1996-0786

http://www.academicjournals.org/AJEST

ACADEMIC JOURNALS
expand your knowledge

African Journal of Environmental Science and Technology

Full Length Research Paper

Rural households' access to water resources under climate impacts based on field evidence in Tigray Region, Ethiopia

G. Honor Fagan[1], Daniel Etongo[1,2,3*], Zenawi Zerihun[4] and Kelemewerk Tafere[5]

[1]National Institute for Regional and Spatial Analysis (NIRSA), Maynooth University, Maynooth W23 F2H6, Ireland.
[2]James Michel Blue Economy Research Institute, University of Seychelles, Anse Royale, P.O. Box 1348, Seychelles.
[3]Department of Environmental Sciences, University of Seychelles, Anse Royale, P. O. Box 1348, Seychelles.
[4]Department of Psychology, University of Mekelle, Mekelle P. O. Box 231, Ethiopia.
[5]Department of Sociology, University of Mekelle, Mekelle P. O. Box 231, Ethiopia.

Received 12 March, 2019; Accepted 18 April, 2019

The climatic condition in Ethiopia is semi-arid and this has implications especially for rural communities in the country that are largely dependent on surface water. In water scarce areas across four districts in the Tigray region, a survey of 595 households was carried out, and two shared dialogue workshops was held. In this study, the following issues were examined: (i) Access to water in relation to sources, distances covered, gender and time taken; (ii) Local perceptions on current (2014-2017) and future (2018-2021) access to water, and (iii) The types of water conflicts encountered and their causes. Results indicate 50.8% of the surveyed households collected water from dugout ponds and 24% from rivers. Chi-square test showed a statistical significance at the 1 and 5% level, respectively for distance covered and time taken to water sources. Although gender was not significant statistically, females (*N*=440) were more involved than males (*N*=155) in fetching water. Immediate problems arise for householders and specifically women and girls that travelled more than 2 km to collect water. Climate change was mentioned as the key driver that reduced access to water resources whereas tanks with water brought in truck by the government was reported as reason for current increase in access to water. However, future access to water was perceived as unpredictable due to the impacts of climate change. At least 40% of households reported that a member had encountered conflict while accessing water, conflict that manifested itself as verbal accusation and physical fighting. The majority of such instances of conflict resulted from water shortage, followed by pollution from livestock droppings. Project interventions that promote watershed rehabilitation through different ecosystem-based adaptation approaches should be supported locally to restore nearby degraded water sources while improving the functionality of boreholes and existing taps to ensure access and sustainability of water infrastructures.

Key words: Water demand, vulnerability, dugout pond, water catchment, collaborative management, semi-arid.

INTRODUCTION

The Sustainable Development Goals (SDGs), Target 6.4, addresses issues related to water scarcity with the aim of ensuring sufficient water for the population, the economy and the environment by increasing water-use efficiency across all sectors in the society (Vanham et al., 2018). Specifically, the overall objective of this target is "*to substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity by 2030*" (UN, 2015a). Despite such an ambitious set of global goals, recorded progress, however, is slower than needed to meet these targets by 2030 (UN, 2017). To make matters worse, shortages in water supply, uncertain changes in replenishment rates for both surface and groundwater, and deterioration of quality with the potential to reduce both usability and health safety water-related issues are expected to soar in sub-Saharan Africa (Nkem et al., 2011).

Furthermore, it should be noted that Africa's demand and supply chains for fresh water are changing exponentially despite huge investments in water infrastructures (Nkem et al., 2011). Great efforts to improve access to water during the Millennium Development Goals' (MDG) mandate were oriented towards attaining coverage which resulted in a claim that 91% of the population worldwide in 2015 had access to improved water sources (UN, 2015b). Although such achievements are commendable, it leaves us with the impression that an additional 9% coverage could have solved the world's water crisis. This is far from being true because coverage does not translate to sustainability. Globally, populations that have no drinking water service at all and collect water directly from surface water sources such as rivers, lakes and irrigation canals face serious risks to their health and well-being. An achievement was reported in reducing this number when the population using surface water decreased from 4% in 2000 to 2% in 2015. However, of the 159 million using surface water in 2015, 147 million lived in rural areas, and over half lived in sub-Saharan Africa, where 10% of the population still drinks surface water (WHO and UNICEF, 2017: 38). In Ethiopia, this percentage is a little higher with over 12% of Ethiopians still relying on surface water in 2015 (WHO and UNICEF, 2017: 39).

In the most recent Joint Monitoring Programme Report, figures for 2015 show that 844 million people still lacked even a basic drinking water service. Furthermore, 263 million people spent over 30 minutes per round trip to collect water from an improved source (constituting a limited drinking water service) and 159 million people still collected drinking water directly from surface water sources, 58% of whom lived in sub-Saharan Africa (JMP, 2015). This compares unfavourably with the 2012 figures which state that at that time globally 750 million people lacked access to safe drinking water. This problem of access to safe clean water exacerbates, and is exacerbated by, the fact that in 2015, 2.3 billion people still lacked even a basic sanitation service (JMP, 2015). There is a small decrease in this figure from that recorded for 2012, wherein approximately 2.5 billion (1 in 3) did not have access to basic or improved sanitation, mainly as a result of poor water resourcing (WWDR, 2012).

Population growth, agricultural intensification, urbanization, industrial production and pollution, and climate change are beginning to overwhelm and undermine nature's ability to provide key functions and services according to the United Nations *Sustainable Development Goal 6 Synthesis Report 2018 on Water and Sanitation* (UN, 2018). A recent study indicated that climate change will increase the pace of the global hydrologic cycle with accompanied rise in temperature, variability and changes in precipitation patterns (Daniel, 2011). That is not to suggest that climate change is the only, or even the principal, pressure affecting rural livelihoods. Land degradation is considered a severe problem in Ethiopia due to the influence of its topography which affects both land qualities and water resources (Tadesse et al., 2017). Furthermore, Ethiopia loses about 1.9 billion metric tons of fertile soil from the highlands every year and the degradation of land through soil erosion is increasing at a high rate. The consequences of soil erosion and land degradation on crop yields have led to the expansion of farmlands by smallholders around watersheds in Eastern Tigray (Alemayehu et al., 2009).

The specific objectives of this study were to determine the role of gender, distance covered, time taken and the impact of climate change on access to water. Considering the fact that these communities are heavily dependent on open sources such a dugout ponds, rivers and streams, the time spent in the queue is not relevant in this study. Therefore, three research questions are addressed in this study based on distance, gender and time to water sources used in Chi-Square tests of independence. The first H_o states that distance covered has no effect on water sources used by households, while the H_1 states that there is an effect. The second H_o states that there is no relationship between gender and water sources used by households, while the H_1 states that there is a relationship. The third H_o states that there is no association between time taken and water sources used by households, while the H_1 states that there is an association. These key questions will be considered in greater detail in the analysis together with other issues such as perceived impacts of climate change on access to water, the type and causes of water conflicts. Given that rainfall projections for Ethiopia are uncertain and climate variability is exacerbated by a number of existing risks such as drought (Calow et al., 2013), an insight into

*Corresponding author. E-mail: Daniel.Etongo@unisey.ac.sc. Tel: (+248) 4381222. Fax: (+248) 4371695.

rural community's access to water is both timely and important. Such insights based on field evidence are invaluable especially for the SDG Target 6.4, which aims to address water scarcity and to substantially reduce the number of people suffering from water scarcity by 2030.

MATERIALS AND METHODS

Case study area in Ethiopia

Tigray is one of the regional states of Ethiopia located in the northern part of the country and lies between 12° 15′ N and 14° 50′ N and 36° 27′ E and 39° 59′ E with a total land area of 80,000 km². Administratively, it consists of five zones and 34 rural districts also known as 'Woreda', an Ethiopian local administrative unit that forms a district. It has a population of 4.3 million people of which 80.5% live in rural areas (Mekuria et al., 2007). Four districts were selected for this study by the WaterSPOUTT project; this project has as its objective to transform access to safe drinking water through the application of integrated social sciences, education, and solar technologies in vulnerable communities in Africa (Etongo et al., 2018: 4).

The case study sites were selected from the Eastern and Southern zones as follows: Serawat 10 km West of Mekelle, May Nebri 50 km South of Mekelle, Harena 15 km North of Mekelle, and Tsuwanet 55 km North of Mekelle (Figure 1). The rationale for their selection was based on locating communities surrounding ponds and streams that were in use as sources of domestic water supply, but where these unsafe water sources were being predominantly used at homes and in schools. Administrative units using local boundaries in the Tigray Bureau served as a guide in the selection of the four case study areas (Fagan et al., 2018). Three of the four case study districts are heavily dependent on surrounding dugout ponds and wells, while the fourth district relies on a stream closer to the community. Although the fourth district has tap water, it was not fully functional at the time of the survey that took place between June and September 2017. However, the dugout ponds and wells do not contain water all-year-round and these communities have to access water from distant rivers and/or functional boreholes from neighboring communities (Edossa, 2008).

The study area falls within the semi-arid agro-climatic zone having highly dissected and rugged terrain (Virgo and Munro, 1978). The region consists of central mountain highlands of uneven topography composed of peaks and plateaus dissected by gorges rising up to 3900 m a.s.l while the plains that are predominantly located in the north-western lowlands is as low as 500 m a.s.l. (Haregeweyn et al., 2006). Agro-ecologically, it is classified as a highland and midland area, with mean annual air temperature of 22.8°C and a maximum of 27.2°C. Annual precipitation ranges from 515 to 872 mm (Gebremedhin, 2004). This region has a bimodal rainfall pattern with smaller amounts of rainfall that occur between the months of November and March and the major rainy season of June and September, which is locally called "*Kiremti"* (Gebrehiwot and Van der Veen, 2013). The small rains are unreliable and insufficient for crop production. However, the regional climate is characterized by large spatial and temporal variations and frequent droughts. Especially of note is the one that occurred in 2015 a consequence of climate change due to variability in rainfall patterns.

The lithology of the study area is comprised of Mesozoic sedimentary rocks and Tertiary basalt (Nyssen et al., 2002). Soils of the study sites developed in calcium carbonate-rich parent material of the Agula Shale formation, which consist mainly of Marl and Limestone (Beyth, 1972). Agriculture is the main sector of the economy and constitutes nearly 45% of the total regional Gross Domestic Product. The importance of agriculture to the regional economy can be gauged by the fact that it directly supports about 80% of the population in terms of employment and livelihood. Agricultural systems are dominated by small-scale farmers with an average land holding of less than 1 hectare per family characterized by low input and output rain-fed mixed cropping with traditional irrigation technologies in place for centuries now (Solomon and Kitamura, 2006). The major crops cultivated in the study area include barley (*Hordeum vulgare*), wheat (*Triticum sativum*), teff (*Eragrostis teff*) and millet (*Eleusine coracana*). Rainfall in most of the arid and semi-arid regions of Ethiopia, and in Tigray in particular, is not sufficient to support rain-fed agriculture especially with prolonged periods of drought that are recurrent in the last three decades (Berhane et al., 2016).

Data collection and analysis

This current study began with a shared dialogue workshop (SDW) on water resources with opinion leaders and other stakeholders in the Tigray Region. Within the context of WaterSPOUTT, a SDW is a forum that brings academics as well as technicians, educators, politicians, practitioners, community leaders, and household members together at regular intervals (once every six-month-period) to identify challenges and obstacles to, and opportunities for, the uptake of solar technologies at the household, community, and regional level (Etongo et al., 2018). The Social Science Work Package of the project focuses on socio-cultural, institutional and governance issues around water during the SDWs. Therefore, the 3rd and 4th SDWs that occurred in November 2017 and May-June 2018 were specifically organized by WaterSPOUTT partners at Mekelle University to address issues around access to water.

Household surveys and field visits to the study sites complemented the data collection process. Given that the livelihood activities are similar across the case study sites, namely dependence on subsistence farming/livestock and the use of similar water sources (Fagan et al., 2018), a random sampling method was applied which resulted in the selection of 595 households. Questions asked in the household survey included what water sources were used; available water sources, distance covered by households to access water, household perceptions on their current (2014-2017) and future (2018-2021) access to water, types of water conflicts encountered and their causes. The collected data were mostly categorical and satisfy the following two assumptions for Chi-Square tests for independence. Assumption 1: datasets having at least two variables measured at an ordinal or nominal level (that is categorical data). Assumption 2: The two variables should consist of two or more categorical independent groups. Example of independent variables that meet these criteria include distance to main water source (4 groups: <500 m, 500-900 m, 1 km and >2 km), gender of household heads (2 groups: male and female), and time taken to water sources (5 groups: <10 min, 10-30 min, 30 min, 1 h, 1-2 h and >2 h).

The complementary qualitative data from the SDWs on issues around water was analyzed using verbatim transcription and Wordstat 7 (PROVALIS RESEARCH, Montreal, QC, Canada) content analysis software that enabled us to identify the key themes emanating from the discussion. The Wordstat 7 software was used because of its ability to find themes or relationships in verbatim responses, focus group transcripts, or other text sources. It involved four main steps as follows (Adam et al., 2015): (1) identification of the main themes; (2) attributing codes to the main themes; (3) classification of responses under the main themes; and (4) integration of themes and responses into narratives. Furthermore, descriptive methods using Chi-Square tests of independence were applied to test the three hypotheses. The results are presented in the form of pie charts and column graphs using the Statistical Package for Social Science (SPSS) version 23 (IBM Corp. Released 2015. IBM SPSS

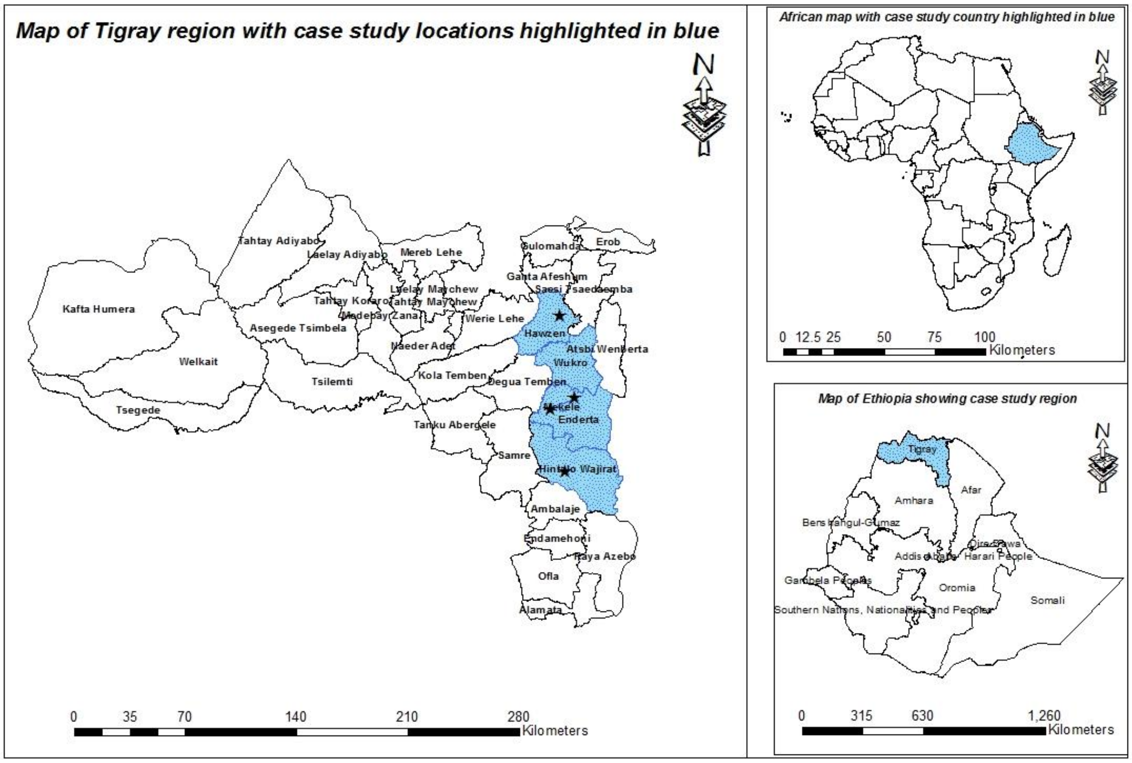

Figure 1. Case study location highlighted in blue.

Statistics for Windows, Version 23.0. Armonk, NY, USA).

RESULTS AND DISCUSSION

Access to available water sources

The majority of the surveyed households in the study area collected water from dugout ponds (50.8%). The use of rivers was reported by 24% while another 10.4% of the households collected water from dug wells (Figure 2). In Ethiopia the percentage of the rural population reported to have safely managed services and to have basic services is 4 and 26%, respectively. Water usage is determined by economic policy, population change, consumption patterns, technological infrastructure and water policy (Fagan et al., 2017). This is so because the installation of large-scale water treatment plants in rural Ethiopia is difficult due to the scarcity of resources and scattered settlement (Abatneh et al., 2014).

Additionally, a Chi-Square test was conducted to verify if the distance covered by households had an effect on the water sources used. The test result indicated that distance covered by households did have an impact on water sources used because the H_o was rejected in favour of the H_1 given that $p<$ alpha (Table 1).

The relatively high percentage of households using dugout ponds relates to minimal resource requirement for construction where rainwater-harvesting ponds constitute an important feature on the Tigrayan landscape. Taps were found only at *May Nebri* and were undergoing rehabilitation at the time of the survey. According to a recent study conducted in the Tigray Region (Berhane, 2018), over 78,000 dugout ponds have been constructed since the year 2000 in order to increase access to rural water supply. Despite such efforts and investment by the government and Non-Governmental Organizations (NGOs), our research identified that most of the constructed ponds are not functional with overall poor performance levels and insufficient impacts to local communities was widely observed (Fagan et al., 2018, 2017). Some of the challenges that affect the performance of rainwater harvesting ponds based on field observations, key informants and from SDWs are inadequate site selection, absence of a biophysical survey during design and construction, leakage and evaporation losses, poor management of the ponds and the impacts of climate change (Berhane, 2018).

Furthermore, another statistical test was conducted with the H_o to find out that there is no relationship between gender and water sources used by households. The test result failed to reject the H_o given that p >alpha (Table 2). As such, water sources are not gender sensitive, but rather, accessibility is likely to be influenced by availability.

The problem will no doubt be further compounded

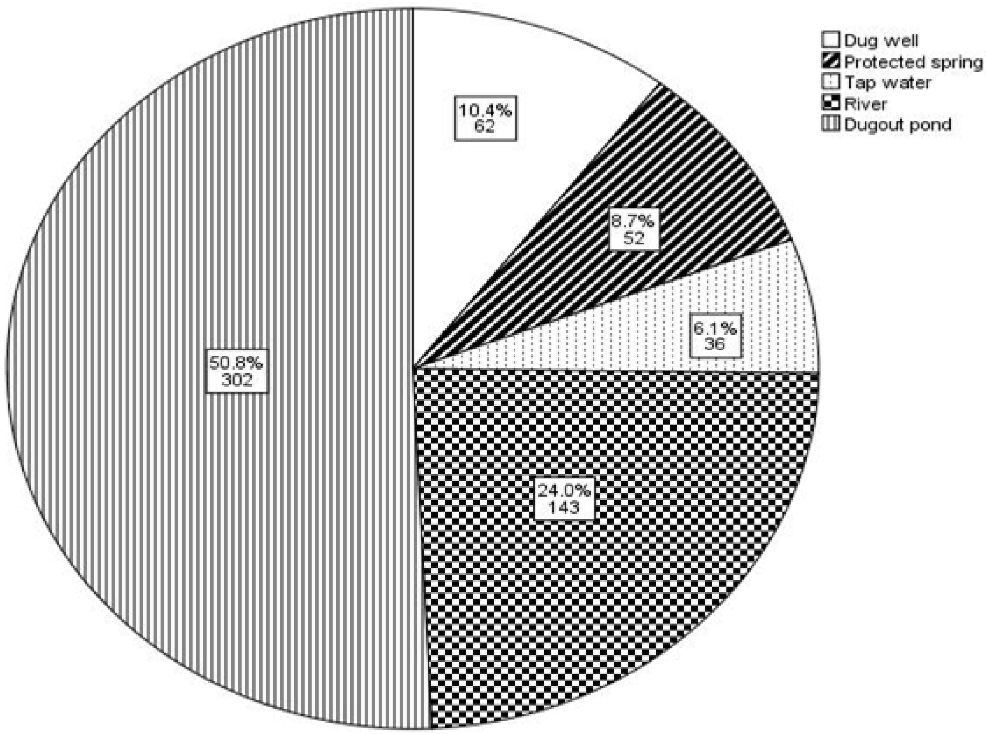

Figure 2. Primary sources of water used by households in the case study area.

given that climate models have predicted temperatures in Ethiopia will rise over the coming years, increasing by 2.1°C in 2050 and 3.4°C by 2080 (FDRE, 2007). On the other hand, rainfall has witnessed a high degree of variability during the last five decades and is expected to continue and to be accompanied by frequent and severe droughts, thereby increasing the burden on water (Deressa et al., 2011). Immediate problems arise for householders and specifically women and girls then in that our study revealed that female were more dominant than males in accessing water from the different sources (Table 2). Furthermore, our result indicated that distance had an effect on access to water (Table 1) of which some of the surveyed households travelled more than 2 km to collect water. The main reasons provided to us during a field visit in the area in July 2017 was that nearby sources such as dugout ponds and wells easily dry-up (Figure 3) while the few available water sources also suffer from constant pollution from livestock droppings.

The test result between water sources used by households versus time taken to arrive at these sources showed a 5% level ($p \leq 0.05$) statistical significant (Table 3). Information gathered from SDWs and during a field visit to the study sites further reaffirm our findings of householders using rivers at distant location as reliable water sources. Travelling for longer distances to access water is not a surprise in rural Ethiopia as corroborated by an earlier study in which approximately 60% of those residing in rural areas travel more than 1 h and up to 5 h daily to collect water. This burden falls disproportionately on women who are solely responsible for collecting water and with such time demands, it is not surprising that per capita water use especially in rural areas in Ethiopia is low (Calow et al., 2015).

Water and climate change: Local perceptions and field evidence

Most households in this study perceived a decline concerning their current access (2014-2017) to water. The explanation provided by one of the households in *May Nebri* is that their “family has been living here for more than 50 years and several nearby streams have disappeared and water in ponds gets evaporated easily compared to five decades ago” (MN27). Another household said, “we have not experienced the kind of drought we had in 2015 in the last thirty years. Not only did we lose our livestock, but all surface water except for a river which 2 hours from our community completely dried-up” (S45). It is evident that water resources are vulnerable to the impacts of climate change and the main environmental challenge, in addition to land degradation, that Ethiopia and neighbouring countries are facing today is water scarcity (Mekonnen et al., 2015a, 2015b). Other reasons for water scarcity mentioned by key informants in the Tigray Region include poor management of water points, lack of adequate water infrastructures, and

Table 1. A cross-tabulation between water sources versus distance covered.

Main water source versus distance covered			Distance to main water source from home				Total
			<500 m	**500-900 m**	**1 km**	**>2 km**	
Main water source	Dug well	Count	17	18	16	11	62
		Expected count	3.5	11.8	9.3	37.4	62.0
	Protected spring	Count	3	7	18	24	52
		Expected count	3.0	9.9	7.8	31.4	52.0
	Tap water	Count	1	13	6	16	36
		Expected count	2.1	6.8	5.4	21.7	36.0
	River	Count	11	21	12	99	143
		Expected count	8.2	27.2	21.4	86.3	143.0
	Dugout pond	Count	2	54	37	209	302
		Expected count	17.3	57.4	45.2	182.2	302.0
Total			34	113	89	359	595

Chi-square tests	**Value**	**df**	**Asymp. Sig. (2-sided)**
Pearson chi-square	129,082[a]	12	0.000
Likelihood ration	115,012	12	0.000
Linear-by-linear association	70,855	1	0.000
Number of valid cases	595	-	-

Symmetric measures		**Value**	**Approximate significance**
Nominal by nominal	Phi	0.466	0.000
	Cramer's V	0.269	0.000
Number of valid cases		595	

(a) 3 cells (15.0%) have expected count less than 5. The minimum expected count is 2.06. Not assuming the null hypothesis. (b) Using the asymptotic standard error assuming the null hypothesis.

increasing demand for irrigation and livestock watering.

However, some of the households perceived their current access to water has stayed the same while others were of the opinion that it has increased during the said period. Next most mentioned reason for the increase in current access to water was the provision of water tanks that were installed at schools and health centres (Figure 4). Over 70% of the surveyed households mentioned the role of the government in bringing water in trucks from distant locations to fill-in the tanks especially during the dry season.

The climatic condition in Tigray is semi-arid and according to the Climate Change Vulnerability Index, Ethiopia is ranked seventh among countries at risk from the impacts of climate change (Maplecroft, 2015). This has implications for water resources for various uses such as domestic, livestock watering and even for the traditional irrigation systems used by smallholder farmers which have been practiced for centuries. To make matters worse, it has been estimated that two-thirds of the world population will be living in areas facing water-stressed conditions by the year 2025 (Ahmad, 2002). Adequate and accessible water supply is a prerequisite for socio-economic development (IFAD, 2012; Hunter et al., 2010), and it is clear that water resourcing still remains a major health and livelihood challenge in Ethiopia in general, and in Tigray in particular.

In relation to their hopes for improving future access to water, many of the surveyed households were of the opinion that it is unpredictable. One household explained that, "one of our neighbouring community use to have similar problem on water but now they have a functional borehole, but for us, we cannot tell what will happen in the future concerning access to water" (H22). It is not a surprise that the majority of the households surveyed are not certain concerning their future access to water

Table 2. A cross-tabulation between gender and water sources used.

Gender versus water sources used			Gender		Total
			Female	Male	
Water source used	Dug well	Count	43	19	62
		Expected count	45.8	16.2	62.0
	Protected spring	Count	39	13	52
		Expected count	38.5	13.5	52.0
	Tap water	Count	28	8	36
		Expected count	26.6	9.4	36.0
	River	Count	111	32	143
		Expected count	105.7	37.3	143.0
	Dugout pond	Count	219	83	302
		Expected count	223.3	78.7	302.0
Total			440	155	595

Chi-square tests	**Value**	**df**	**Asymptotic significance**
Pearson Chi-Square	2,306[a]	4	0.680
Likelihood Ration	2,322	4	0.677
Linear-by-Linear Association	0.072	1	0.789
N.of Valid Cases	595		

Symmetric measures		**Value**	**Approximate significance**
Nominal by nominal	Phi	0.062	0.680
	Cramer's V	0.062	0.680
Number of valid cases			595

(a) 0 cells (0.0%) have expected count less than 5. The minimum expected count is 9.38. Not assuming the null hypothesis. (b) Using the asymptotic standard error assuming the null hypothesis.

especially with the high dependence on water sources that are highly vulnerable to the impacts of climate change. One of the case study communities, *May Nebri,* have taps that were expected to be functional a month after our survey. Households in this community were convinced that their water problems will be solved by tap water being provided, but worried about the functionality of the taps given the pervious very long period of breakdown. Therefore, both current and future access to water, especially under a changing climate, would require water technologies that are functional and can be easily maintained.

Conflicts over access to water

Out of the 595 surveyed households across the four case study communities, a total of 40.7% (*N*=242) had encountered at least one type of conflict. These conflicts occurred across different stakeholders, and manifested as verbal accusation and physical fighting as reported by 43.8 and 31.8% of surveyed households respectively (Figure 5). Additionally, disputes were also reported to have occurred with the water user committees (WUCs), and also with government representatives at the regional level especially with the Tigray Regional Health Bureau and Tigray Bureau of Agriculture and Rural Development. Both Bureaus have the mandate (especially the former) to improve community access to water.

Shortage of water is the predominant cause of conflicts in the case study community as reported by 69.4% of the surveyed households. Pollution from livestock droppings (22.3%) and the breakdown of dug wells (8.3%) (Figure 6) were also mentioned. Excessive demand on water resources for agricultural, domestic, and industrial activities combined with a growing population contribute

Figure 3. Rainwater harvesting pond at *Serawat* with water at full capacity as seen in the month of October 2016 (Figure 3a) while in July 2017, the same pond is completely dry (Figure 3b).

Table 3. Water sources used versus time taken to arrive at these sources.

Water sources versus time to access these sources			Time taken to arrive at water source					Total
			Below 10 min	10-30 min	30 min-1 h	1-2 h	Above 2 h	
Main water sources	Dug well	Count	0	5	9	5	43	62
		Expected Count	0.3	5.1	6.5	9.3	40.8	62.0
	Protected spring	Count	0	3	9	5	35	52
		Expected Count	0.3	4.3	5.4	7.8	34.3	52.0
	Tap water	Count	0	2	4	10	20	36
		Expected Count	0.2	3.0	3.8	5.4	23.7	36.0
	River	Count	0	21	18	18	86	143
		Expected Count	0.7	11.8	14.9	21.4	94.2	143.0
	Dugout pond	Count	3	18	22	51	208	302
		Expected Count	1.5	24.9	31.5	45.2	199.0	302.0
Total		Count	3	49	62	89	392	595
Chi-square tests			**Value**	**df**	**Assymptotic significance**			
Pearson chi-square			29,653[a]	16	0.020			
Likelihood ration			29,302	16	0.022			
Linear-by-linear association			0.418	1	0.518			
Number of valid cases			595					

Table 3. Contd.

Symmetric measures		Value	Approximate significance
Nominal by nominal	Phi	0.223	0.020
	Cramer's V	0.112	0.020
Number of valid cases			595

(a) 8 cells (32.0%) have expected count less than 5. The minimum expected count is 18. Not assuming the null hypothesis. (b) Using the asymptotic standard error assuming the null hypothesis.

Figure 4. A hand-dug well close to a primary school in *Tsuwanet* with walls that easily collapse and also visible is a rainwater tank and a white storage tank close to the school building (Figure 4a). With financial support from World Vision International, a stone wall was constructed in May 2017 to protect walls from collapsing and also from livestock (Figure 4b).

to water shortage and conflicts. In three of the study areas, with the exception of *Tsuwanet*, water sources were accessed by humans and livestock together. It is clear that as reported in the present results (Figure 6) from information gathered from visits to the study sites (Figure 7) and the discussions at SDWs, that conflicts arose because of livestock droppings in water sources making it unfit for some domestic uses showing agricultural and domestic needs clashing.

Limitations of the study

This study faces a number of limitations. First, it could have been much better to have a dichotomous group: improved access and unimproved access to water. With these two categories, the factors that affect water users in both groups could be identified easily. But this was not the case because these communities are highly dependent on untreated water sources and *May Nebri* had taps that were not functional at the time of the survey. To overcome this limitation, water sources used by the surveyed households were considered.

Next, self-reported assessment by households can be biased, especially if the issue under investigation is considered sensitive. This was the case with the question that focuses on the type of water conflicts encountered by household members. Although issues concerning rape are mentioned during SDWs, households that have a member who is a victim of rape, are not willing to share such information.

CONCLUSIONS AND POLICY RECOMMENDATIONS

Despite the progress recorded during the mandate of the

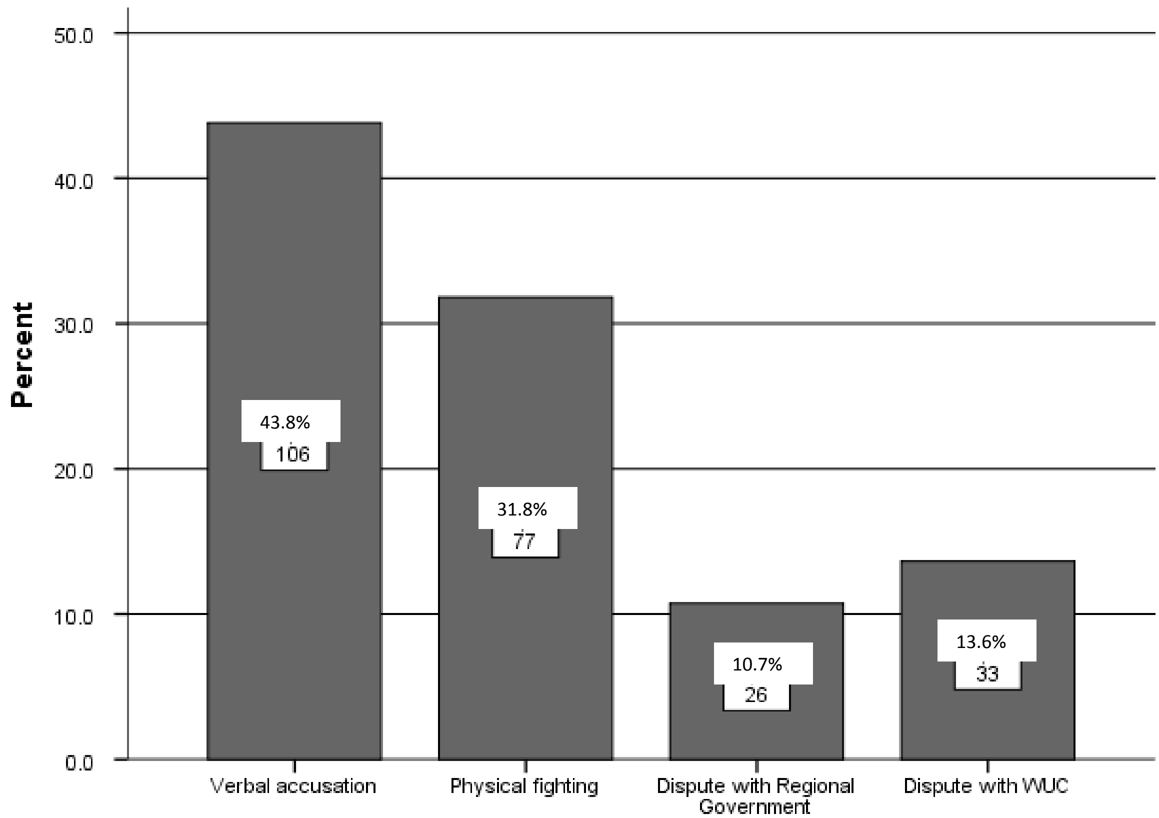

Figure 5. Type of conflicts encountered by surveyed households while accessing water.

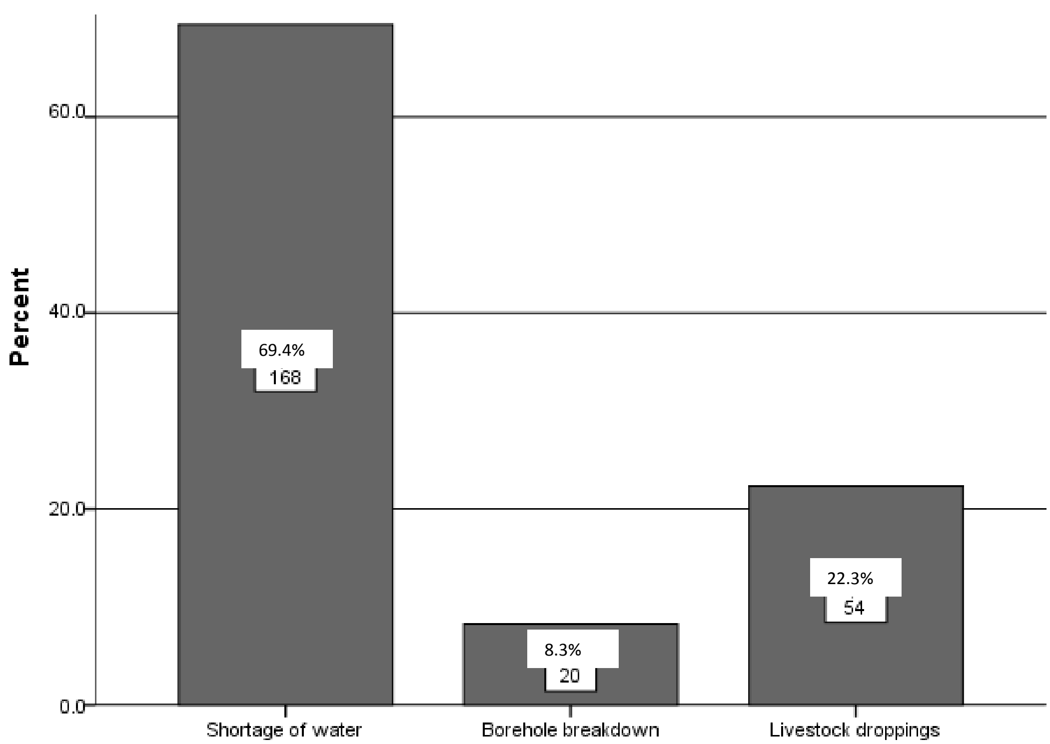

Figure 6. Causes of conflicts encountered by households.

Figure 7. Water sources predominantly used across the four study communities with visible signs of cattle sharing three of the four sources with human.

MDGs, the majority of households in rural areas in the Tigray Region in particular still lack access to safe and reliable sources of water. The Chi-square test results showed a statistical significance at the 1 and 5% level, respectively for distance covered and time taken to water sources. Immediate problems arise for householders and specifically women and girls that travelled more than 2 km to collect water. Although gender was not significant statistically, females (*N*=440) dominated males (*N*=155) in collecting water. Some of the challenges that affected the performance of rainwater harvesting ponds aside from the impacts of climate change based on field observations, key informants and from SDWs included inadequate site selection, absence of a biophysical survey during design and construction and poor management. Despite the occasional provision of water by the government by bring water in trucks, climate change was highly perceived to have reduced current access to water while future access was highly unpredictable.

Furthermore, at least 40% of households reported that a member had encountered conflict while accessing water, conflict that manifested itself as verbal accusation and physical fighting. The majority of such instances of conflict resulted from water shortage, followed by pollution from livestock droppings. The government have responded to the scarcity of water by bringing in water tanks with truckloads of water especially to some primary schools and health centres in the case study areas. However, the majority of the surveyed households perceived their future access to water as unpredictable given that some springs, hand-dug wells and rainwater harvesting ponds are completely dried-up during certain period of the year. The consequences therefore are that longer distances are covered to access water from relatively more reliable sources such as rivers or from neighbouring communities with boreholes and water pumps that are functional. Generally, per capita water use in the case study locations and the rural areas in Ethiopia is low given that most household members travel more than 2 hours to collect water, the majority of whom are women and female children.

Aside from the low per capita water use, different types of conflicts were recorded such as verbal accusation and physical fighting in addition to disputes between stakeholders. It is clear that as reported in the results from information gathered during a visit to the study sites and the discussions at SDWs, that conflicts arose because of livestock droppings in water sources making it unfit for some domestic uses showing agricultural and domestic needs clashing. Project interventions that promote watershed rehabilitation through different ecosystem-based adaptation approaches should be supported locally to restore nearby degraded water sources while improving the functionality of boreholes and existing taps to ensure access and sustainability of water infrastructures. Water allocation is also important to avoid waste and conflicts. For example, water from ponds should be allocated for other domestic purposes such as washing, cleaning to avoid the waste of water. Such sources should also be used for small-scale irrigation and for the watering of livestock.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors would like to thank their collaborators at Mekelle University, Ethiopia for organizing and carrying out the fieldwork for this study. Lastly, they are thankful to all the stakeholders and community members for the time taken out to participate in the baseline survey across the four rural communities in Tigray Region, Ethiopia. This research was funded by the European Commission H2020-Water-5c-2015 awarded to the WaterSPOUTT Project, grant number 688928.

REFERENCES

Abatneh Y, Sahu O, Yimer S (2014). Purification of drinking water by low cost method in Ethiopia. Applied Water Science 4:357-62.

Adam YO, Pretzsch J, Darr D (2015). Land use conflicts in Central Sudan: Perceptions and local coping mechanisms. Land Use Policy 42:1-6.

Ahmad MD (2002). Estimation of net groundwater use in irrigated river basin using geo-information techniques: A case study in Rechna Doab, Pakistan. PhD Thesis, Wageningen University, Wageningen, The Netherlands.

Alemayehu F, Taha N, Nyssen J, Girma A, Zenebe A, Behailu M, Deckers S, Poesen J (2009). The impacts of watershed management on land use and land cover dynamics in Eastern Tigray (Ethiopia). Resources, Conservation and Recycling 53:192-198.

Berhane G (2018). Benefits and challenges of Dugout Rainwater Harvesting Pond in Tigray Region, Ethiopia. In: Leal, F.W.; de Trincheria, G.J. (eds.), "Rainwater-Smart Agriculture in Arid and Semi-Arid Areas," Springer, Cham, Switzerland 259-280.

Berhane G, Gebreyohannes T, Martens K, Walraevens K (2016). Overview of micro-dam reservoirs (MDR) in Tigray (northern Ethiopia): Challenges and benefits. Journal of African Earth Sciences 123(2):210-222.

Beyth M (1972). Paleozoic-Mesozoic Sedimentary basin of Mekele outlier. American Association of Petroleum Geologists Bulletin 56:2426-2439.

Calow R, Ludi E, McKenzie A, Seifu K (2015). Climate and environmental risk screening for rural water supply in Ethiopia: A guidance note for programme staff. Available online at https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/10072.pdf Retrieved on 11 June 2018.

Calow R, Ludi E, Tucker J (2013). Achieving water security: lessons from research in water supply, sanitation and hygiene in Ethiopia. Rugby, UK: Practical Action Publishing Ltd.

Daniel E (2011). Vulnerability assessment of surface water supply systems due to climate change and other impacts in Addis Ababa, Ethiopia. Department of Earth Sciences, Aquatic Climatology: Uppsala University, Uppsala, Sweden. Available online at http://uu.diva-portal.org/smash/get/diva2:452439/FULLTEXT01.pdf. Retrieved on 20 May 2018.

Deressa T, Hassan RM, Ringler C (2011). Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. The Journal of Agricultural Science 149:23-31.

Edossa L (2008). The impacts of rural water supply and management system on livelihood of user communities: A case of Babile Woreda, East Harerge Zone. M.A. Thesis, College of Development Studies, Addis Ababa University, Addis Ababa, Ethiopia.

Etongo D, Fagan GH, Kabonesa C, Asaba RB (2018). Community-Managed Water Supply Systems in Rural Uganda: The Role of Participation and Capacity Development. Water doi:10.3390/w10091271.

Fagan GH, Etongo D, Zerihun Z, Tafere K, Chiwaula L, Mulwafu W, Morse T, Luwe K, Asaba R, Kabonesa C, Wessels B (2018). A Socio-Spatial Survey of Water Issues in Ethiopia, Malawi, Uganda and South Africa. Draft Report, Work Package 5 – Social Science Team, WaterSPOUTT Project.

Fagan GH, Etongo D, Zerihun Z, Tafere K, Chiwaula L, Mulwafu W, Morse T, Ziba S, Asaba R, Kabonesa C, Wessels B (2017). Water Governance in the Era of the Sustainable Development Goals: The Case of Ethiopia, Malawi, Uganda and South Africa. Draft Report, Work Package 5 – Social Science Team, WaterSPOUTT Project.

Federal Democratic Republic of Ethiopia (FDRE) (2007). Climate change adaptation programme of action (NAPA). Ethiopia Ministry of Water Resources and National Meteorological Agency, Addis Ababa, Ethiopia.

Gebrehiwot T, Van der Veen A (2013). Climate change vulnerability in Ethiopia: disaggregation of Tigray Region. Journal of Eastern African Studies 7(4):607-629. DOI: 10.1080/17531055.2013.817162.

Gebremedhin T (2004). Assessing and mapping areas susceptible to water erosion using integrated remote sensing GIS tools and minimal ground survey in the Atsibi sub-Watershed. A case study in Tigray region, Ethiopia," International Institute for Geo-information Science and Earth Observation; Enschede, The Netherlands.

Haregeweyn N, Poesen J, Nyssen J, De Wit J, Haile M, Govers G, Deckers S (2006). Reservoirs in Tigray (Northern Ethiopia): Characteristics and sediment deposition problems. Land Degradation and Development 17:211-230.

Hunter PR, MacDonald AM, Carter RC (2010). Water Supply and Health. PLOS Medicine 7:1-10. DOI:10.1371/journal.pmed.1000361.

International Fund for Agricultural Development IFAD (2012). Water and Food Security, Rome, Italy. Available online at http://www.ifad.org/documents/10180/331fafbc-fd68-4a8d-80a8-06f121a3cf37. Retrieved on 25 May 2018.

Joint Monitoring Programme (JMP). Progress on Sanitation and Drinking Water – 2015 Update. Geneva: WHO/UNICEF JMP for Water Supply and Sanitation. Available online at https://data.unicef.org/wp-content/uploads/2015/12/Progress-on-Sanitation-and-Drinking-Water_234.pdf. Retrieved on 22 November 2018.

Maplecroft (2015). Climate change vulnerability index 2015. Maplecroft's Climate Change and Environmental Risk Atlas (CCERA), Maplecroft, United Kingdom.

Mekonnen M, Keesstra SD, Baartman JE, Ritsema CJ, Melesse AM (2015a). Evaluating sediment storage dams: structural off-site sediment trapping measures in Northwest Ethiopia. Cuadernos de Investigacion Geografica 41(1): 7-22.

Mekonnen M, Keesstra SD, Stroosnijder L, Baartman JEM, Maroulis J (2015b). Soil Conservation through sediment trapping: a review. Land Degradation and Development 26:544-556.

Mekuria W, Veldkamp E, Haile M, Nyssen J, Muys B, Gebrehiwot K (2007). Effectiveness of exclosures to restore degraded soils as a result of overgrazing in Tigray, Ethiopia. Journal of Arid Environment 69:270-284.

Nkem JN, Munang R, Jallow B (2011). Decentralizing solutions for Rural Water Supply Under Climate Impacts in sub-Saharan Africa. Environment: Science and Policy for Sustainable Development 53(2):14-17.

Nyssen J, Moeyersons J, Poesen J, Haile M, Deckers J (2002). The environmental significance of the remobilization of ancient mass movements in the Atbara-Tekeze headwaters, Northern Ethiopia. Geomorphology 49:303-322.

Solomon H, Kitamura Y (2006). Traditional irrigation management in Betmera-Hiwane, Ethiopia: the main peculiarities for the persistence of irrigation practices. Journal of Mountain Science 3:139-146.

Tadesse L, Suryabhagavan KV, Sridhar G, Legesse G (2017). Land use and land cover changes and soil erosion in Yezat Watershed, North Western Ethiopia. International Soil and Water Conservation Research 5:85-94.

United Nations (2015a). Transforming our world: the 2030 Agenda for Sustainable Development. Seventieth session of the United Nations General Assembly. Available online at:

http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E. Retrieved on 11 July 2018.
United Nations (2015b). The Millennium Development Goals Report: Time for Global Action for People and Planet. Available online at http://www.un.org/millenniumgoals/2015_MDG_Report/pdf/MDG%202015%20rev%20(July%201).pdf. Retrieved on 1 May 2018.
United Nations (2017). Progress too slow on global goals for sustainable development. Available online at https://www.reuters.com/article/us-un-globalgoals-progress-idUSKBN1A22A2. Retrieved on 11 July 2018.
United Nations (2018). Sustainable Development Goal 6 Synthesis Report on Water and Sanitation. Available online at https://sustainabledevelopment.un.org/content/documents/19901SDG6_SR2018_web_3.pdf. Retrieved on 22 July 2018.
Vanham D, Hoekstra AY, Wada Y, Bouraoui F, de Roo A, Mekonnen MM, van de Bund WJ, Batelaan O, Pavelic P, Bastiaanssen WGM, Kummu M, Rockström J, Liu J, Bisselink B, Ronco P, Pistocchi A, Bidoglio G (2018). Physical water scarcity metrics for monitoring progress towards SDG target 6.4: An evaluation of indicator 6.4.2 Level of water stress. Science of the Total Environment (613-614):218-232.
Virgo KJ, Munro RN (1978). Soil and erosion features of the central plateau of Tigray, Ethiopia. Geoderma 20:131-157.
WHO and UNICEF. Progress on Drinking Water, Sanitation and Hygiene: 2017 Update and SDG Baseline. Geneva: World Health Organization (WHO) and the United Nations Children's Fund (UNICEF). Available online at http://www.who.int/mediacentre/news/releases/2017/launch-version-report-jmp-water-sanitation-hygiene.pdf. Retrieved on 1 November 2018.
World Water Development Report – UNESCO. Managing Water Under Uncertainty and Risk. Report Number 4, Paris, 2012. Available online at https://www.zaragoza.es/contenidos/medioambiente/onu//newsletter12/789-eng-sum-ed4.pdf. Retrieved on 15 December 2018.

Vol. 13(6), pp. 241-252, June 2019
DOI: 10.5897/AJEST2018.2643
Article Number: 96371DE60872
ISSN: 1996-0786

http://www.academicjournals.org/AJEST

ACADEMIC JOURNALS
expand your knowledge

African Journal of Environmental Science and Technology

Full Length Research Paper

Impacts of soil and water conservation practices on livelihood: The case of watershed in Gambela region, Ethiopia

Gatbel Chot[1], Awdenegest Moges[2] and Amanuel Shewa[3*]

[1]Department of Natural Resources Management, College of Agricultural Sciences, Arba Minch University, Ethiopia.
[2]School of Biosystems and Environmental Engineering, Hawassa University, Ethiopia.
[3]Department of Rural Development and Agricultural Extension, College of Agricultural Sciences, Arba Minch University, Ethiopia.

Received 22 December, 2018; Accepted 18 January, 2019

In this study, multistage sampling technique was used. 132 households were selected out of 2,943 households in three sampled kebeles (the lowest administrative structure in Ethiopia) of Godere Woreda (*Woreda* is administrative structure above *Kebele)*. Household-based interview, key informants interview (KII) and transect walk were used in order to collect data. Practiced households have harvested an average of 44.74 quintal of crop production per hectare per year while non-practiced households reaped a mean of 23.29 quintal of crop production per hectare per year with mean difference equivalent to 21.5 kg while practiced households earned an average of 3282.58 and non-practiced households earned a mean of 2661.97 Ethiopian birr per household per year with mean difference equivalent to 620.6. Practiced households demand an average of four persons while non-practiced households require an average of two persons per household. Practiced households use a mean of 30.89 kg of Di-amonnium phosphate (DAP) while non-practiced households use an average of 62.92 kg in their crop fields with mean difference equivalent to 32.03 kg. Practiced households use a mean of 22.27 kg of Urea fertilizer per household in their crop fields whereas non-practiced households use an average of 53.56 kg with mean difference equivalent to 31.28 kg of Urea fertilizer per household. With these findings, it is rationale to conclude that SWC measures have positive impact on crop production. It has slight contribution to household income. Labour demand (household and hired) increase, level of inorganic fertilizer use decrease but use of organic fertilizer increase. Thus, it is worth to recommend that non-practiced households need to be aware about the advantages of conservation measures but with due consideration to challenges hindering adoption. SWC measures need to be integrated with other income generating activities.

Key words: Impacts, Livelihood, practiced, non-practiced, household, adoption.

INTRODUCTION

Eighty five percent of Ethiopia population depends on small scale and rain fed agriculture as a source of livelihood (UNDP, 2016). However, agricultural production from smallholder farmers do not keep pace with rapidly

*Correspondent author. E-mail: ashewa@ymail.com. Tel: +254911828557.

rising population in the country (Ethiopia) and thus resources degradation is eminent (GTPII, 2016). This resources degradation could be attributed to factors like population pressure, topographic gradient, land fragmentation, overstocking of livestock, land use conversion, variability in climatic elements, and traditional agriculture practices. While Ethiopia population is currently growing at a rate of three percent (3%) (World population prospect, 2017), agricultural production rate was reported to decline from 9.6 to 6.3% at the end of the country's first growth and transformation plan (Adimasu, 2012). A dramatic increase in population and concurrent decline in agricultural production is an indication of poverty prevalence for agro-dependent population.

The complexity and fragility of Ethiopia's landscape makes its soil highly susceptible to land degradation and consequently the serious negative impact on farmers' livelihood and food security status. Natural resources degradation is closely linked to community livelihood. For instance, a degraded watershed has a few or limited opportunities for water harvesting and management, difficulty in accessing clean water for domestic uses, no or limited opportunities to participate in income generating activities because all these opportunities are directly linked to the health of watershed. Thus, community livelihood would be seriously affected in unhealthy watershed. Therefore, community based participatory watershed development and planning was adopted with the aim to improve livelihood of farmers and enhance ecosystem functions (Lakew, 2005).

At regional context, Gambela, as one of the administrative region in Ethiopia has its landscape dominated by lowland topographic characteristics and a moisture-stressed area; however, the topography of Godere district is at the transitional zone between escarpment of Sheka Zone of SNNPR and Gambela plain of the Anuak Zone (Gambela Agriculture and Natural Resource Bureau, 2017). Thus, it is the part of Gambela which is prone to soil erosion by water because of its location in upland relative to other part of Gambela (Gambela Agriculture and Natural Resource Bureau, 2017). Majority of this area has been under the threat of soil erosion caused by runoff and thus reduced the productivity of the land and crops production as well. This scenario negatively affects the livelihood of most households particularly the poor rural population since their livelihood mainly depend on agriculture (USAID, 2009). An effort to curb natural resources degradation, particularly land degradation in farmland and communal grazing land and thus improve rural livelihood has been attempted by the Ethiopia government in partnership with sustainable land management project in Zeiy watershed in Godere district of Majang zone, Gambela region. However, communities of this watershed (Zeiy) were reported to be reluctant to implement soil and water conservation practices mainly because they are unaware about the importance of conservation practices (Gambela Agriculture and Natural Resource Bureau, 2017). Sustainable land management project has been a long time partner of Ethiopia government in its fight against land degradation and improvement of livelihood through enhancing agricultural production across the country (MoA, 2013).

The impact of these interventions have been assessed in many parts of Ethiopia and the results of those assessments have been used to inform farmers about the advantages of managing their own farmlands and improving pastureland productivity through SWC measures and thus increase their participation in watershed development activities which could even improve their livelihood.

However, there is no study which assessed the impact of watershed interventions particularly soil and water conservation measures in Zeiy watershed of Majang zone, Gambela Regional state. Therefore, this study was initiated in order to assess the impacts of soil and water conservation practices on farmers' Livelihood in Zeiy watershed of Majang Zone, Gambela Regional State in order to fill this knowledge gap.

METHODOLOGY

Description of the study area

Godere is part of Majang zone which is bordered on the southeast by SNNPR and on the west by the Mengeshi district. The largest town in this district is Meti. This district lies at the coordinates of 7°9'30″-7°29'00″N latitude and 35°00'00″-35°30'00″E longitude.

Godere district's Agro-ecology is wet *kola* with altitudinal ranges of 500-1000 m.a.s.l having undulating terrain features and slope range of 2-4% (gentle slope) (Livelihood, 2009; Wikepedia, 2017). There are two distinct rainy seasons (Belg and Meher) which stretch from mid-February to December. The area receives on average 1600-2100mm of rainfall per year (USAID, 2009). Figure 1

Research approach

This study followed mixed research approach. Both qualitative and quantitative data were collected and analyzed. Qualitative data such as household characteristics and adoption of organic fertilizer were collected. Quantitative data related to crop yield, income and amount of inorganic fertilizer were also collected and analyzed and output presented in the results section of this manuscript.

Sampling Technique and Size Determination

For this study, a multistage sampling technique was followed. First, the whole watershed was clustered into three clusters based on topographic gradient (elevation) or the location along the landscape which was very subjective. These clusters are upstream (2,062-1,549 m.a.s.l), midstream (1,375-1,362 m.a.s.l) and downstream (1,192-1,162 m.a.s.l) (Gambella Agriculture and Natural Resource Bureau, 2017). Thus, a simple random sampling technique was applied in order to select one kebele from each cluster. As a result of this random selection, three kebeles namely, Kabo, Mehakelgna

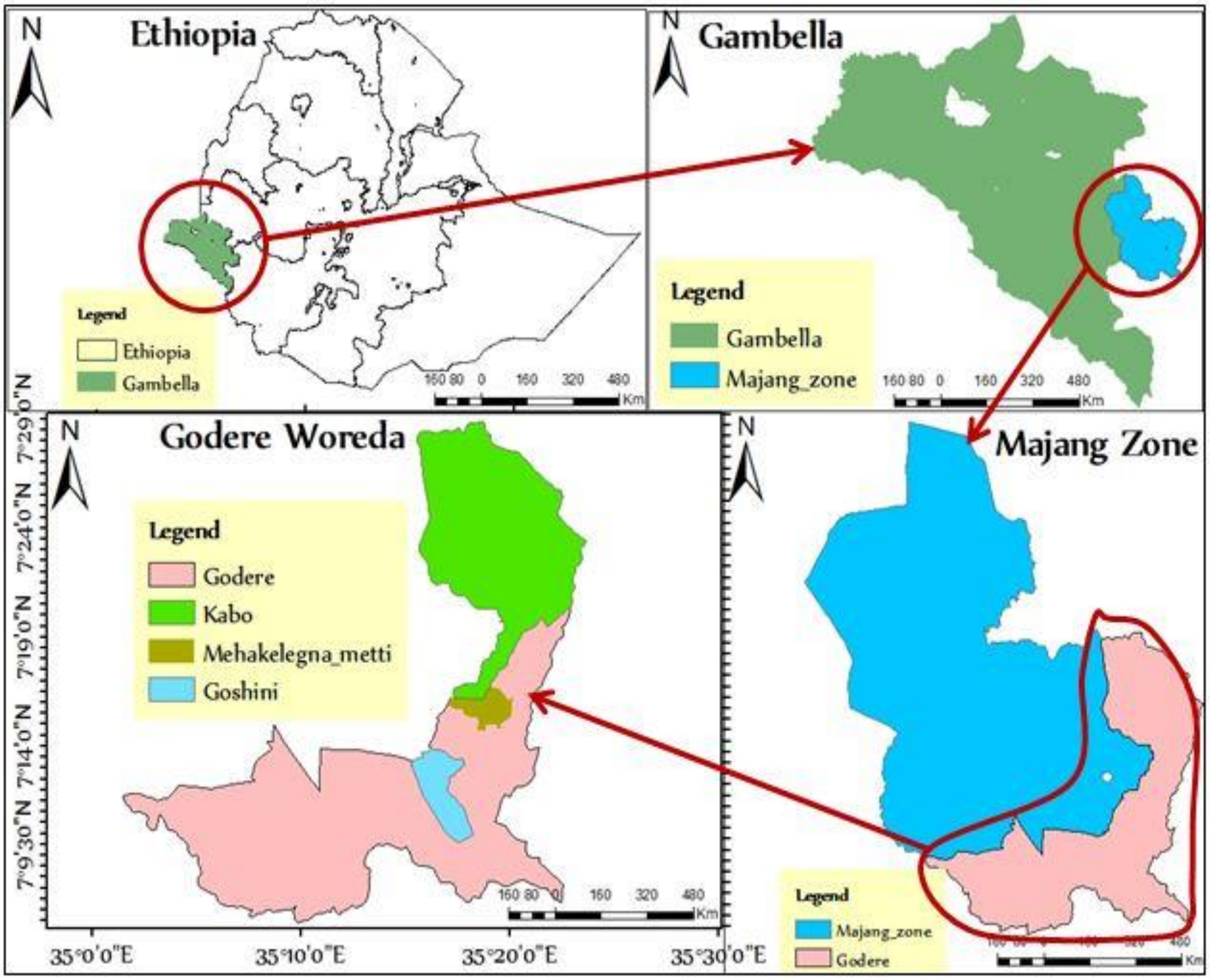

Figure 1. Map of the study area.
Source: CSA (2007).

Metti and Goshini were selected from upstream, midstream and downstream respectively.

Second, since it was very difficult to obtain secondary data on adoption, in each selected kebele snowball sampling technique was used to ensure that SWC practiced and non-practiced households were included in the survey. With this technique, all households in each selected kebele were considered as non-practiced (maintenance of status quo) and the first respondent was selected randomly by following the transect walk.

In order to determine the appropriate sample size for the study, a Kothari (2004) sample size determination formula was used. Kothari's sample size determination formula is explained here below. Zeiy watershed (study area) has 8,829 households from nine rural kebeles (Gambella Agriculture and Natural Resource Bureau, 2017) and considered as a study population. Meanwhile, from the total households of the watershed, three study kebeles namely Kabo, Mehakelegna Metti and Goshini constitute 2,943 total households.

By taking 10% as a proportion (p) of the target population with ninety 95% confidence interval (Z=1.96) and 5% acceptable error margin (e), a total sample size (n) for the study was calculated from the target population according to the Equation 1:

$$n = \frac{z^2 pqN}{e^2(N-1)+z^2 pq} \qquad (1)$$

Where, n= the minimum number of sample size within the range of acceptable error margin; N= the total number of households of the target population; z= confidence level (95% which is equivalent to 1.96); e= acceptable error margin (5%); p= proportion of sampled households; q= estimate of the proportion of households to be sample.

By substituting the above equation, a total sample size of one hundred thirty two (132) respondents was obtained. Using the above calculated sample size, another sub-sample which is proportional to the size of the minimum target population was also determined. For calculation of the sub-sample size refer to the Equation 2:

$$ni = \frac{\mathrm{Ni}}{\mathrm{N}}(\mathrm{n}) \qquad (2)$$

Where, ni= the required sample size from each selected *kebele*; N_i=Total number of households in each selected *kebele*; N= Total number of households in all selected *kebeles*; n = Total sample size from the target population.

By using the equation above, a sub-sample size was determined from each selected kebele. Accordingly, thirty four (34), forty four (44) and fifty four (54) respondent households were selected from Kabo, Mehakelegna metti and Goshini respectively for household based interview.

Data analysis

Independent sample t-test has been used in order to compare the means of data between two independent samples (practiced and non-practiced households). These samples are SWC practiced and non-practiced households. Frequencies tables were analyzed to know the proportion of each and every variable in the study. Descriptive statistics was performed for continuous variables. Cross-tabulation was also performed for categorical variables. Chi-square and student t-tests were used for categorical and continuous variables respectively in order to test the significant of the mean difference between two groups (SWC practiced and non-practiced). Pearson correlation and linear regression were used to test the relationships and effects among variables.

RESULTS AND DISCUSSION

Current state of soil and water conservation in Zeiy Watershed

According to Hurni et al. (2016), SWC measures are recommended to be implemented based on agro-ecology and land use type. All SWC measures are classified into physical, agronomic and vegetative type and their implementation is agro-ecological and land use type specific. Thus, based on Hurni et al. (2016) the study watershed could be classified as wet kolla agro-ecology (wet lowland) with its altitude ranges from 500-1000m above sea level (m.a.s.l) and average annual rainfall range of 1600-2100 mm (USAID, 2009).

The analysis result indicated that majority of respondent households in Mehakelegna metti (9%) and Kabo (11%) adopted integrated SWC measures which combine different physical, biological and agronomic measures whereas in Goshini (13%) most respondent households are largely practicing agronomic conservation measures.

Analysis result indicated that, out of 50% of households who practiced soil and water conservation measures, half (25%) of households adopted combination of different soil and water conservation measures. Field observation has indicated that households who practices conservation measures constructed contour soil bund and trenches in a field where coffee is intercropped with *Sesbania sesban* plant species in order to control runoff, reduce raindrop impact and diversification of crops while at least 4% of practiced households implemented land management practices such as zero tillage practices and application of organic fertilizer (Figure 2). Mixing of various conservation measures improve the effectiveness of the measures toward controlling soil erosion. For instant, key informant interview has shown that contour soil bunds stabilized with *vetiver grasses* are highly effective in controlling runoff. Reduction of runoff minimizes soil erosion risk which affects soil quality and thus reduces crop production. But with reduction of runoff by conservation structures, crop production should improve as a result. The remaining 50% are non-practiced households.

Income sources distribution

Rural income generating activities (RIGA, 2015) project on its survey across Ethiopia obtained that 51% share of household income is derived from crop production. This study result shows that 58% of the total households in the study watershed earned their income from the crop sales. If this % share of crop sales is disaggregated into kebeles, it become 12, 26 and 20% from Kabo, Mehakelegna metti and Goshini derived their income from crop marketing respectively. Income source is linked to livelihood strategy; therefore households who derived greater proportion of their income from crop production are more likely to engage in soil and water conservation in order to increase their agricultural production and consequently acquired their required income. Rural communities who pursue agriculture as source of their livelihood are highly probable to implement conservation measures in their farmlands as intensification of agriculture is the survival option and they should work hard to improve crops production.

Type of crop grown by SWC adoption classes

Analysis of result also revealed that 15% of households who practiced soil and water conservation measures grow different type of crop either in rotation or mixed in the same field. These include intercropping of *S. sesban* with coffee and mixing of maize with leguminous plant like soya bean. Growing of fruits such as mango, avocado, pineapple and banana in home garden is also common practice. However, majority of households who do not practice conservation largely grow food crops such as maize and sorghum in their fields. Type of crop grown by the household could influence the decision of the household to invest in soil and water conservation. For instant, households who grow cash crops are more likely to practice soil and water conservation measures because of their desire to increase the production of those crops grown for cash and improve household income. In addition, different crops have different adaption mechanism to their environment. Crops that are sensitive to soil degradation require improvement of soil quality which could push the household depending on those degradation sensitive crops to implement conservation measures in order to promote the production of those crops. Thus, crop varieties and type could influence households to adopt conservation measures.

Chi-square test result indicated that there is no

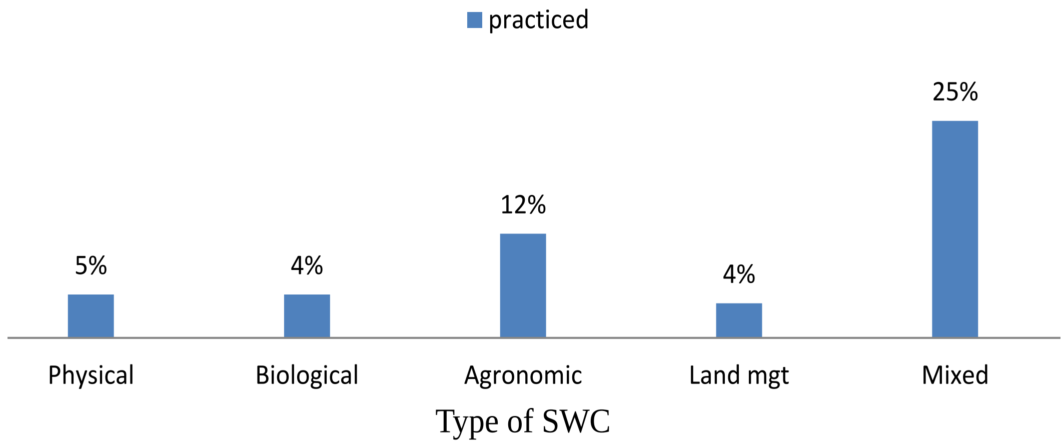

Figure 2. Types of SWC measures under practice in the study area.

significant difference (Pearson chi-square=0.044, p=0.834) between groups (practiced and non-practiced) regarding the type of crops grown by the households. This may be partly because non-practiced households also grow fruit crops like mango, avocado, pineapple and banana since both groups defend on rain fed farming practices because SWC measures practiced in the area were not implemented along with water harvesting technique which could have boosted the crops productivity and thus increase production per household for households who practiced soil and water conservation measures. In this study area, field observation and key informant interview indicated that coffee is grown by many households as a cash crop. In Figure 3 it can be observed that non-practiced households grow mainly food as source of food and cash. These food crops are mainly maize and sorghum which is grown by non-practiced households too. Thus, many crop types are commonly grow by both groups which could be an evident that both groups should not differ significant by crop type.

Impacts of soil and water conservation measures on crop yield

The analysis result indicated that the mean total crop yield for SWC practiced respondent households is higher (44.74quintal per hectare per household) than SWC non-practiced respondent households (23.29 quintal per hectare per household) with mean total crop yield difference equivalent to 21.5 quintal per hectare per household (Table 1).

The hypothesis that whether there is crop yield difference or not between SWC practiced and non-practiced households was tested with student t-test and the result indicated a highly significant difference ($p<0.05$) in mean total crop yield between SWC practiced and non-practiced households (Table 1). With this hypothesis test result, the null hypothesis that there is no crop yield difference between SWC practiced and non-practiced households could be rejected while the alternative hypothesis that there is crop yield difference between SWC practiced and non-practiced households could be accepted.

The relationship between SWC adoption and crop production per household was tested with Pearson correlation and linear regression. Analysis result revealed that there is positive and statistically significant relationship between SWC adoption and crop production with Pearson correlation equal to 0.414 and $p<0.05$. This relationship suggested that adoption of SWC may increase crop production. Field observation during the first round visit in dry season indicated that fields of practiced households have more crop residues that are deliberately left in the field as mulch than non-practiced households. The next round field visit in rainy season indicated that crops in the field of practiced households where mulch had been in crop field in dry season look greener than crop grow in previously burned fields. This may be an indication that SWC adoption improve soil quality and consequently increase crop production. The present of perennial crops such as banana, mango and avocado and other biological conservation measures like *vetiver* grass in the farms of practiced households protect their fields from both water and wind erosion and hold soil nutrient in place which is beneficial for crop production.

In general, different studies argued that crop yield is influenced by various factors including soil quality, crop varieties, climate, land management and topographic gradient.

However, factors like soil quality, land management and topographic gradient can be influenced by SWC measures such that organic matter accumulation from agronomic and biological SWC measures enhance soil quality while physical conservation are capable to alter topographic gradient and thus land management change

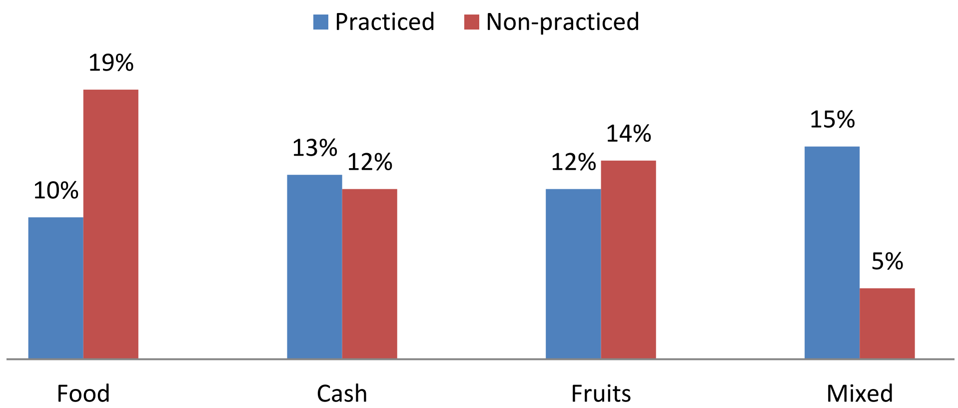

Figure 3. Type of crop and adoption of SWC practices.

Table 1. Mean crop yield for practiced and non-practiced households.

Parameter	Practiced	Non-Practiced	Mean difference	T-value	P-value
Total Average crop yield (Q/ha)	44.74	23.29	21.5	5.19	0.00(p<0.05)

afterwards. Regarding farm size of the two groups, analysis result revealed that practiced households have mean land holding size of 1.03 hectare per household while non-practiced households have 1.43 hectare per household. This indicated that non-practiced households have slightly larger farm size than practiced households. If farm size alone is a guarantee for crop yield, non-practiced households could have higher crop yield than practiced households. The soil type is mainly fertile fluvisols and deep well drained dystric nitosols of moderate fertility (Gambela Agriculture and Natural Resource Bureau, 2017).

Field observation indicated that the soil looks dark brownish and feel slightly gritty. This soil type and texture was considered the same for all households and then could not cause any yield different between groups. As reported by Demelash and Stahr (2010), Hailu (2017) and Gebregziabher et al. (2016) that soil and water conservation measures improved soil textures, reduce bulk density, increase infiltration rate, increase organic matter content and increase nutrient availability, thus in Zeiy watershed households who practiced soil and water conservation a field with improved soil fertility than non-practiced households. This could be another reason for increase in yield of those households who practiced soil and water conservation than non-practiced households. Other potential external factors like rainfall, temperature and humidity that could influence crop yield were considered to be constant. In addition, topographic influence is another influential factor that might affect crop yield. Households who practiced soil and water conservation practices constructed conservation measures which reduced slope length and gradient and then minimize the impact of runoff on top soil removal which contain many essential plant growth nutrients such nitrogen, phosphorous and potassium. Reduction of crop nutrient losses could in turn increase crop production. An effort by the government to increase the production of smallholder farmers might be another reason for improvement in crop production of smallholder farmers because it was reported that the contribution of crop sub-sector to country‘s GDP was 27.4% at the end of GTPI (GTPII, 2016).

In line with this finding, Abebe (2015) found an improvement in crop yield of adopter households as compared to non-adopter in Adwa and Amba Alagie district in Tigray region. Yenealem (2013) also indicated that there is additional crop production value equal to 1,510.42 birr for adopter households than non-adopter in west Harareghe, Oromia region. Another finding from Hadush (2015) revealed that crop production increase to 0.673ton/ha in smallholder farms who adopted SWC measures in Adwa district, Tigray region. According to Benin (2006), stone terraces had significant positive impacts (42%) increase on average crop yields for lower-rainfall parts of the Amhara region. In addition, Pender and Gebremedhin (2006) indicated higher crop yields from plots with stone terraces (an average yield increase of 23%). Another study conducted by Tugizimana (2015) in Nyamasheke District, Rwanda has shown that SWC measure has significantly improved a bean yield. According to Menale (2007), there was high positive additional mean crop production value of 412 ETB as a result of SWC measures adoption in low rainfall area of

Tigray.

In contrary, different experimental and survey results indicated that SWC measures reduce crop yields in high rainfall area or because of medium to long term benefits of the practices. For instance, Kassie and Holden (2006) reported that physical conservation measures (*Fanya juu*) resulted in lower yield in a high rainfall area of the Ethiopian highlands in western Amhara region. Menale et al. (2007) reported low crop yields in the fields with conservation structures and insignificant mean crop production value in high rainfall area of Amhara region and the finding was supported by Baptista et al. (2015) who reported crop yield decline in the fields with SWC practices in the high rainfall watershed of Ribeira Seca Watershed, cape verde. From this scientific argument, it is rational to conclude that rainfall distribution greatly influences the value of soil and water conservation measures and the associated crop yields whereby high value of crop yield as a result of soil and water conservation is obtained in low rainfall areas and vice versa.

Impacts of soil and water conservation measures on household income

The analysis result indicates that the mean total households income per year for practiced households is relatively higher (3,282.58ETB per household) than non-practiced households (2,661.97ETB per household) with mean income difference equivalent to 620.6ETB (Table 4). The hypothesis that whether there is income level difference or not between SWC practiced and non-practiced households was tested with student t-test and the result indicated a non-significant difference ($p>0.05$) in mean total income between SWC practiced and non-practiced households (Table 2). Analysis result in Table 2 below also depicted that there is income level difference between two groups of households (SWC practiced and non-practiced) though the difference is not statistically significant. Thus, the null hypothesis that there is no income level difference between SWC practiced and non-practiced households could be rejected while the alternative hypothesis that there is income level difference between SWC practiced and non-practiced households could be accepted.

The relationship between SWC adoption and household income was tested with Pearson correlation and linear regression. Analysis result indicated that there is positive but statistically non-significant relationship between SWC adoption and household income with Pearson correlation equal to 0.09 and $p>0.05$. This relationship suggested that adoption of SWC may improve household income of practiced farmers than non-practiced households. In addition, adoptions of SWC measures affect household income positively due to small increase in household income of practiced household. The income difference between the two groups is statistically non-significant due to the fact that non-practiced households engage in other income generating activities (off-farm) such as self-employment and hired labour in agricultural and non-agricultural labour. These income generating activities supplement their limited income they earn from crop production. Key informant interview explained that some household members engage in coffee production and bee keeping enterprises in the form of hired labour and earn some money for their livelihood. Moreover, SWC measures may increase income level of the households who practiced conservation measures because these conservation practices have reduced soil erosion and consequently improve soil quality which creates a better medium for crops growth. Key informant interview indicated that implementation of SWC practices improve fodder availability which provide high nutritious feed for livestock and thus sales of livestock and their products increase the amount of income earned by the household. Field observation also show that SWC practiced households diversify their crops which increase timing of crop harvest and consequently increase the spatial availability of crop products. This increases the products to be sold and boost income of households.

Despite positive mean difference which show an additional income to households who practiced soil and water conservation than non-practiced households, independent sample t-test result indicated that there is no significant difference between practiced and non-practiced respondent household in term of total income (t1.03, $p= 0.31$, Table 2 above). The rationale behind lack of significant income difference between households who adopted SWC measures and those who did not adopt might be because of the fact that the two groups engage in alternative income generating activities. For instant, non-practiced households engaged in off/non-farm activities and both groups are involved in the collection of wild fruits/roots. These additional sources of income should reinforce the income from crop production and thus give an alternative source of income. In addition, households who engage largely on crop production by improving the land productivity through soil and water conservation measures incurred opportunity cost for other income generating activities leading to reduction of income level from other sources and thus the mean income difference for two groups should not be possibly significant. However, this is not an indication that the two groups could have similar income instead slight variation in the mean income level of the households who adopted and those who do not adopted conservation measures. With households who adopted having relatively higher income than those who not adopted the soil and water conservation measures in their farmlands.

This finding is in line with the study conducted by Abebe (2015) in Adwa and Amba alajie, Tigray Regional state which indicated that adopter households had relatively better income compare to non-adopter

Table 2. Mean annual income for practiced and non-practiced households.

Parameter	Practiced	Non-practiced	Mean difference	T-value	P-value
Total mean annual income per household (ETB)	3282.58	2661.97	620.6	1.03	0.31(p>0.05)

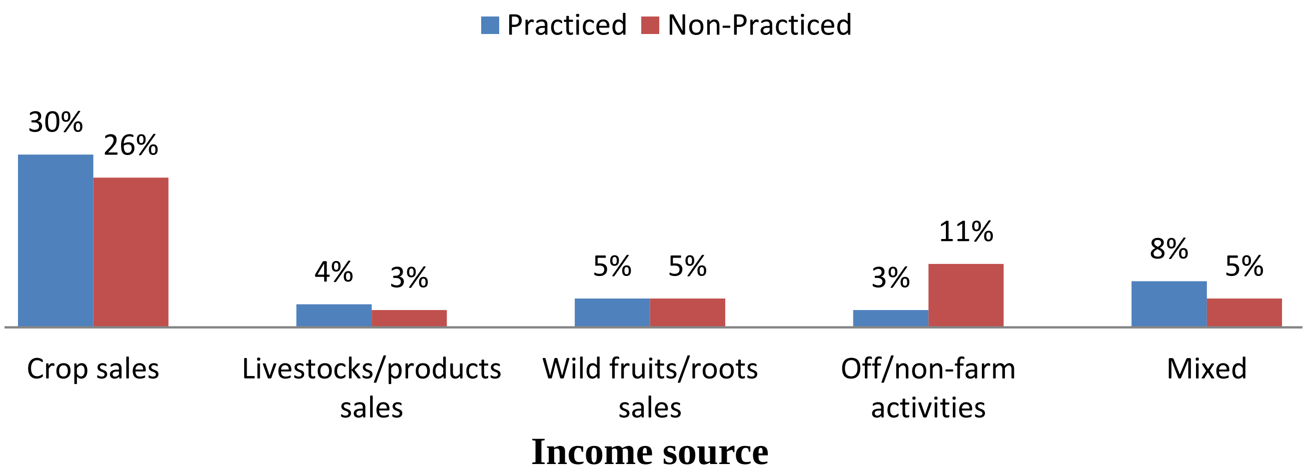

Figure 4. Income source and adoption of SWC practices.

households. In addition, Yenealem (2013) found that gross annual income of households who implemented SWC measures increase to 4,288.29 ETB than non-adopter households in west Harareghe, Oromia region. However, another study by Yitayal and Adam (2014) in Adama district of Oromia region found that SWC practices resulted in less significant positive impact on gross household income because of short duration of the practices. Moreover, a study conducted by Meaza (2015) in Adwa district, Tigray region indicated that the total average household income increase from 3990ETB to 7313.5ETB after adoption of SWC practices. These are the empirical findings which indicate the financial implication of SWC measures adoption at the household level across the country.

In addition, summary statistics analysis result revealed that majority of practiced respondent households (30%) derived much of their income from crops marketing and at the same time largest proportion of non-practiced respondent households (26%) also earn most of their income from the sales of crop products (Figure 4).

This agrees with the study of Abebe (2015) which has shown that majority of households in Amba Alajie and Adwa depends on crop production as a dominant source of their livelihood. This shows high dependency of Ethiopian rural farmers on crops farming practices. SWC practiced respondent households also derive some of their income from combination of different income sources followed by income earned from wild fruits/roots collected from nearby forest and small proportion of income from the sales of livestock and livestock products. The variation of income sources within practiced respondent households is not significant while it is true within non-practiced respondent households. This large variation within non-practiced respondent households as well as between practiced and non-practiced respondent households resulted in significant difference of income sources between two groups (practiced and non-practiced) ($p<0.05$). Similarly, the major source of income in Bokole and Toni sub-watershed was reported to be crop production which indicated that households could engage in soil and water conservation in order to boost crop productivity (Kebede and Mesele, 2014).

Effects of soil and water conservation on rehabilitating farm land

This study focused mainly on labour and fertilizer use for farm production by households. Data on farm labour requirement and the use of fertilizer by individual farmers were collected at household level and analyzed. The analysis results are presented below.

Labour

Analysis result in Table 3 indicates that SWC practiced

Table 3. Adoption of SWC and its impact on labour.

Parameter	Practiced	Non-Practiced	Mean difference	t-value	P-value
HH labour (persons/HH)	4.00	2.00	-1.91	-11.74	0.001
Hired labour (persons/HH)	2.00	0.35	-1.65	-9.60	0.0002

(HH)-household, (t)-student test and (p)-is probability value

households use higher labour force (both household and hired labour) than non-practiced households. The labour requirement (household and hired) difference between groups is statistically significant with t-value equal to -11.74 ($p<0.05$) for household labour and -9.6 ($p<0.05$) for hired labour.

The relationship between soil and water conservation adoption and labour requirement (household and hired) was tested with Pearson correlation and the result indicated that there is positive and statistically significant relationship between two variables with Pearson correlation and p-value equal to (0.717** and $p<0.05$) and (0.644** and $p<0.05$) for household and hired labour respectively where (**) indicate that correlation is statistically significant at 0.01 level of significant. The impact of soil and water conservation adoption on labour demand (household and hired) was also tested with linear regression and result revealed that there is statistically significant positive impact on labour (household and hired) with standardized coefficient of beta (β) similar to Pearson correlation for both household and hired labour.

From the analysis results, SWC practiced households were found to require more labour (household and hired) than non-practiced households. This is mainly because investment in SWC practice is accompanied by construction and maintenance of physical SWC, planting of vegetative and agronomic measures as well as harvesting of crops which require man power. The positive correlation between SWC adoption and labour demand indicates that as household decide to adopt soil and water conservation, they could ensure the present of family members that are capable for farm work or else they could hired additional people to execute their farm activities. This association between SWC adoption and labour demand may favor some households especially those with medium to high family size and income as well as households characterized by large proportion of active age groups so that individuals are available for farm work but it is at the same time a threat to small sized and low income households since they are unable to offer man power or even cannot afford to hired additional labour for their farm activities.

According to study conducted in Uganda by Boyd et al. (2000), it was reported that 54% of studied households supplemented their household labour with hired labour while 60% of households engage in labour-sharing arrangement because of the high labour demand of SWC measures. However, the same study by Boyd et al. (2000) in Tanzania indicated that there was no clear indication about the relationship between labour availability and decision to invest in SWC measure merely because of long term nature of the investment in conservation measures. According to study conducted by Teshome (2013) in Anjeni and Debre Mewi watersheds, construction of soil bunds and fanya juu require 150 persons/day/ha in Anjeni and 75 persons/day/ha for soil bunds construction in Debre Mewi watershed and stone bunds construction require 125 persons/day/ha in both watersheds.

This labour requirement is far higher than the labour requirement in this study area mainly because in this study area majority of households adopted mixed SWC measures where physical conservation measures are combined with agronomic and biological measures in the same field. Additional reason may be because this study emphasized SWC measures in croplands only and average farm size may be lower than mean farm size studied in Anjeni and Debre Mewi watersheds. These findings indicated how intensive SWC labour requirement is and its challenge to small size and economically inactive households. In this study area, households use both household members and some households supplement it with hired labour in order to accomplish farm activities.

Fertilizers

Analysis result in (Table 4) indicated that SWC non-practiced households use much amount of inorganic fertilizer such as DAP (62.92 kg/ha) and Urea (53.56 kg/ha) than practiced households. Hypothesis that whether there is statistically significant difference between practiced and non-practiced households in term of fertilizer use or not was tested with t-test and result indicated that there is statistical significant difference between two groups in the use of DAP and Urea (Table 4) below show t-value and probability value.

In addition, relationship between soil and water conservation adoption and fertilizer use was tested with Pearson correlation and the result indicated that there is negative and statistically significant relationship between two variables with Pearson correlation and p-value equal to (-0.637** and $p<0.05$) and (-0.662** and $p<0.05$) for DAP and Urea respectively where (**) indicate that

Table 4. Adoption of SWC and its impact on fertilizer use.

Parameter	Practiced	Non-Practiced	Mean difference	t-value	P-value
DAP (kg/ha)	30.8939	62.9242	32.03030	9.416	0.002
Urea (kg/ha)	22.2727	53.5606	31.28788	10.066	0.001

Table 5. Adoption of SWC and manure/compost use.

Parameter	Whether household apply manure/compost or not.			
	Yes		No	
	N	%	n	%
Practiced	51	38.6	15	11.4
Non-practiced	20	15.2	46	34.8

(n)-is number of respondent and (%)- is percent of respondent Pearson chi-square (29.289), p-value<0.05.

correlation is statistically significant at 0.01 level of significant. The impact of soil and water conservation adoption on fertilizer use was also tested with linear regression and result revealed that soil and water conservation adoption negatively and significantly affect level of fertilizer use with the same standardized coefficient of beta (β) to Pearson correlation for both DAP and Urea fertilizer.

The impact of soil and water conservation adoption was also assessed with the hypothesis whether there is significant different between soil and water conservation practiced and non-practiced households in term of organic fertilizer (manure/compost) use. Respondent households were asked whether they apply manure/ compost on their plots or not and result indicated that majority of practiced household (38.6%) apply manure/ compost on their farm than non-practiced households (15.2%) (Table 5). Pearson chi-square indicated that there is statistically significant difference between practiced and non-practiced households in term of the use of manure/compost with Pearson chi-square (29.289) and probability value ($p<0.05$).

As per analysis results, SWC practiced households use lesser amount of inorganic fertilizer (DAP and UREA) than non-practiced households. This might be due to the fact that, the amount of fertilizer applied by the individual household is determined by factors like precedence soil fertility, type of crop and amount of available income to purchase fertilizer. SWC measures not only improve soil fertility through addition of organic matters on soil and increase in crop yield but also improve income and shift of crop type through either crop rotation or switching from annual to perennial crops. With adoption of SWC measure, it is expected that soil fertility might improve and thus soil nutrient should be available in soil profile. This availability of soil nutrient should reduce crop nutrient requirement and therefore application of additional nutrient in the form of fertilizer in order to supplement crop nutrient demand decline afterward.

In addition, the negative relationship between SWC and the level of fertilizer application indicates that as households adopt SWC measure, soil fertility might be improved through addition of organic matters by crop residues and direct fixation of other nutrients such as nitrogen by leguminous plants. This improvement in soil quality by SWC practices might lead to reduction in the amount of fertilizer applied by households. Moreover, Table 5 above indicated that households who practiced SWC measure mainly applied manure/compost than non-practiced. This is partly because practiced households mainly grow fruits and cash crops while non-practiced households primarily grow annual crops such as cereals which require too much fertilizer particularly inorganic type of fertilizer.

Demelash and Stahr (2010) have reported statistically significant difference between conserved and non-conserved farmlands in term of soil organic matter content, total nitrogen and available phosphorus of which conserved farmlands have higher soil organic matter content, total nitrogen and available phosphorus than non-conserved farmlands due to the fact that SWC measures increase accumulation of organic matter on soil surface, nitrogen fixing plants integrated with SWC measures fix nitrogen into the soil and increase nitrogen content while increased organic matter increase available phosphorous in the soil.

In addition, a study conducted by Hishe et al. (2017) found statistically significant difference between conserved and non-conserved farmlands in term of soil organic matter where higher mean organic matter content was recorded in conserved farmland than in non-conserved fields. Another study carried out by Hailu (2017) reported that there was significant different between conserved and non-conserved plots in term of soil organic carbon content, total nitrogen and available phosphorous of which conserved plots have relatively higher soil organic carbon, total nitrogen and available phosphorus than non-conserved plots due to accumulation of organic matters and presence of leguminous plants in conserved plots.

These findings suggested that adoption of SWC measures may improve availability of soil nutrients which in turn reduce crop nutrient requirement and application of additional fertilizer as well. According to Sawyer (2013) cereals growers were identified to apply lesser amount of manure/compost in their farmlands than other farmers but applied higher amount of inorganic fertilizer such as DAP and UREA. Sawyer (2013) also reported that fertilizer application rate vary among crop types. For instant, it range between 50-100 kg/ha for maize, 6 kg/ha for sorghum, more than 45 kg/ha for Potatoes, onions, and other vegetables and below 10 kg/ha for banana, coffee, and other perennial crops. These study results indicated that type of crop may determine the amount and type of fertilizer to be applied to the fields. In this study area most non-practiced households grow cereals such as maize and sorghum and thus require higher amount of inorganic fertilizer such as DAP and UREA in order to meet nutrient requirement of these crop type but majority of SWC practiced households grow mixed crop type mainly fruits and cash crops with low nutrient requirement and thus require low amount of fertilizer to be applied onto their farmlands.

Conclusion

In order to fill the gap, impacts of SWC on crop production, household income and level of input use has been conducted in Zeiy watershed, Gambella region. Three hypotheses have guided the survey. These hypotheses include whether there could be significant difference between SWC practiced and non-practiced households in term of crop production, household income and level of input use. As a result, the survey analysis results have indicated that there is statistically significant difference between SWC practiced and non-practiced households in term of crop production, labour demand (household and hired) and fertilizer (inorganic and organic) use. However, statistically non-significant mean difference between SWC practiced and non-practiced households has been obtained in term of household income. Despite positive and statistically significant relationship obtained between SWC adoption and crop production, labour demand (household and hired) and use of organic fertilizer, household income has shown positive but non-significant relationship while inorganic fertilizer level has shown negative and significant relationship. With these findings, it is rational to conclude that SWC measures have positive impact on crop production, contribute slightly to household income, increase labour demand (household and hired), decrease level of inorganic fertilizer use and increase use of organic fertilizer.

Adoption of SWC measures must be combined with activities that generate other income in order to supplement farm income. Other income generating activities like beekeeping and promotion of high value cash crops. Some households may need to implement SWC measures but lacks of capability preclude them. These include shortage of labour, low income to hire additional labour and so on. Availability of extension services could help to identify those households and thus concerned office like Agriculture and Natural Resource Bureau should work in close collaboration with such households.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGMENTS

We would like to acknowledge the Arba Minch University for funding this study. We would also like to thank all respondent households for their valuable contribution.

REFERENCES

Adimassu Z (2012). Effect of soil bunds on runoff, soil and nutrient losses and crop yield in the Central Highlands of Ethiopia. Resource Management Papers No.76., Wageningen,the Netherlands.

Baptista I, Fleskens L, Ritsema C, Querido A, Tavares J, Ferreira A, Reis E, Gomes S, Varela A (2015). Soil and Water Conservation Strategies in Cape Verde (Cabo Verde in Portuguese) and Their Impacts on Livelihoods:An Overview from the Ribeira Seca Watershed. Land 4(1):22-44.

Boyd C, Turton C, Hatibu N, Mahoo HF, Lazaro E, Rwehumbiza FB, Okubal P, Makumbi M (2000). The contribution of soil and water conservation to sustainable livelihoods in semi-arid areas of sub-Saharan Africa. The contribution of soil and water conservation to sustainable livelihoods in semi-arid areas of sub-Saharan Africa (102).

Central Statistical Agency (CSA) (2007). Central Statistical Agency (CSA), Population and Housing Census of Ethiopia, Administrative Report. Addis Ababa: CSA.

Demelash M Stahr K (2010). Assessment of integrated soil and water conservation measures on key soil properties in South Gonder, North-Western Highlands of Ethiopia. Journal of Soil Science and Environmental Management 1(7):164-176.

Gebregziabher G, Abera DA, Gebresamuel G, Giordano M, Langan S (2016). An Assessment of Integrated Watershed Management in Ethiopia. Colombo, Sri Lanka: International Water Management Institute (IWMI). 28 p. (IWMI Working Paper 170).

Growth and Transformation Plan (GTPII) (2016). Federal Democratic Republic of Ethiopia: Growth and Transformation Plan. Addis Ababa, Ethiopia: National Planning Commission.

Hadush M (2015). The Role of Community Based Watershed Management for Rural Livelihood in Wereda Adwa, Central Tigray Zone. International Journal of Weather, Climate Change and Conservation Research 2(1):22-46.

Hailu W (2017). Impact of Physical Soil and Water Conservation Structure on Selected Soil Physicochemical Properties in Gondar Zuriya Woreda. Resources and Environment 7(2):40-48.

Hishe S, Lyimo J, Bewket W (2017). Soil and water conservation effects on soil properties in the Middle Silluh Valley,northern Ethiopia. International Soi land WaterConservation Research 5:231-240.

Hurni H, Berhe WA, Chadhokar P, Daniel D, Gete Z, Grunder M, Kassaye G (2016). Soil and Water Conservation in Ethiopia: Guidelines for Development Agents. Second revised edition. Bern, Switzerland: Centre for Development and Environment (CDE), University of Bern; with Bern Open Publishing (BOP).

Kassie M, Köhlin G, Bluffstone R, Holden S (2011). Are soil conservation technologies ''win–win?'' A case study of Anjeni in the northwestern Ethiopian highlands. Natural Resources Forum 35(2):89-99.

Kebede W, Mesele N (2014). Farmers' Adoption of Soil and Water Conservation Technology: A Case Study of The Bokole and Toni Sub-Watersheds, Southern Ethiopia. Journal of Science and Development 2:1.

Kothari CR (2004). Research Methodolgy: methods and techniques. New Delhi, India: New Age International.

Lakew D, Volli C, Asrat W, Yitayew A (2005). Community-based Participatory Watershed Development:A Guideline. (1st ed.). Addis Ababa: Federal Democratic Republic of Ethiopia.

Menale K, Jean P (2007). Impact of Soil Conservation on Crop Production in the Northern Ethiopian Highlands. International Food Policy Research Institute.

Ministry of Agriculture (MoA) (2013). Sustainable Land Management Projectphase - II. Final Social Assessment Report. Addis Ababa, Ethiopia.

Rural Income Generating Activities (RIGA) (2015). Components of Income Aggregate: "2011-12 Ethiopian Rural Socioeconomic Survey, Prepared for the Rural Income Generating Activities (RIGA) Project, of the Agricultural Development Economics Division, Food and Agriculture Organization. FAO.

Sawyer N (2013). Agricultural production in Ethiopia: Results of the 2012 ATA Baseline Survey. International Food Policy Research Institute, Research for Ethiopia Agriculture Policy (REAP), Washington, DC.

Teshome A (2013). Financial Viability of Soil and Water conservation Technologies in North western Ethiopian highlands. Applied Geography P 37.

Tugizimana J (2015). Effects of soil and water conservation techniques on soil productivity and bean grain yield in Nyamasheke District, Rwanda. A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science (Land and Water Management) in the School of Agriculture and Enterprise Development, Kenyatta University.

United Nation Development Program (UNDP) (2016). Agricultural Growth and Transformation:Strengthening National Capacity through Sustainable Increases in Agricultural Production and Productivity.

United State Agency for International Development (USAID) (2009). Gambella, Coffee, Honey and Cereal (GCH) LZ. Gambella Region, Ethiopia.

Wikepedia (2017). Godere (woreda). Retrieved December 22, 2017, from https://en.wikipedia.org/wiki/Godere (woreda)

Yenealem K, Fekadu B, Jema H, Belaineh L (2013). Impact of Integrated Soil and Water Conservation Program on Crop Production and Income in West Harerghe Zone, Ethiopia. International Journal of Environmental Monitoring and Analysis 1(4):111-120.

Yitayal A, Adam B (2014). The Impact of Soil and Water Conservation Program on the Income and Productivity of Farm Households in Adama District, Ethiopia Science, Technology and Arts Research Journal 3(3):198-203.

Vol. 13(6), pp. 253-259, June 2019
DOI: 10.5897/AJEST2019.2693
Article Number: 8B54A3360952
ISSN: 1996-0786

http://www.academicjournals.org/AJEST

ACADEMIC JOURNALS
expand your knowledge

African Journal of Environmental Science and Technology

Full Length Research Paper

Assessment of heavy metals [As, Cu, Zn] from boreholes in the Western Region of Ghana

Nkuah M. and Agbemafle R.*

College of Agriculture and Natural Sciences, School of Physical Sciences, University of Cape Coast, Ghana.

Received 13 April, 2019; Accepted 3 May, 2019

Ground water is the source of drinking water for many people around the world, especially in rural areas. A lot of parameters such as the concentrations of Arsenic, Copper, Zinc and other heavy metals in conjunction with other physico-chemical properties contribute to the suitability of water for drinking and for other purposes. This study was carried out in the Bibiani-Anhwiaso-Bekwai District of the Western region of Ghana to assess the presence and the levels of selected heavy metals (As, Cu, Zn) pollution of boreholes from different villages in the study areas using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). The result of the study revealed that, the mean concentrations of As, Cu and Zn in the analyzed samples were 0.00143, 0.0186 and 0.0329 mg/L, respectively. The analysis of variance showed that there were significant differences in the Arsenic concentrations among the eight boreholes (F=4.078, P=0.033). However, the differences in the concentrations of Copper (F=1.592, P=0.264) and Zinc (F=0.741, P=0.647) from the eight boreholes were not significant. Concentrations of the selected heavy metals in analysed water samples were below the acceptable limits of World Health Organization (WHO) and Ghana Environmental Protection Agency (GEPA). The concentration of the selected heavy metals may be attributed to the activities of panners, improper disposal of sewage and solid materials containing toxic chemicals and the indiscriminate use of farming inputs such as fertilizers and pesticides which have impacted on the water quality of the selected boreholes in the study areas. Although the levels of the selected heavy metals in these water samples did not exceed WHO and GEPA permissible limits, it is necessary for residents in the study areas to be provided with potable water.

Key words: Ground water, heavy metals, Arsenic, Copper, Zinc.

INTRODUCTION

Heavy metals are unique among pollutants that cause adverse health effects in that they occur naturally and, in many instances, are ubiquitous in the environment. Regardless of how metals are used in consumer products or industrial processes, some level of human exposure is, in most instances, inevitable. Furthermore, many are biologically essential but become toxic with increasing dosage. Metals are an important emerging class of human carcinogens. Several more metals and their compounds are suspected to have carcinogenic potential in humans (IARC, 1980). The toxic heavy metals entering the ecosystem may lead to geo-accumulation,

*Corresponding author. E-mail: ragbemafle@ucc.edu.gh.

bioaccumulation and biomagnifications. Heavy metals like Fe, Cu, Zn, Ni and other trace elements are important for proper functioning of biological systems and their deficiency or excess could lead to a number of disorders. Food chain contamination by heavy metals has become a burning issue in recent years because of their potential accumulation in bio-systems through contaminated water, soil and air. Therefore, a better understanding of heavy metal sources, their accumulation in the soil and the effect of their presence in water and soil on plant systems seem to be particularly important issues of present-day research on risk assessments (Lokeshwari and Chandrappa, 2006). Gold mining in recent times has become unpopular as it is regarded as a significant source of Hg, Pb and heavy metal contamination of the environment owing to activities such as mineral exploitation, ore transportation, smelting and refinery, disposal of the tailing and waste waters around mines (Essumang et al., 2007; Hanson et al., 2007; Obiri, 2007; Singh et al., 2007). In the Bibiani-Anhwiaso-Bekwai District, the major economic activities have developed around important resources like gold, bauxite, food and cash crops which in effect has necessitated the emergence of service rendering industries. The district is one of the leading producers of cocoa in the region and has the highest concentration of bauxite, which is still being actively mined. These resources and industries have attracted migrants in search of jobs in the district, including gold and bauxite mining**.** The gold and bauxite mining work is conducted all over the district and during raining season the metals and other contaminates present in mines enter into the surface and ground water by leaching or by the overflow of water from mines. In artisanal and small-scale mining, it is a common practice for waste material to be removed and piled in large mounds at the mining site. These piles of tailings often contain heavy metals found in the ore and in many instances also contain mercury waste that was used during the amalgamation of gold (Cobbina et al., 2015). In such instances, these tailings are exposed to the elements and can be easily weathered, releasing toxic metals into the soil, adjacent water bodies and ultimately groundwater. Although the small-scale mining is a lucrative business, the practice is a dangerous activity as heavy metals are released to the environment (Aryee et al., 2003). However, once mining has taken place, the minerals are broken down due to exposure to oxygen and water. The toxicity level of a few heavy metals can be just above the background concentrations that are being present naturally in the environment [Fatah, 2008]. Hence thorough knowledge of heavy metals is rather important for allowing providing proper defensive measures against their excessive contact. Therefore, it is necessary to monitor these selected heavy metals of the selected boreholes from different villages of the district for safety assessments of the environment and human health. The aim of this study is to assess the selected heavy metals (As, Cu, Zn) pollution of boreholes from different villages in the Bibiani-Anhwiaso-Bekwai District of the Western Region of Ghana.

MATERIALS AND METHODS

The Bibiani-Anhwiaso-Bekwai District is located in the North-eastern part of the Western region. It covers an area of 873 km^2 representing 8.6% of the total land area of the region. Bibiani, the district capital is 88 km from Kumasi in the Ashanti region and 356 km from the regional capital, Sekondi. Bibiani-Anhwiaso-Bekwai District is located between latitude 6^0 3” N and longitude 2^0 3” W. The district is bounded on the north by the Atwima Mponua District in the Ashanti region, south by the Wassa Amenfi in the Western region, west by the Sefwi-Wiawso district in the Western region and east by the Denkyira North and Amansie East in the Central region and Ashanti region respectively (Figure 1).

The lowest and highest points in the district are 350 and 660 m above sea level. The district is also located in the equatorial climate zone with annual rainfall averages between 1200 and 1500 mm. The pattern of rainfall is bimodal, falling between March-August and September to October. Humidity is relatively high averaging between 75% in the afternoon and 95% in the nights and early mornings (Fatah, 2008).

Experimental procedure

750 ml of water sample was collected from each borehole two times for a period of two months from villages in the Bibiani-Anhwiaso-Bekwai District of the Western Region. Samples were collected from one borehole each located at Akaaso, Kwawkrom, Subri and Surano. Samples were also taken from two boreholes each from Chirano and Anyinase because these villages are more populated and therefore have more boreholes than the other villages. A total of eight water samples were collected during each visit. Samples were collected from May to June 2017. During the sample collection at the sites, each pre-cleaned plastic bottle was thoroughly rinsed with water from that particular borehole and a reasonable amount of the water was pumped out before they were collected. All collected samples were placed in an ice chest before they were transported to the Environmental, Health and Safety Laboratory of SGS Laboratory Services Ghana Limited Tema, for analysis. Each sample was thoroughly mixed by shaking and 50 ml transferred into a Griffin beaker. 1 ml of 1:1 HNO_3 and 1 ml of 1:1 HCl were added to the Griffin beaker containing 50 ml of de-ionised water. The Griffin beaker with its content was then placed in a heat block and the temperature adjusted to 95^0C to provide evaporation for two and a half hours. The digested sample was cooled and topped up to the 50 ml mark with de-ionised water ready for analysis using ICP-MS (Agilent 7900 model). A blank prepared from de-ionised water as well as the standard reference solution for each parameter was used to calibrate the instrument. The instrument was adjusted until the acceptable calibration was achieved. Once the required calibration was achieved, the samples were run to determine the concentration of the metals (As, Cu, Zn) in the sample.

RESULTS AND DISCUSSION

Heavy metal concentrations in borehole water

The total levels of As, Cu and Zn in borehole water sampled from the Bibiani-Anhwiaso-Bekwai District are

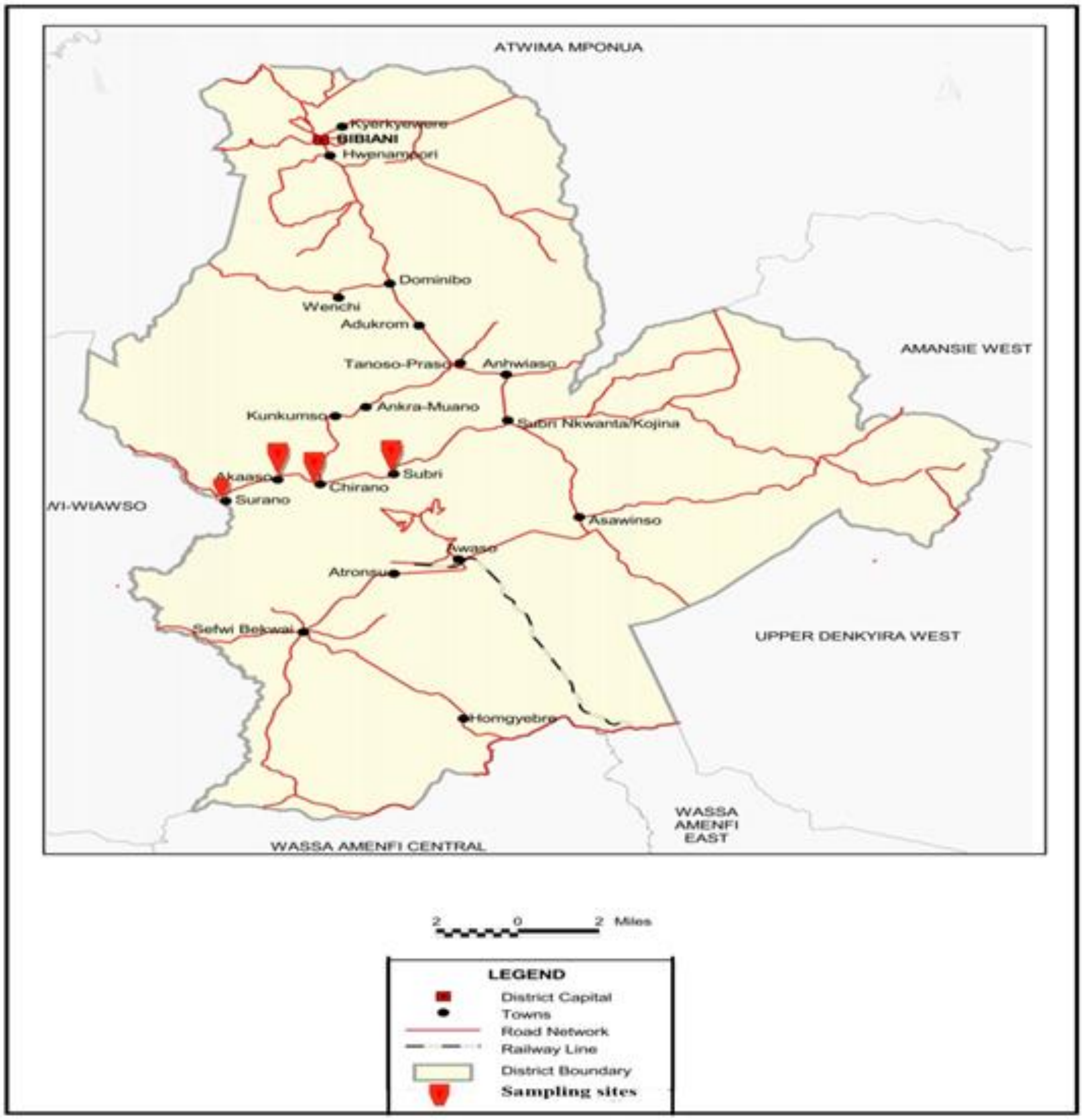

Figure 1. Map of the study area showing the various communities.
Source: http://www.bab.ghanadistricts.gov.gh) (Fatah, 2008).

shown in Table 1. The minimum and maximum levels of As in the borehole water was <0.0005 and 0.0046 mg/L respectively with mean total of 0.00143 mg/L. The mean As concentrations in the borehole water were below the WHO and GEPA permissible limits of 0.01 and 1.0 mg/L respectively. The mean total of Cu concentration in the borehole water was 0.0186 mg/L with minimum and maximum levels of 0.002 and 0.125 mg/L respectively. The mean Cu concentrations in the borehole water were below the WHO permissible limits of 2.0 mg/L. From Table 1 the minimum level of Zn recorded was 0.01 mg/L and maximum of 0.10 mg/L with total mean of 0.0329 mg/L. This was however lower than the WHO and GEPA permissible limits of 3.0 and 10.0 mg/L respectively. In artisanal and small-scale mining, it is common practice for waste material to be removed and piled in large mounds at the mining site. These piles of tailings often contain heavy metals found in the ore and in many instances, also contain mercury waste that was used during the amalgamation of gold (Cobbina et al., 2015). In such instances, these tailings are exposed to the elements and can be easily weathered, releasing toxic metals into the soil, adjacent water bodies and ultimately groundwater. Although the small-scale mining is a lucrative business, the practice is a dangerous activity as heavy metals are released to the environment (Aryee et al., 2003). This study considered As, Cu and Zn contamination of borehole water sampled from the Bibiani-Anhwiaso-Bekwai District in the Western Region of Ghana.

Table 1. Levels of As, Cu and Zn in borehole water in comparison with Ghana Environmental Protection Agency (GEPA) and World Health Organization (WHO) permissible levels of heavy metals concentrations.

Parameter (mg/L)	Minimum	Maximum	Mean ± SE	WHO maximum permissible limits	GEPA permissible limits
Arsenic	<0.0005	0.0046	0.00143 ± 0.0004	0.01	1.0
Copper	0.002	0.125	0.0186 ± 0.0081	2.0	5.0
Zinc	0.01	0.100	0.0329 ± 0.0060	3.0	10.0

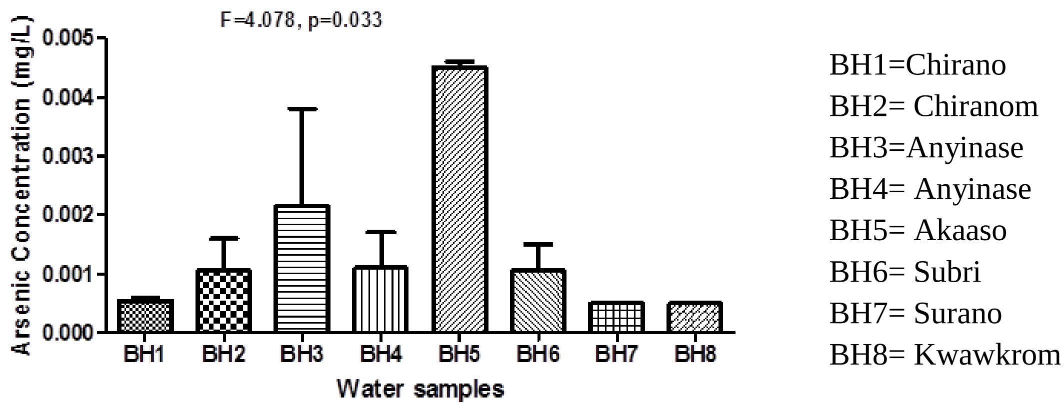

Figure 2. As concentrations in sampled borehole water.

As concentrations in borehole water

Figure 2 shows the level of As in some sampled borehole water. The mean As concentrations recorded for all the boreholes were below the WHO and GEPA permissible limits. However, in comparing the individual borehole water, the level of As was higher in Akaaso (BH5) with mean of 0.0045 mg/L. The second borehole water from Chirano (BH2) recorded higher levels of As compared to the first borehole (BH1). On other hand, the As levels were higher in the water for the first borehole (BH3) compared to the second (BH4) sampled in Anyinase. The borehole water sampled from Surano (BH7) and Kwawkrom (BH8) recorded the least As levels of <0.0005 mg/L. However, analysis of variance showed that there were significant differences in the As concentrations among the eight boreholes ($F = 4.078$, $P=0.033$). GEPA guideline for dissolved As concentration is 0.01 mg/L. The borehole water sampled from Surano and Kwawkrom recorded As levels below the detection limit of the laboratory. However, water sampled from the boreholes in Akaaso and Anyinase recorded mean values that were higher compared to the other borehole although the levels were within GEPA permissible guideline value. As is found in the deep bedrock materials as well as the shallow glacial materials in the study area. They are also found alongside gold ores such as arsenopyrites (FeAsS) (Smedley and Kinniburgh, 2002). As is usually present in the environment in inorganic form. The inorganic As easily dissolves and enters underground and surface waters. The presence of As in the environment may be attributed to residual As from former pesticidal use and smelter emission from ores of gold such as arsenopyrites from the sulphur treatment plant. Thus, during ore crushing and panning by the small scale gold miners, arsenopyrite like As is released into the environment and it finally finds its way into sediments of underground and surface water (Kaye, 2005). Also in most aquifers, bio-geological interactions dominate as the source of As, interaction of As with organic and mineral colloids can elevate its concentration (He and Charlet, 2013). Franblau and Lillis (1989) reported cases of sub-chronic As intoxication resulting from ingestion of contaminated well water. Acute gastrointestinal symptoms, central and peripheral neuropathy, bone marrow depression, hepatic toxicity, skin pigmentation occurred when the mean level of As from the contaminated well from which the inhabitants depend were between 0.03 and 0.08 mg/L. Comparing the mean As values in the Franblau and Lillis (1989) study to the calculated As concentration obtained in this study, which residents in Bibiani-Anhwiaso-Bekwai district ingest daily from drinking the borehole water, it was found out that the mean As concentration in water is lower than the estimated As value used in Franblau and Lillis (1989) study. Hence, symptoms associated with As intoxication would be less for residents in the study area. Drinking water contaminated with As is one of the major

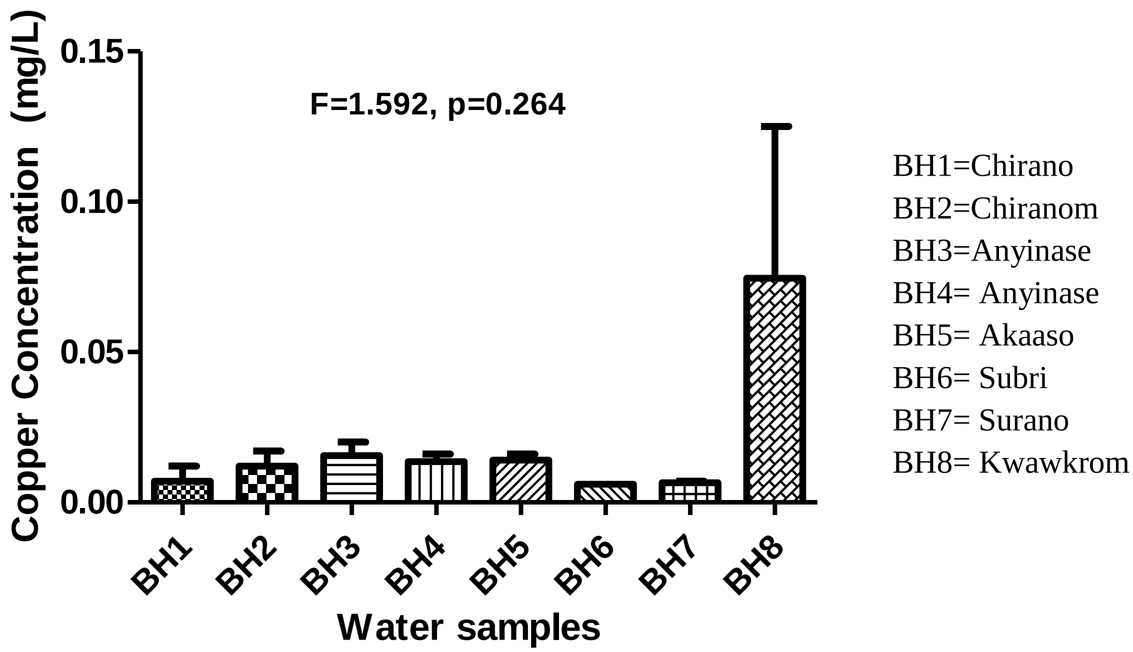

Figure 3. Copper concentrations in sampled borehole water.

causes for As toxicity in more than 30 countries in the world (Chowdhurry et al., 2000). If the As level in ground water is 10-100 times the value given in the WHO guideline for drinking water (10 µg/L), it can be a threat to human health (Hoque et al., 2011). Most of the reports of chronic As toxicity in man focus on skin manifestations because of its specificity in diagnosis. Pigmentation and keratosis are the specific skin lesions that indicate chronic As toxicity (Martin and Griswold, 2009).

Cu concentrations in borehole water

Figure 3 shows the level of copper in some sampled borehole water. The mean Cu concentrations recorded for all the boreholes were below the WHO and GEPA permissible limits. However, comparing the individual borehole water, the level of Cu was higher in Kwawkrom (BH8) with mean of 0.0745 mg/L. The second borehole water from Chirano (BH2) recorded higher levels of Cu compared to the first borehole (BH1). On other hand, the Cu levels were higher in the water for the first borehole (BH3) compared to the second (BH4) sampled in Anyinase. The borehole water sampled from Subri and Surano recorded the least Cu levels of 0.0060 and 0.0065 mg/L respectively. However, analysis of variance showed that the differences in the concentration of Cu from the eight boreholes were not significant (F = 1.592, P=0.264). Generally, very low levels of Cu were observed for all the water samples at the sampling sites when compared with the GEPA and WHO guidelines limit of 5 mg/l for drinking water. The mean values of Cu in the boreholes recorded at Kwawkrom were higher than the other borehole water samples.

The high concentration of Cu in the BH8 (Kwawkrom) may be due to the improper disposal of Cu wire by the inhabitants which may leach down into the boreholes. The borehole water sampled from Subri and Surano recorded the very low Cu levels. The presence of Cu in the study area may be due to the excavations made by panners in the course of prospecting for gold in the Bibiani traditional area. Such activities lead to the weathering and leaching of this metal from waste rock dumps (Obiri, 2007). Other sources of Cu are the weathering of the rocks, which contain high levels of Cu. Similarly, improper disposal of Cu wire may also account for the presence of Cu in the study area. Most Cu compounds will settle and be bound to either water sediment or soil particles. Soluble Cu compounds form the largest threat to human health. Long-term exposure to Cu can cause irritation of the nose, mouth and eyes and it causes headaches, stomach aches, dizziness, vomiting and diarrhoea. Intentionally high uptakes of Cu may cause liver and kidney damage and even death (Obiri et al., 2010). Osredkar and Sustar (2011) reported that long-term exposure to high concentrations of Cu has a link with a decline in intelligence with young adolescents.

Zn concentrations in borehole water

The level of Zn in some sampled borehole water is presented in Figure 4. The analysis of variance shows

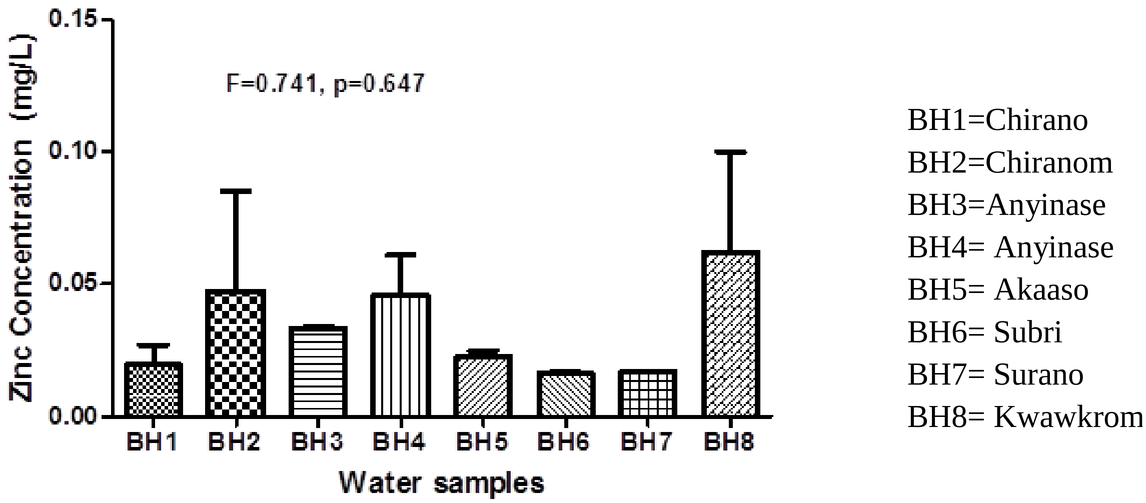

Figure 4. Zn concentrations in sampled borehole water.

that the Zn concentrations do not vary significantly among the eight boreholes (F = 0.741, P=0.647). However, comparing the individual borehole water, the level of Zn was higher in Kwawkrom (BH8) with mean of 0.0625 mg/L. This may be as a result of the leaching of Zn from piping and fittings in the area. The second borehole water from Chirano (BH2) and Anyinase (BH4) recorded higher levels of Zn compared to the boreholes BH2 and BH3. The borehole water sampled from Subri (BH6) and Surano (BH7) recorded the least Zn levels of 0.0160 and 0.0170 mg/L respectively. The mean Zn concentrations recorded for all the boreholes were below the WHO and GEPA permissible limits. No significant difference was observed in the concentrations of Zn in the water samples from the different sources. In natural surface waters, the concentration of Zn is usually below 10 µg/L, and in ground waters, 10-40 µg/L (Van Leeuwen, 2000). In tap water, the Zn concentration can be much higher as a result of the leaching of Zn from piping and fittings. Taking too much Zn into the body through food, water, or dietary supplements can also affect health. The levels of Zn that produce adverse health effects are much higher than the Recommended Daily Allowances (RDAs) for Zn of 15 mg/day for men and 12 mg/day for women.

If large doses of Zn (10-15 times higher than the RDA) are taken by mouth even for a short time, stomach cramps, nausea, and vomiting may occur (Hotz and Brown, 2004; Roohani et al., 2013). Ingesting high levels of Zn for several months may cause anemia, damage of pancreas and decrease levels of high-density lipoprotein (HDL) cholesterol (Plum et al., 2010). Zn content in the borehole water samples ranged from 0.01 to 0.1 mg/L with a mean value of 0.0329 mg/L is within WHO maximum allowable of 3.0 mg/L for drinking water (Table 1). This indicates that water from the sampled boreholes contain the right proportion of Zn which is an essential plant and human nutrient element. The low concentration further implies the boreholes do not have caustic taste, hence ideal for consumption and other domestic uses.

Conclusion

The results of the study showed that the boreholes from the various sampling sites are contaminated with heavy metals; however, the mean concentrations do not exceed WHO/GEPA permissible level for drinking water. This raises less concern about the quality of drinking water being used by residents in the study area. The study has established that the concentrations of heavy metals, mainly As, Cu and Zn recorded in the borehole water from Chirano, Anyinase, Akaaso, Subri, Surano and Kwawkrom were below GEPA and WHO standards, rendering the water somewhat safe for domestic use. However, it is important for residents in the study area to be provided with more potable water.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Aryee BN, Ntibery BK, Atorkui E (2003). Trends in the small-scale mining of precious minerals in Ghana: a perspective on its environmental impact. Journal of Cleaner Production 11(2):131-140.

Chowdhurry UK, Biswas BK, Chowdhurry HR, Samanta G, Mandal BK, Basu GC, Borti D (2000). Groundwater arsenic contamination in Bangladesh and west Bengal, India, Environmental Health Perspective 108(5):393-397.

Cobbina SJ, Duwiejuah AB, Quansah R, Obiri S, Bakobie N (2015). Comparative assessment of heavy metals in drinking water sources in two small-scale mining communities in northern Ghana. International Journal of Environmental Research and Public Health

12(9):10620-10634.
Essumang DK, Dodoo DK, Obiri S, Yaney JY (2007). Arsenic, Cadmium, and Mercury in Cocoyam (Xanthosoma sagititolium) and water cocoyam (colocasia esculenta) in Tarkwa a mining community. Bulletin of Environmental Contamination and Toxicology 79:377-379.
Fatah L (2008). The impacts of coal mining on the economy and environment of South Kalimantan Province, Indonesia. ASEAN Economic Bulletin 25(1):85-98.
Franblau A, Lillis R (1989). Acute arsenic intoxication from environmental arsenic exposure. Archives of Environmental Health 44:385-390.
Hanson R, Dodoo DK, Essumang DK, Blay Jr., Yankson JK (2007**)**. The effect of some selected pesticides on the growth and reproduction of fresh water oreochromis niloticus; chrysicthys nigrodigitatus and clarias gariepinus. Bulletin of Environmental Contamination and Toxicology 79:544-547.
He J, Charlet L (2013). A review of Arsenic presence in China drinking water. Journal of hydrology 492:79-88.
Hoque MA, Burgess WG, Shamsudduha M, Ahmed KM (2011). Delineating low – arsenic groundwater environments in the Bengal Aquifer system Bangladesh. Applied Geochemistry 26(4):614-623.
Hotz C, Brown KH (2004). Assessment of the risk of zinc deficiency in populations and options for its control. The Food and Nutrition Bulletin 25(1):194-195. Http://www.bab.ghanadistrict.gov.gh, accessed on 10/05/16, 5: 30 pm.
IARC (1980). Monographs on the carcinogenic risk to humans and their supplements: some metals metallic compounds. International Agency for Research on Cancer, IARC monographs, volume 23.
Kaye A (2005). The effects of mine drainage water from Carrock Mine on the water quality and benthic macro-invertebrate communities of Grainsgill Beck: a preliminary study. Earth and Environment 1:120-154.
Lokeshwari H, Chandrappa GT (2006). Impact of heavy metals contamination of Bellandur lake on soil and cultivated vegetation. Current Science 91(5):622-627.
Martin S, Griswold W (2009). Human health effects of heavy metals. Environmental Science and Technology Briefs for Citizens 15:1-6.
Obiri S (2007). Determination of Heavy Metals in Boreholes in Dumasi in the Wassa West district of Western region of the Republic of Ghana. Environmental Monitoring and Assessment 130:455-463.
Obiri S, Dodoo DK, Essumang DK, Armah FA (2010). Cancer and non-cancer risk assessment from exposure to arsenic, copper, and cadmium in borehole, tap, and surface water in the Obuasi municipality, Ghana. Human and Ecological Risk Assessment 16(3):651-665.
Osredkar J, Sustar N (2011). Copper and Zinc, Biological Role and Significance of Copper/Zinc Imbalance. Journal of Clinical Toxicology S3:001.
Plum LM, Rink L, Haase H (2010). The essential toxin: impact of zinc on human health. International Journal of Environmental Research and Public Health 7(4):1342-1365.
Roohani N, Hurrell R, Kelishadi R, Schulin R (2013). Zinc and its importance for human health: An integrative review. Journal of Research in Medical Sciences 18(2):144-157.
Singh N, Koku JE, Balfor B (2007). Resolving water conflicts in mining areas of Ghana through public participation; A Community Perspective. Journal of Creative Communications 2:361-382.
Smedley PL, Kinniburgh DG (2002). A review of the source behavior and distribution of arsenic in natural waters. Applied Geochemistry 17:517–568.
Van Leeuwen FXR (2000). Safe drinking water: the toxicologist's approach. Food and Chemical Toxicology 38:S51-S58.

Related Journals: