

A Systematic Discourse of Mining as a Land Use Activity on Water Resources in Ghana

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Abstract

One of the serious costs associated with development in recent times is water pollution. This is so because globally, humanity is approaching its carrying capacity, by enlarging its consumption footprints. These undoubtedly, have had dire consequences including death of many people, through cancers and other life threatening diseases. The Ghanaian situation does not depart from the pollution status quo, especially in the mining sector. Using preponderantly secondary information from peer-reviewed articles and institutional documents, this paper examined the incidence of water pollution and its implication for human health in mining communities in Ghana. The challenge of non-compliance and enforcement of environmental laws has given leeway to the populace and industries to operate, to a larger degree, with careless abandon. With the mining industry as a case study, the plight of the vulnerable rural people as regard water pollution is revealed. Their only source of drinking water and sometimes livelihood is the water bodies that are mostly polluted in the mining process. The government of Ghana and the Environmental Protection Agency are therefore called upon to balance the benefits from the mining industry and the safety of the water bodies of mining communities.

Keywords

Land Use Activities, Water Resources, Mining, Non-compliance

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1. Introduction

Pollution is undoubtedly one of the crucial negativities associated with man's quest to develop [1]. Of particular importance is the effects of mining as a land use activity on surface water supply and quality [2]. According to [3], humanity has now exceeded its ecological footprint and now overshoots the earth's capacity by more than 40%. In other words, humanity is using resources and turning them into waste faster than the earth's living systems can absorb and turn them back to resources [3]. These wastes accumulate in the atmosphere, on the land and in various water bodies to result in the pollution of these environmental systems. What makes this problem disturbing is the fact that these wastes have poisonous components which are seriously harmful to

human health and biodiversity in general.

Pollution as a concept defies a single definition. However, for the purpose of this essay, pollution may be defined as the occurrence and introduction of wastes into the environment and the impact of these wastes on the environment. Judging from this premise it can be deduced that the main cause of pollution is the generation of wastes of various kinds. According to [4], the global economy is generating increasing amount of hazardous waste in countries that lack the systems and resources for their proper management. Even in countries where these waste management systems exist, waste management problems still persist. Land and water pollution, results from the deposition of wastes from domestic, industrial and agricultural sources onto the earth surface and hydrological systems [5].

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The introduction of various forms of waste, including mining effluents into water bodies also result in water pollution. Water pollution in particular should be a global concern because of its potential consequence of water scarcity and the damaging effect it has on aquatic biodiversity. It was in this direction that the Monaco Declaration emphasized an ongoing ocean acidification that could affect food web [6]. This might lead to sustained changes in commercial fish stock, threatening protein supply and food security for millions of people as well as the multi-billion-dollar fishing industry.

According to [7], high pollution in Northern China has resulted in the prevalence of water scarcity as polluted water is held from supply. However, some water is allowed in supply despite it being polluted, beyond the WHO, and environmental protection agencies' allowable limits. But its persistence in the region means the laws are not rigorously enforced enough. Government's efforts are invariably thwarted by the attitudes of the public and some saboteur enforcement agencies. [8] describe pollution as the outcome of the introduction of chemicals, particulate matter or microscopic organisms into the earth physical environmental systems. These concentrations cause adverse metabolic changes to humans and other living species, that uptake these toxins from the environment. The proliferation of automobiles, construction activities, landfills and heavy industrialization are the very avenues of pollution of the environment. The end result of this is the death of millions of people per annum worldwide, lung cancer and heart diseases [9].

Keeping the environment and people safe from the harmful substances and hazardous waste is far beyond management [4]. It involves working to avoid these dangers entirely by removing them from production and use. The ultimate question remains whether this is possible in an era where the generation of waste and use of chemicals has become part of us. This is emphasized by [10] that over the past half century, there has been an accelerated release of artificial chemicals into the environment. There are other wastes from industries, mining, agriculture and domestic sources. All these settle around us, negatively impact our lives and grow to known as pollution. The objective of this paper is to examine the incidence of water pollution problems associated with mining, both legal and illegal, in Ghana.

2. Method

This is a desktop study that undertook a systematic discourse of the contextual review of relevant secondary information, pertaining to land and water pollution emanating from human land use and misuse activities of the environmental sub-

system. Of particular importance is the effect of mining activities, both formal and illegal on the water quality and quantify in the context of Ghana. Copious literature on Ghana, Africa and the world were also critically reviewed for the study.

2.1. Ghana's Profile

Ghana is a country on the West Coast of Africa and has one of the most thriving democracies on the continent. It has often been referred to as an "island of peace" in one of the most chaotic regions in the world. It shares boundaries with Togo to the east, la Cote d'Ivoire to the west, Burkina Faso to the north and the Gulf of Guinea to the south. Ghana occupies an area of 238,537 square kilometres with a population of almost 28.3 million inhabitants. The country lies just above the equator and is on the Greenwich meridian line which passes through the seaport of Tema, about 24 km to the east of Accra, the capital. Its southernmost coast at Cape Three Points is 4° 30' north of the equator. From here, the country extends inland for some 670 kilometers. The distance across the widest part measures about 560 kilometers. Half of the country lies less than 152 meters (500 ft.) above sea level, and the highest point is 883 meters (2,900 ft.).

A recent discovery of oil in the Gulf of Guinea has made Ghana an important oil producer and exporter. Ghana's terrain is mostly low plains with some scattered hills criss-crossed by rivers. The Volta Lake, the world's largest artificial lake is located in Ghana. Mountain Afadja (Afadjato) is Ghana's highest peak with 885 m (2,904 ft). The hill is located in the Agumatsa Range. Ghana has a low topography with a tropical and savannah regions split into ten regions: Ashanti Region, Brong-Ahafo Region, Central Region Eastern Region, Greater Accra Region, Northern Region, Upper East Region, Upper West Region, Volta Region Western Region.

Ghana's water resources are divided into surface and groundwater sources. The surface water resources are mainly from three river systems that drain Ghana. These are Volta, South Western and Coastal river systems. The Volta system is made up of the Red, Black and White Volta Rivers as well as the Oti River. The Volta river has been dammed at Akosombo to form Lake Volta, the world's largest artificial lake. The South-Western river system is made up of the Bia Tano, Ankobra and Pra rivers. The Tordzie/ Aka, Densu, Ayensu, Ochi-Nakwa and Ochi-Amisshah comprise the Coastal river systems. These river systems make up 70%, 22% and 8% respectively of Ghana's total land area of about 240,000 km². In addition to these, the only significant natural freshwater lake in Ghana is Lake Bosumtwi. This is a meteoritic crater lake located in the forest zone, with a

surface area of 50 km², and a maximum depth of 78m.

The most densely populated parts of the country are the coastal areas, the Ashanti region around Kumasi, the Ashanti capital and largest city is Accra. The spoken languages include English (official), Akan (Twi–Fante), and about

seventy more West African languages. The country's economy is dominated by agriculture, which employs about 60 percent of the working population. Ghana is one of the leading exporters of cocoa in the world. It is also a significant exporter of commodities such as gold and lumber.



Figure 1. Administrative Map of Ghana.

2.2. Theory of PPP

This paper is hinged on the theory of polluter pays principle (PPP) which was first mentioned as a recommendation of the Organization for Economic Co-operation and Development (OECD) in May 1972 and reaffirmed in November 1974 [11], [2]. The PPP premises on the assertion that “the

polluter has to bear the cost of steps that he is legally bound to take to protect the environment, such as measures to reduce the pollutant emissions at source and measures to avoid pollution by collective treatment of effluent from a polluting installation and other sources of pollution” [12].

Also, from the OECD recommendations, the main functions of the polluter pay principle was to allocate costs of pollution

prevention and control measures in order to ensure rational use of scarce environmental resources including water resources. The principle was further to ensure that the polluter bears the expense of carrying out the measures defined by public authorities to ensure that the environment is in an acceptable state [11]. In this regard therefore, both the *polluter* and *public authorities* have the responsibility of ensuring that the environment is in acceptable state after any land use activity. Unfortunately, the environmental authorities in Ghana appear not to be up to task [13] hence the seemingly difficult applicability of the principle. As a result, miners, both legal and illegal most often go scot free after grievously polluting water resources that are of immense importance to communities and the nation as a whole [14].

[15] argues that few people disagree with the assertion that those who cause damage to the environment must "pay" for those damages as this seems to appeal to the sense of justice.

Ensuring that polluters bear the costs of their activities also enhance economic efficiency whilst at the same time solving the otherwise incalculable social and health implications of pollution. Notwithstanding these straightforward benefits of the principle however, questions have been raised as to what constitutes pollution, who are the polluters, how much must the polluters pay and to whom they must make the payment [15]. Also, issues concerning whether the polluter must pay bothers two different outcomes; allocation efficiency and equity [2]. According to [2], there are two interpretations to the PPP including the efficiency interpretation and the equity interpretation. The efficiency interpretation echoes the assertion that pollution costs should be internalized by mining companies, in order to achieve an efficient allocation of resources in spite of distributive issues. The equity interpretation on the other hand considers fair distribution of pollution costs among all recipients. It therefore incumbent on the public authorities in Ghana to properly operationalize the concept to ensure that miners operate within laid down procedures.

3. Results and Discussions

3.1. The Mining Industry and Water Pollution in Ghana

Mining in Ghana can be seen as a necessary evil; providing foreign exchange whilst depriving peasant rural populates of their very lives and source of livelihood be way of water pollution with mining chemicals. According to [16], the mining sector has since 1991 been the largest contributor to total merchandise exports, with the exception of 2004, when it was overtaken by the cocoa sector. Over the period, it has

provided an average of 42% of the total merchandise exports. [16] further adds that Ghana's gold exports totaled US\$2.2 billion in 2008. Also the mining sector contributed an average of 5.5% GDP from year 2000 to 2008. Gold accounts for over 95 per cent of Ghana's total mineral revenues. In 2012, the country produced 3.3 per cent of the world's gold, with total exports worth US\$5.64 billion— making it the second largest producer in Africa after South Africa [17].

Pollution associated with mining, however, has been in existence for some time but in recent times, mining in Ghana is increasingly becoming unpopular. This is because of the various environmental damages associated with the industry. They include the loss of lives and property, the destruction of the very livelihood of people by way of polluting their water bodies through the spillage of chemicals like cyanide and mercury. The health of the rural inhabitants is therefore always at risk. As important as water is to human wellbeing, pollution of any form brings about serious threats especially in a place where potable water is an already scarce commodity [2]. Unfortunately, this is the case in many mining communities in rural Ghana. The two main mining chemicals causing water pollution in such mining areas are cyanide and mercury.

3.2. Incidence of Water Pollution

According to [18] artisanal gold mining activities in Ghana are rampant. Meanwhile, majority of the populace; particularly those engaged in mining activities are unaware of the dangers posed by mercury. The big mining companies who are expected to know better also take undue advantage of the flexible or non-existing laws and pollute water bodies.

Mercury concentrations in human blood, urine, hair, nail and fish from Ankobra and Tano basins in the southern-western part of Ghana have been discovered [18], [19]. Also, there is an evidence of mercury and artisanal pollution in soils, food crops and fish around Obuasi, the main mining town in Ghana and its environs. This has serious health implications. It could cause damage of the brain, kidney and lungs. In extreme cases, it could cause diseases like acrodynia (pink disease), Hunter-Russell syndrome and Minamata disease [19].

The Wassa Association of Communities Affected by Mining in 2004 made a statement on cyanide spillage of the Bogoso Gold Mining Limited from a new tailings dam of the company [20]. As a result, many rivers that flow into big river Ankobra were polluted. The cyanide spillage affected a lot of communities. The Environmental Protection Agency investigated and confirmed that the source of the sodium cyanide discharge was indeed from the company but no sanction action was heard. Such irregularities on the part of

the EPA encourage other mining companies to do same.

The disturbing news is that residents continue to use this water even after pollution because mainly because they do not have any alternative. The inhabitants will surely suffer the negative impacts of using polluted water. There will always be disease outbreaks in the face of limited or non-existent health facilities [21]. What is most pathetic is the health of pregnant women and innocent unborn children who will suffer the consequences of someone's profit. It is not even as if the money accrued from the mining earnings is used for development in the local vicinity. What is therefore expected to become of these people who suffer at the expense of mining revenue for the government who hardly have their development at heart? One expects that Ghana being a signatory to the Basel convention and the Stockholm convention on Persistent Organic Pollutants should be able to deal better with this situation. Human health is at stake. But it seems lack of effective collaboration among the Environmental Protection Agency and other law enforcement institutions are preventing this. The alternative source of water provided by some 'merciful' mining companies are woefully inadequate while some of these boreholes bring out polluted water as shown in figure 2 below:

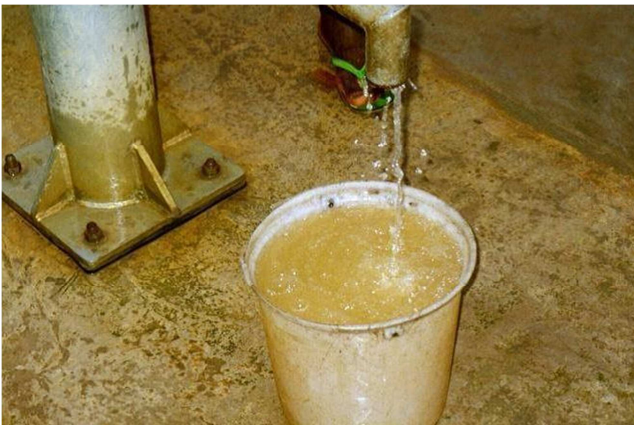


Figure 2. Water from borehole provided by AGA Iduapriem mine for Nkwantakrom community.

Source: WACAM, 2007

3.3. Water Supply and Mining in Ghana

Ghana is endowed with a range of mineral resources; hence its previous name the Gold Coast was a clear manifestation of the quantity of gold it is endowed with, especially in the southern sector particularly Obuasi, Tarkwa and Pristea [13]. The mining sector is therefore vibrant, employing a range of skilled and unskilled labour whilst at the same time contributing immensely towards the country's GDP [19]. [22] has it that mining contributes about 9.1% of Ghana's GDP and employs about 260,662 people formally. The country equally has a number of surface and ground water sources

[23]. The surface water comprises major river systems such as the Volta River with its tributaries (red, black and white), river *Oti, Bia, Tano, Ankobra, Pra, Todzie, Aka, Densu, Ayensu and Och-Nakwa* all draining the southern sector of Ghana.

Coincidentally, a significant proportion of these water resources in Ghana are found in mining areas. As a result, there is continual pollution of surface and underground water which poses serious threats to the environment, human lives and development at large [24], [13]. It is therefore argued that environmental laws need to be re-oriented appropriately with stricter sanctions to tackle the negative impacts of mining on water resources [13]. Environmental compliances tools like the Environmental Impact Assessment (EIA) process must be streamlined and properly enforced.

Aside the enormous benefits that accrue from mining, [2] argue that mining as a land use activity has had many negative and sometimes irreversible damages on water resources. Both water quality and quantity are mostly compromised by mining activities particularly the illegal type, popularly known as *galamsey* [14]. Even though mining companies are guided by rules and regulations, water supply in most mining communities has not been given the necessary importance that it deserves for the realization of sound human health and environmental quality [2].

A recent study by [14] revealed that River Bonsa, a major source of water in Tarkwa Nsuaem is at the threshold of drying up due to small scale illegal mining activities in and around the river. The quantity of water produced by the river reduced from 1.2 million gallons of water a day to about 2.6 million to 3.42 million litres of water a day due to illegal mining activities in and very close to the river [14]. Presently, the river has lost its mandate of providing water for industrial and domestic use for the whole municipality. In addition, people in the area are threatened by health and socially related issues due to the consistent use of deadly chemicals in the water by illegal miners [24], [14].

According to [25], one of the main reasons why water quality and quantity keep deteriorating in mining communities in Ghana is that community stakeholders and land owners are not consulted before mining concessions are given out. They further argue that small scale miners and companies may choose to engage with local communities to enhance their corporate image or totally fail to do so. In this regard therefore, the real needs of mining communities with respect to water resources is not so much of a concern to mining concessioners. [2] also critically asserts that mining in Ghana, particularly illegal mining has had irreversible impacts on water resources both for irrigation and domestic usage. He further argues that the lucrative nature of mining

activities has pushed the youth especially who use crude methods and dangerous chemicals like mercury to mine in and around major rivers in Ghana. Consequently, rivers like Pra, Ankobra, and Birim among others are polluted to the extent that cannot be used for domestic or irrigation purposes.

A study by [19] revealed that the Pra river together with its tributaries have 48.40 ± 26.08 ng/ml and 27.59 ± 18.23 ng average dissolved mercury concentration respectively. What makes this a matter of concern is that these levels are way beyond the World Health Organization's guideline value of 1.0 ng. Meanwhile, these excessive concentration of mercury are because of illegal gold mining activities at the expense of the Pra River. It is also important to state that since the river is not stagnant, the pollutants flow downstream making it impossible for all communities along the river to use it for any purpose.

[26] therefore concludes that the mining industry, both small and large scale, legal and illegal have had a lot of significant negative impact on the environment, particularly water bodies. River bodies and underground water continue to be the main water source for drinking, household activities and sometimes industrial purposes. The onus therefore lies on the Ghana Water Commission, the Environmental Protection Agency, community members and all other affected stakeholders to help protect water resources. Water remains indispensable in human activities, linked to the provision of a lot of services directly or indirectly including human health and other socio-economic activities [27]. There is therefore the urgent need to critically delve into how Ghana's water resources especially surface water bodies could be protected from dangerous chemicals like mercury from mining activities.



Figure 3. Sign post in a mining community cautioning against swimming, fishing and wading in a polluted water body.

Source: WACAM, 2007

3.4. Health Implications of Water Pollution

One of the most devastating implications of water pollution is its effect on human health [28]. Water is undoubtedly indispensable in human life and survival [29]. The daily need of water for a person is between three and nine liters, depending on the climatic conditions. Each person annually needs between 1 m^3 and 3 m^3 of highest quality water free of pathogenic organisms, harmful chemicals, low in inorganic salts, and not containing odorous compounds [30]. There is therefore a direct linkage between water pollution and human health [31]. The United Nations Committee on Economic, Cultural and Social Rights, interpreting the provision of the International Covenant on Economic, Social and Cultural Rights in 2002, asserted that water is fundamental for life and health. The human right to water is necessary for leading a healthy life. In fact, water is a pre-requisite to the realization of all other human rights [29]. Any attempt therefore to reduce water quality or quantity is a cause for alarm.

According to [32], pollution has reduced water access by two thirds (2/3) and this situation is a truism in Ghana. Rivers in Ghana constitute one of the main sources of clean drinking water and a result, any alteration in its quality directly affect the health of people [28]. Small scale illegal mining, "gallamsey" mostly occur close to or in major water bodies making the water susceptible to pollution from mercury and other chemicals which pose serious health risks to all inhabitants along such water bodies [24], [19]. A recent study by [14] revealed that the consistent use of deadly chemicals from mining in and around River Bonsa in Tarkwa Nsuaem have had critical implications on the health of most inhabitants along the river.

It is also interesting to know that the global health burden associated with water pollution is overwhelming, with an estimated 4000-6000 children dying each day from diseases associated with lack of access to safe drinking water [33]. According to [28] also, about 3.4 million deaths occur yearly in developing countries due to water related health issues. This makes the protection of water bodies from pollution by mining crucial. A recent study by [34], [35] revealed that sediment mercury concentrations in most rivers in mining communities have surpassed guideline values by the World health organization and hence not safe for human consumption. Meanwhile, most people in such areas have no alternative water source. There is an urgent need for the Environmental Protection Agency (EPA) in Ghana to issue the appropriate sanctions [13] and internalize the polluter pays principle even for illegal miners to revert the health implications associated with mining related water pollution in Ghana.

Water pollution affects mostly poor rural residents who have

no other alternative but the already polluted water bodies [14]. This results in rampant infestation of the people by deadly diseases. Unfortunately, health facilities are lacking in such areas so many people definitely lose their lives through this pollution situation. Even if there are a lot of health facilities, it does not give the leeway for mining companies to pollute water bodies. The EPA, Water Resources and Minerals Commission of Ghana and government must therefore set their priorities right and rise up to the task. In as much as mining contribute to economic development, it cannot be done at the expense of people's lives, their livelihoods and productive water bodies [24].

4. Conclusion

Pollution is a global concern; from the already industrialized economies to emerging economies down to the poorest country. This is mainly because the capacity of the land, water bodies and the atmosphere to absorb the pollutants released has been exceeded. Water pollution in Ghana as a result of mining land use activities is connected largely to ignorance on the part of individuals of the environmental consequences of their actions. Environmental laws are also relaxed or unenforced and that has given mining companies the freedom to operate. This, government turns a blind eye on because of the tax and foreign exchange associated with the mining industry. It is therefore expected that all appropriate institutions to rise up to pollution prevention however means possible to avert its dreadful consequences.

References

- [1] Mannucci, Pier Mannuccio, and Massimo Franchini, (2017). Health Effects of Ambient Air Pollution in Developing Countries. *International Journal of Environmental Research and Public Health*, 14 (9), p. 1048.
- [2] Appiah, Divine Odame, and Kabila Abass, (2014). "Water supply and mining: the policy paradox in Ghana." *Water Policy* 16, no. 5 (2014): 945-958.
- [3] Global Footprint Network, (2010). Footprint Basics http://www.footprintnetwork.org/en/index.php/GFN/page/basics_introduction/
- [4] United Nations Environment Programme (2010). Harmful substances http://www.unep.org/pdf/UNEP_Profile/Harmful_substances.pdf
- [5] Ackom, George, (2016). Vehicle Emission Enforcement, Driver and Vehicle Licensing Authority (DVLA), Ghana, 01 November 2016.
- [6] Second International Symposium on the ocean in a high-CO₂ World, (2008). The Monaco Declaration <http://www.oceanacidification.net/Symposium2008/MonacoDeclaration.pdf>
- [7] The World Bank, State Environmental Administration, P. R. China, (2007). Cost of Pollution in China; Economic Estimate of Physical Damages, Washington D. C. http://siteresources.worldbank.org/INTEAPREGTOPENVIRONMENT/Resources/China_Cost_of_Pollution.pdf.
- [8] Hogan, Michael and Slanina, Sjaak, (2010). Air pollution http://www.eoearth.org/article/Air_pollution?topic=49506
- [9] World Health Organization, (2003). Health aspects of air pollution with particulate matter, ozone and nitrogen dioxide: report on a WHO working group, Bonn, Germany 13-15 January 2003.
- [10] Organization of Economic Co-operation and Development, (2001). African Environmental Outlook, Our Environment, Our Wealth, Chapter 11 (Chemicals)
- [11] European Commission, (2012). Principles of EU Environmental Law; The Polluter Pays Principle, Workshop on EU Legislation.
- [12] Organisation for Economic Co-Operation and Development, (1992). The Polluter-Pays Principle OECD Analyses and Recommendations, Environment Directorate, Paris.
- [13] Fatawu, Nasirudeen Abdul, and Allan Andrew, (2014). Managing the impacts of mining on Ghana's water resources from a legal perspective. *The Journal of Energy and Natural Resource Management*, 1 (3), pp. 156-165.
- [14] Kusi-Ampofo, Solomon and Boachie-Yiadom, Theophilus, (2012). Assessing The Social and Environmental Impacts of Illegal Mining Operations in River Bonsa, a research Report Commissioned by Pure Fm, Tarkwa and funded by the Business Sector Advocacy Challenge (BUSAC) fund, 40 pp.
- [15] Cordato, Roy, (2001). The polluter pays principle: a proper guide for environmental policy. Institute for Research on the Economics of Taxation.
- [16] Hinde, Camila, (2010). Ghana: A supplement to Mining Journal. Mining Journal Special Publication, Ghana. 1-12.
- [17] McQuilken, James and Hilson Gavin, (2016). Artisanal and small-scale gold mining in Ghana. Evidence to inform an 'action dialogue'. IIED, London, 44p.
- [18] Donkor, Augustine Kwesi. Vincent Nartey, Bonzongo Jean-Claude., and Adotey Dennis, (2006). Artisanal Mining of Gold with Mercury in Ghana, *West African Journal of Applied Ecology*, Volume 9, January-June, 2006, ISSN 0855-4307.
- [19] Amankwah, Emmanuel, (2013). Impact of illegal mining on water resources for domestic and irrigation purposes. *ARNP journal of Earth Sciences*, 2 (3), pp. 117-121.
- [20] Wassa Association of Communities Affected by Mining (WACAM), (2007). Mining and Community Water Pollution. (<http://www.wacamghana.com/app/webroot/img/documents/4af460c32ea9c.pdf>)
- [21] Clarke, Edith, (2010). Health Impact Assessment in Extractive Industries within Ghana, Occupational & Environmental Health Unit, Ghana Health Service, Ministry of Health Ghana.
- [22] Ghana Statistical Service, (2014). Revised Gross Domestic Product. [Online]. Available: http://statsghana.gov.gh/docfiles/GDP/GDP2015/Revised_Annual_GDP2014_Jan2015.pdf
- [23] Government of Ghana, (2007). Ghana National Water Policy.

- [24] Aragon, Fernando, and Juan Pablo Rud, (2012). Mining, pollution and agricultural productivity: evidence from Ghana.
- [25] Gardner, Alex, Duff Nick, Ainuson Kweku and Samuel Manteaw, (2015). Regulating Mining Water Use and Impacts in Ghana: Comparing Australian and Ghanaian Law for Reform Ideas, International Mining for Development Centre.
- [26] Owusu, Phebe Asantewaa, Samuel Asumadu-Sarkodie, and Polycarp Ameyo, (2016). A review of Ghana's water resource management and the future prospect. *Cogent Engineering*, 3 (1), p. 1164275.
- [27] Biswas, Asi., (2005). An Assessment of Future Global Water Issues, *Water Resources Development*, Vol. 21, No. 2, 229–237.
- [28] Macdonald, Karunia, Mark Lund, and Melanie Blanchette, (2015). Impacts of Artisanal Small-Scale Gold Mining on Water Quality of a Tropical River (Surow River, Ghana).
- [29] United Nations Population Fund, (2003). *Global Population and Water, Access and Sustainability, Population and Development Strategies Series*, No. 6.
- [30] Zehnder, Alexander, Hong Yang, and Roland Schertenleib, (2003). Water Issues: The Need for Action at Different Levels, Water Policy Article, *Aquatic Sciences* 65 (2003) 1–20, EAWAG, Dübendorf.
- [31] Kahinda, Jean-marc Mwenge, Akpofure Taigbenu, and Boroto Jean, (2007). Domestic Rainwater Harvesting to Improve Water Supply in Rural South Africa, *Physics and Chemistry of the Earth* 32 (2007) 1050–1057
- [32] World Health Organization, (2006). *Children's Health and the Environment, WHO Training Package for the Health Sector* World Health Organization.
- [33] Moe, Christine and Richard Rheingans. (2006). *Global Challenges in Water, Sanitation and Health*, Journal of Water and Health, IWA Publishing.
- [34] Rajae, Mozhgou, Samuel Obiri, Allyson Green, Rachel Long, Samuel J. Cobbina, Vincent Nartey, David Buck, Edward Antwi, and Niladri Basu, (2015). Integrated assessment of artisanal and small-scale gold mining in Ghana—Part 2: Natural sciences review. *International journal of environmental research and public health*, 12 (8), pp. 8971-9011.
- [35] Hidayati, Nuril, Titi, Juhaeti, and Fauzia Syarif., (2009), Mercury and Cyanide Contaminations in Gold Mine Environment and Possible Solution of Cleaning Up by Using Phytoextraction, *Hyhati Journal of Biosciences*, p 88-94, Vol 16, No. 3.