International Journal of Water Resources and Environmental Engineering

Volume 7 Number 8 October 2015

ISSN-2141-6613

Academic Journals

www.academicjournals.org/ijwree

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International Journal of Water Resources and Environmental Engineering

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Vol. 7(8), pp. 101-108, October, 2015
DOI: 10.5897/IJWREE2015. 0608
Article Number: 01566AB55748
ISSN 2141-6613

http://www.academicjournals.org/IJWREE

International Journal of Water Resources and Environmental Engineering

Full Length Research Paper

Interim environmental influence of oil exploration on human lives in Ghana: a case of Half Assini and Efaso

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Received 26 January 2015; Accepted 27 August 2015

This paper focused on the interim environmental influence of oil and gas exploration activities on human lives in the Half Assini and Efaso communities in Jomoro District of the Western region of Ghana. Two stage sampling technique was used. It employed purposive sampling of residents living in the Jubilee Oil field environs. After, simple random sampling was used to select 300 respondents from the study area out of a population of about 8,000. The factors of adverse environmental change as a result of oil exploration considered in the study include air, noise and visual pollution. The multinomial logistic estimation model revealed that the likelihood of perception of air pollution's influence on the environment was positively and significantly related to oil exploration. That of noise pollution was not significant. Visual pollution (disposal of sea weeds) was likewise an eyesore at the beach.

Key words: Interim environmental influence, exploration activities, adverse environmental change, environmental pollution, Half Assini, and Efaso communities.

INTRODUCTION

Natural resources are the wealth of any country and the discovery and exploitation of such resources give hope to the citizens, as they are hailed as the beginning of a country's economic asset. Ghana's Jubilee oilfield is a world-class, long-life production asset, located in the Jomoro District is reported to contain up to 3 billion barrels (480×10^6 m^3) of light oil and was discovered in 2007 by Kosmos Energy and developed by Tullow Oil. It is located 60 km offshore, between the Deep-water Tano and West Cape Three Points blocks in Ghana. It is one of West Africa's largest discoveries of the last two decades. First production from the initial development phase was in late 2010. Average production is approximately 104,000 barrels of oil per day, and Jubilee partners are working to enhance field performance (IMF, 2014). Half Assini and Efaso (study areas) are communities that are about 50 kilometers away from the Jubilee oilfield (Figure 1).

Natural resources such as oil, gas, minerals and timber are expected to continue to play a significant role in resource abundant economies, as demand from rapidly growing economies increases, and as supplies of non-renewable resources decline and renewable resource harvests approach maximum sustained yield levels. Not surprisingly, countries richly endowed with natural capital

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Figure 1. A map of the Jubilee Oilfield and the settlements of Half Assini and Efaso in the Western Region of Ghana. (Source: www.google.com.gh)

have the potential to derive significant current income from resources (OECD, 2011).

The 1992 Rio Declaration on Environment and Development asserts that, 'human beings are at the center of concerns for sustainable development' (United Nations Environment Programme, 1992) and advocates for conscious ways of protecting the environment from any possible harm. In today's modern society however, the quest to develop speed and make life comfortable for human beings has rather taking overriding priority than a means to keep the environment safe (Abdulai, 2013). If natural resource development is properly managed, the associated revenue can be used to speed up growth, reduce inequality, contribute towards higher human development outcomes, create employment and lift people out of poverty (IMF, 2014; Kwofie, 2014; Camdessus, 2013).

The wealth created from oil could bring foreign earnings into a country and improve the living conditions of the population, when well managed. Natural resource wealth thus forms a strong base for income creation and sustained economic development in any country (Futukpor, 2012). This notwithstanding, the costs of natural resources management worldwide are high, disproportionately affecting less developed countries and the poor, who are more likely to depend directly upon resources for their livelihoods.

Poor resource management includes failing to manage renewable resources on a sustainable basis and failure to properly invest the revenue from the sale of non-renewable resources among others (Kwofie, 2014). Most critically, the failure to manage non-renewable resources such as oil has a negative effect on the environment. As such, Ghana's oil exploration is no exception.

The major potential environmental effects from offshore drilling occur from the discharge of wastes, including drilling fluids (also referred to as drilling muds), drill cuttings and produced formation water. The decommissioning of platforms/rigs is also a potential environmental problem (Global Marine Oil Pollution Information Gateway, 2015).

In offshore operations, the major sources of pollution derives from atmospheric emissions, wastes like produced and formation water, produced sand, oily drill cuttings, drilling fluids, deck drainage, well treatment fluids, oil spills, sanitary and domestic wastes, etc. The atmospheric, marine and noise pollution which arises from the operation of oil rigs; construction of tank farms and vehicular emissions may impact negatively on air and water quality (Osei, 2011).

In Addition, air, water and soil resources can become contaminated with oil and gas wastes and byproducts. Citizens commonly report that drilling and production activities contaminate water wells, surface waters and soils surrounding well sites; and that air emissions from drilling sites, well heads, compressor stations, pipelines and other oil and gas field infrastructure contribute to air quality concerns.

Dust particles left from drilling may coat the surrounding areas, and flames from burning the natural gas found in oil fields cause air pollution. Gaseous emissions include CO, $S0_2$, NOx, hydrocarbons and particulate from gas flare. Also, oil spills, accidents, and illegal dumping of oil barrels and produced water lead to devastating ecological and health consequences that can last for decades. Many of these chemicals (examples, arsenic, cadmium, mercury, lead, zinc and copper) are detrimental or deadly to aquatic animals as well as man.

Figure 2. A map of Ghana, showing the Western regional capital Takoradi, and the neighbouring countries. (Source: www.google.com.gh).

Entire ecosystems can dissolve as a result of oil contamination Earth works action, 2015; Rain forest foundation, 2015; Chand, 1990).

Offshore exploitation of oil may also lead to coastal pollution in case of massive oil spillage. In water, oil film on the water surface could prevent natural aeration and lead to the death of trapped marine organism. In some cases, fish may ingest the spilled oil or other food materials impregnated with oil and as such become inedible and unpalatable (Olujimi et al., 2011).

Socio-economically, offshore projects may impact fisheries livelihoods through activities onshore (Clers, 2007). Also, degradation of agricultural land which serves as source of income for the people coupled with social unrest arising from unpaid claims of compensation and lack of concern for the people in the exploration area by oil exploration companies is a major challenge in Africa (Olujimi et al., 2011).

Countries affected by environmental pollution as a result of oil exploration include Sudan, Nigeria, Ecuador, Colombia, Azerbaijan, Kazakhstan among others (Dabbs, 1996; Radio Tamazuj, 2015).

Globally, there has been numerous international instruments to curb negative practices on the environment such as halting the worldwide loss of animal and plant species and genetic resources made by major conventions formulated before and at the 'Earth Summit' in 1992. Others are the Montreal Protocol aimed at the phase out of ozone depleting substances and conventions on marine environment and on protection of migratory and endangered species (E & P Forum/UNEP Technical Publication, 1997).

Ghana's recent decision to join the Extractive Industries Transparency Initiative (EITI) is considered a step in the right direction, as this will provide the needed benchmarks that will ensure that natural resources in general are managed efficiently to accelerate growth rather than otherwise (Bank of Ghana Policy Brief, 2007). In addition, Civil Society groups in Ghana are calling on the government to fast-track the passage of the Marine Pollution and Petroleum Exploration and Production Bills into law, to minimize environmental pollution (Ghana web, 2014).

In Ghana, there have been reports already of small spillage occurring leading to controversial fines being imposed on Kosmos Energy by the Environmental Protection Agency (EPA) (Kwawukume, 2010). Since most of the effects on the environment are irreversible, there is therefore an urgent need to examine what is happening now and how best to find remedies so the future generations too will benefit from nature.This study was therefore conducted to critically review the interim implication of oil exploration activities on the Ghanaian environment.

The results will clearly describe the extent of air, noise and visual pollution as a result of oil exploration after 2 years of operation.

METHODOLOGY

Description of the study area

The study was carried out in Half Assini and Efaso in the Jomoro District of the Western region of Ghana. Ghana lies in the center of the West African coast and shares borders with Côte d'Ivoire to the west, Togo to the east, Burkina Faso to the north and the Gulf of Guinea to the south (Figure 2).

Half Assini has geographical coordinates of 5° 3' 0" North, 2° 53' 0" West. It is the capital of Jomoro district which is located at an elevation of 70 m above sea level; with a population of about 8000 is a town with the landscape dotted by many coconut trees. The main occupations of the people is farming and fishing. Commerce and industrial activities also constitute the economic backbone of the area. The community has electricity, running water, markets and a hospital (Ghana Statistical Service, 2012; Hada Italy, 2015,Get a map, 2015) (Figure 1).

Efaso is a community 150 km west of Takoradi, the regional capital. It is a community located near the beach, thus, fishing and petty trade is paramount. The community is less developed compared to Half Assini but the Osagyefo Barge power plant is located there (E & P Forum/UNEP Technical Publication, 1997) (Figure 1).

Research design

The research design employed in this study was mixed (qualitative and quantitative) research. An interview and a questionnaire were

Table 1. Distributive results of variables used in analysis.

Discrete variable	Frequency	Percentage (%)
Perception on change to adverse environment		
0= yes	117	39
1= no change	183	61
Perception on air pollution		
0= yes	126	42
1= no change	174	58
Perception on noise pollution		
0= yes	3	1
1= no change	297	99

Source: Field survey, 2013.

used. It is common that a researcher use several research methods for a single research so that data from each method can supplement and check data from other methods.

Sampling procedure and sample size

The study employed a two stage sampling technique. Residents living in the Jubilee oil field environs (Half Assini and Efaso communities) were purposively sampled. After, simple random sampling was used to select 300 respondents of Half Assini and Efaso, out of about a population of about 8,000.

Data collection instrument

Both primary and secondary data were used. The questionnaire and interview schedule (primary data collection tool), literature review and internet search (secondary data) were employed for the collection of data.

Data analysis and interpretation

The Statistical Package for Social Sciences (SPSS) was used to analyse data. The multinomial logistic regression model was considered suitable for this kind of analysis because it helps to understand and explain relationships among variables and predicts actual outcomes. When the logistic coefficient is positive, it shows a positive relationship between the variables and vice versa. Also, it shows the significant relationship between variables (when $p \leq 0.05$ it is considered significant and vice versa).

In examining the interim environmental influence of oil exploration on human lives, the multinomial logistic regression model was used in the analysis. The factors of adverse environmental change as a result of oil exploration considered in the study include air, noise and visual pollution. The likert type attitudinal question: 'there is an adverse environmental change, do not know and no adverse environmental change' was used to show respondents' perception concerning a particular factor of adverse environmental change. Qualitative analysis (by observation and interview with residents) catered for the analysis of visual pollution.

Air, noise and visual pollution were considered in this study because most oil exploration activities face these challenges, thus, the Jubilee Oil is no exception. The other factors of environmental pollution as a result of oil exploration (land, thermal and water pollution) were ignored in this study. Though they may have an influence on the lives of residents, it is currently secondary, that is, the impact can only be realized after decades. Since this study was done after two years of oil exploration, the other factors will not be clearly visible to have any influence on residents.

ANALYSIS AND DISCUSSION

The survey and interview findings were analyzed and discussed. It provides a brief overview of the respondents' perception of oil exploration's influence on their environment.

Perception of residents on influence of oil exploration on the environment

In any phase of oil and gas exploration, there is a peculiar primary impact on the environment and these impacts are driven by the release of emissions, discharges, collisions and physical destruction of the seabed and land.

One ecological impact from the offshore oil and gas industry arises from the loss of habitat and biodiversity due to the construction and installation of subsea infrastructure. Such installations do not only directly destroy the habitats but also give rise to suspended particles which can either smother certain species (Amoasah, 2010). Apart from the influence oil exploration has on the flora and fauna, there is also an influence on man.

Table 1 shows the distributive results of variables used in the adverse environmental change analysis. Thirty nine percent (39%) of the respondents confirmed an adverse change in the environment whilst 61% disagreed. Adverse environmental change may not be noticed for a long period of time, thus this result is not so alarming. Factors of adverse environmental change as a result of oil exploration considered in the study include air, noise and visual pollution. Table 1 gives more details of the results.

Table 2. Estimation of adverse environmental change as a result of oil exploration.

Multinomial logistic regression		**Number of observations = 300**	
LR chi^2 (2) = 159.829		Prob> chi ^{2} = 0.005	
Log likelihood = 9.429		Pseudo R ^{2} = 0.413	
Environmental change			
Logisticcoef. Std. Err.	**P > z**		
Air pollution	3.568	0.357	0.000
Noise Pollution	17.978	0.000	0.484

Source: Field survey, 2013.

Further, the multinomial logistic regression model was used to estimate relationship between independent variables (air and noise pollution) and the dependent variable (adverse environmental change as a result of oil exploration).

Mathematically, the regression equation is given as:

$$\Pr(per_i = j) = \frac{e^{x\beta j}}{1+\sum_{k=0}^{2} e^{x\beta k}}$$

Where, *j = 1, 1.2;* $\Pr(per_i)$ is the probability that a household perceives an adverse environmental change; X is the vector of the explanatory variable, and β is a vector of parameters to be estimated (air pollution and noise pollution)

Perception of residents on adverse environmental change due to air pollution

Air pollution is the contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere. Atmospheric emissions are increasingly becoming the subject of concern to both industry and national governments due to its negative effect on the climate (Osei, 2011). Household combustion devices, motor vehicles, industrial facilities (example, being oil exploration) and forest fires are common sources of air pollution. Air pollution may cause respiratory and other diseases, which can be fatal (World Health Organisation, 2013).

Table 1 shows the perception of respondents concerning air pollution as a result of oil exploration. Forty two percent (42%) confirmed air pollution is increasing in their community whilst 58% did not agree. This is a surprise as the oil field is about 50 kilometers away from the two communities where the survey took place. This may be due to the fact that almost half of the residents (especially, in the Efaso community) are fishermen and fish mongers, hence they are always onshore which is closer to the oil field. Thus much impact of air pollution on them. Adverse environmental change due to air pollution has a 'cultural services' impact on the people as well. 'Cultural services'concern the benefits people derive from ecosystems through recreation, cognitive development, relaxation and reflection (Amoasah, 2010). Most of the respondents in Efaso expressed worry about the obnoxious smell at the beach after oil exploration began operation. Others also complained of terrible headaches when they stay at the beach for long hours. As a result, this has deterred them from relaxing and enjoying the cool breeze as they used to. With these comments from the inhabitants of Efaso, it can be affirmed that onshore air pollution impacts are being blamed on the oilfield. This supports a research done by the National Press Release (NPR) in the United States which speculates that as a result of toxic ingestion, many people suffer from skin rashes which require daily injections to prevent swelling, and chronic headaches. Also, fainting spells, vomiting and chronic diarrhea are common symptoms for those impacted by oil extraction. Long term health effects include: Lung disease, liver and kidney damage, damage to the nervous system, malformation, brain damage, miscarriages and many other devastating chronic conditions (Rain forest foundation, 2015).

The multinomial logistic estimation model (Table 2) revealed that the likelihood of the perception of air pollution's influence on the environment was positively and significantly related to oil exploration. This implies that air pollution has an adverse effect on the environment based on the perception of residents in study area.

Perception of residents on adverse environmental change due to noise pollution

The traditional definition of noise is "unwanted or disturbing sound". Sound becomes unwanted when it either interferes with normal activities such as sleeping, conversation, or disrupts or diminishes one's quality of life (US Environmental Protection Agency, 2013).

Studies have shown that there are direct links between noise and health of man. Problems related to noise include stress related illnesses, high blood pressure, speech interference, hearing loss, sleep disruption, and lost productivity. Noise Induced Hearing Loss (NIHL) is the most common and often discussed health effect, but research has shown that exposure to constant or high levels of noise can cause countless adverse health effects (Environmental Protection Agency, 2009). There has also been reported death, reduced growth, impaired hearing and stress, as some of the possible impact of noise from oil and gas operation (Fernández et al., 2005).

Apart from the influence on man, during oil and gas development noise disturbances associated with aircraft, bulk vessels and drilling operational activities are likely to impact negatively on the ecosystem. This may arise from prospecting and survey activities. At certain levels, noise affects the functions of marine organisms. Fish and marine mammals, including whales and dolphins, are particularly affected mostly by sound elevation because of their dependence on sound for reproduction, feeding, and avoiding hazards such as predators and navigation (Sakyi et al., 2012). It was not surprising that Ghana's marine environment is under threat as whales (and other marine mammals and turtles) continue to be washed ashore in the Western and Greater Accra regions since the oil and gas exploration activities began (Aklorbortu, 2013).

Critics are of the view that noise pollution among other factors as a result of the drilling activities might have caused this. Not less than 21 whales had been washed ashore. The EPA has not investigated the cause of the historic beaching of whales but consistently without any scientific grounds, dissociated the drilling of oil at the Jubilee Field from the raging discussion (Dadzie, 2015). This unfortunate situation may not promote a healthy relationship between the people in these regions and the oil companies.

Results from Table 1, shows that 1% of the respondents perceived that there is noise pollution as a result of oil exploration, but 99% disagreed. Oil exploration is being done offshore; hence there is not much noise onshore, in these communities. This is not unexpected due to the oilfield being 50 km away. Noise perceived as pollution was basically from helicopters that transport oil from the rig to Takoradi, the regional capital (Figure 2). However, there may be an influence of noise on the mammals in the sea as discussed.

A further analysis using the multinomial logistic estimation model (Table 2) revealed that the likelihood of the perception of noise pollution's influence on the environment was not significantly related to oil exploration.

Perception of residents on adverse environmental change due to visual pollution (sea weed-*sargassum*)

Waste disposal has become one of the main challenges of globalization. Developing countries are still in the transition towards better waste management but currently have insufficient collection and improper disposal of wastes. Clear government policies and competent bureaucracies for management of solid wastes are needed urgently especially in countries where there is rapid population growth through urbanization into peri-urban areas (Srinivas, 2012).

The main visual pollution observed in the study was sea weeds (Sargassum) along beaches of communities onshore in unusual quantities (Dadzie, 2015). Fishermen from these communities linked the 'blackened' colour of rotting *sargassum* to the recent commencement of oil production, calling on the government to discipline Tullow, the main company operating in the Jubilee Oil Field, and to compensate them accordingly (Ackah-Baidoo, 2013). They believe the sea weeds were uprooted as a result of the distraction of the sea bed in the course of oil exploration. But as discussed earlier no scientific research has been conducted yet by the EPA to confirm this.

On the other hand, representatives from the government and Tullow have countered by stating that the growing presence of *sargassum*, which is an important source of food for numerous aquatic species, has more to do with local fishing habits: that, it is a result of overfishing, not oil production (Ackah-Baidoo, 2013). Thus the real cause of the surging sea weeds on the beach is not known.

Disposing them is one of the greatest challenges in these fishing communities because they form a greater part of the fish catch volumes rendering the fishermen to lose out on income resulting in a gradual and disturbing decline in their livelihoods. Fishermen had no choice but to damp them all over the coast after the removal of fish for consumption and sale (Figure 3).

A complaint of weeds trapping nets and destroying them was also common. The fisher men spend most of their time to remove the weeds and debris from the nets.

When it comes to the community, the weeds are making most coastal communities uninhabitable and depriving them of humane relaxation and fresh breath. Residents cannot longer enjoy the serenity of the beaches endowed them. They also cannot enjoy their swimming as they are likely to have rashes. Some are now even complaining of eye problems. The weeds when left to decompose produces strong stench which they say makes life and pleasure unbearable. With tourism, no tourist will be attracted to unappealing piles of rotting seaweed along the beach. Resorts will have to spend more efforts and money maintaining their beaches or risk losing clients who come there as result of the serenity of the beaches (Kwofie, 2014).

CONCLUSIONS AND RECOMMENDATION

There are two sides to the natural resource coin, especially if it is an extractive resource like oil. One side

Figure 3. Evidence of visual pollution (sea weeds) on the beach of Efaso.

could be the beginning of a transformation, economically, for the country if the wealth is well-managed. Resource exploitation and exploration is always accompanied by various challenges usually environment-related, the second side of the coin. For the second side, a well-designed policy to manage, control and monitor the negative effect on the environment is important.

Operations on oil exploration began in December, 2010, hence its environmental effects may not be seen vividly after just two years of operation; it may take decades to be able to assess its long term implication on the environment. This notwithstanding, the major findings from the study are that communities perceived there is air pollution due to oil exploration and experienced head ache as a result of the obnoxious smell of oil when they stay onshore for long hours.

The influence of noise pollution was not felt much since oil exploration is done offshore (50 km away from communities of study). However noise from helicopters conveying oil from the rig to Takoradi was a little disturbance to residents. In addition, noise pollution is believed to have an effect on the marine mammals as it disturbs their functions. Last but not the least; visual pollution was also observed in the form of sea weeds onshore which have diverse adverse effects on fishermen, the community and tourism.

It is recommended that in order to minimize air pollution, there is a need to establish a citizen advisory council that conforms to international standards of conserving the environment.The Government and oil industries should actively involve major stakeholders (including fishermen, tourism operators, scientists and conservationists) in order to deal with this complex environmental issue. Such a practice can help to avoid or minimize a lot of mistakes that have been made in the past and from other oil exploration countries.

When it comes to visual pollution, there is an urgent need to dispose the sea weeds onshore. This can be done by the collaboration of the Government, the oil industries, waste disposal firms (such as ‘Zoom lion’) and the community members.Sustainable development is needed globally. It dwells on the capacity to improve the quality of human life while supporting ecosystem.There will also be a need to do an extensive research conducted by the EPA, verified by civil societies, and resourced personnel not only to ascertain the nature of the weeds but also how it can be transformed and recycled to benefit farmers as it is believed that it can be used for manure.

Conflict of Interest

The authors have not declared any conflict of interest.

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Vol. 7(8), pp. 109-114, October, 2015
DOI: 10.5897/IJWREE2015.0595
Article Number: 6838A3655749
ISSN 2141-6613

http://www.academicjournals.org/IJWREE

International Journal of Water Resources and Environmental Engineering

Full Length Research Paper

Assessment of contribution of major rivers inflow into the Dongting Lake, China

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Received 30 June, 2015; Accepted 24 September, 2015

The development associated with rapid industrialization and urbanization in Dongting Lake region has been more complex due to large water demand. Therefore study of water variation within the lake region is necessary for wetland protection, conservation and its sustainable management. In this study monitoring of different Hydrological Control Stations, the calculation and analysis was carried out over 2014 based on hydrological data. The results indicated that seasons are the typical main driving factor for water variation in the Dongting Lake; among the rivers, Xiang, Zi, Yuan and Li (also known as "Sishui") accounts for the major part of the inflow discharge into the lake, and therefore the overall trend is featured by a flow pattern from the southwest to the northeast (Chenglingji outlet). The results also indicated that the inflow discharge of major rivers (Li, Yuan, Zi and Xiang) dominates other rivers with approximately 58% input to the lake. On the other hands the discharge from Yangtze River is very low in dry season from December to February, and it becomes high up to the maximum level of 28500 m^3/s during flood period from June to September which is approximately 42% of its annual inflow amount. Similarly, the annual input comparison between Yangtze River and major rivers showed that the large amount of inflow from Yangtze is observed from June to September, which accounted 76% of its total annual inflow to Dongting Lake. While the high inflow from major rivers is observed from May to August, which is estimated at 60% of the major rivers total annual inflow to Dongting Lake. This study has important practical significance for sustainable development of the water management in the Dongting Lake Basin.

Key words: Rivers, Dongting Lake, hydrological control stations, inflow discharge, Yangtze River.

INTRODUCTION

Dongting Lake has served as an essential buffer zone in times of flood, receiving excess water from Yangtze River; which is China's mightiest river and protecting many downstream. In recent decades however, the lake has shrunk dramatically, causing scientists to begin investigating the causes of these changes and their effects on one of the country's most important lakes. "150 years ago, it was 6,250 km^2. 60 years ago, it was 4,350 km^2. Now, it is 2,625 km^2", commented Jiang Yong, on the area of the lake. He also mentioned that, Mud and sand keep silting up in the south of the lake. Therefore the capacity of the lake storage is becoming smaller

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(Sean, 2010).

Flood and waterlogged disaster are frequent and serious, drought disaster occurs sometimes and meteorological disaster is diversified; finally, wetland resources have degraded and ecological balance has been badly shaken. Flood and waterlogged disaster in the Dongting Lake is due to the influence of artificial and natural factors such as abnormal atmospheric circulation and influence of land use change. Gradual loss of biodiversity and disturbances in ecological balance are due to the ecological succession from sand deposit to vegetation, over-fishing, over cultivation of beach area, water pollution and breaking of the return course of fishes by hydraulic structures (Mao and Xia, 2002).

Contribution of the lake in meeting the water demand of the region: Dongting Lake is a multi-use water body. It can be used for drinking water, flood control, shipping, waste disposal, fisheries, aquaculture and irrigation, and also can be used as a source of tourism and recreational activities. Rapid sedimentation of Dongting Lake causes difficulties for water storage and flood control. In the summer 1998, China experienced the worst flooding in 40 years along the Changjiang River and caused many damages (Spignesi, 2004). To reduce damages in the future in the Changjiang River Basin, the Chinese government adopted a new policy, “return land to the lake”, which trends to increase the water storage to buffer the flood during flood season, over half million people living inside diked lands were relocated in the following five years and the lake area was increased by about 779 km^2 (WRBHP, 2002).

The full development and utilization of water resources of this area reflect to the economic development and maintenance of ecological balance (Wan et al., 2012). The lake water was oligotrophic in 1960s, but the increased anthropogenic inputs into the lake have resulted in the deterioration of its water quality in many parts of the lake. In 2005, the arsenic and cadmium poisoning events took place in the Li River, a branch of the Xiang River, and in the lower reaches of the Xiang River, respectively (Hunan Water Administration, 2006). During the summer when water temperature becomes high enough to activate decomposition of organic matter, a great amount of inorganic nitrogen and phosphorus accumulated in the sediment regenerate into the water to supply with nutrients that prompts the phytoplankton growth. Enhanced production of organic substances in the water due to phytoplankton growth not only results in the water pollution, but also brings about serious environmental problems such as occurrence of water bloom, depletion of dissolved oxygen in the bottom water and drastic change in the aquatic biota or ecosystem. Dongting Lake Basin heavily populated with 10.08 million of people (EPD, 2010), it is also one of China’s leading rice-producing regions; it is also known for cotton and fish production. Dongting Lake was China’s largest lake during the Han dynasty.

Actually it is the China second-largest flesh water lake and it is divided into three parts; East Dongting Lake, South Dongting Lake and West Dongting Lake. It is inextricably linked with the Yangtze River in its Northern part through Songzi mouth, Taiping mouth, and Ouchi mouth of the Yangtze River runoff bleeder, and has four river system supply the "Li, Yuan " and "Zi, Xiang" river in Eastern part and Southern part respectively. The Dongting Lake joins again the Yangtze River at its outlet at Chenglingji (Du et al., 2001). The rich sediment of the marshland attracted farmers, and several embankments were built to keep out the Yangtze River and to gain more farmland. Unfortunately, silting of mud and sand in the lake, in addition to the anthropogenic environmental transformations in the lowland areas, reduced the lake area and its storage capacity and caused rapid deterioration of the lake’s flood diversion and flood storage functions. This diminishing capacity increased the occurrence of flood disasters, mainly because of the rupture of embankments. Until 1998, the lake had 228 embankments and was surrounded by a farmland area of 0.34 million ha. After a disastrous flood in 1998 that took a death tool of 3,656 deaths, made 378,000 persons homeless, and resulted in an economic loss of US $737 million, the State Council of the People’s Republic of China formulated a policy, the Return Land to Lake Program, to prevent flooding (Chen, 2002).

Therefore the objectives of this study were to identify Hydrological Control Stations, calculation of water inflow and outflow to the lake and yearly contribution of major rivers in order to estimate seasonal water variation in the lake region, which is important for its sustainable use and management.

METHODOLOGY

Study area description

Dongting Lake Figure 1, the second largest fresh water lake in China, lies in the middle reaches of the Yangtze River between 28º-30º 00' Latitude and 111º 00'-113º 30' Longitude Figure 2. It is fed by the Yangtze River via three outfalls (Songzi, Taiping and Ouchi), distributary channels, in the north; the Li River and Yuan River in the west; and the Zi and Xiang Rivers in the south. Floods are discharged into the lower Jingjiang reaches of the Yangtze River via the unique outlet at the Chenglingji hydrological station (Xue et al., 2012). The lake plays very important roles in maintaining water resources of Yangtze River and aquatic ecosystem equilibrium (Yang et al., 2007). The main flood season is from June to September and the lake wetland is inundated during this period. The lake water level decreases gradually and goes into the dry season from October. From April of next year, the water level rises again due to the flooding. The water level of Dongting Lake fluctuates greatly, about 12.9 m on average from 1955 to 2008, in a year. Dongting Lake also provides habitat for many protected species. The 3 natural wetland reserves, East, South and West Dongting Nature Reserves in this area are all recognized Ramsar sites, (Ramsar, 2005).

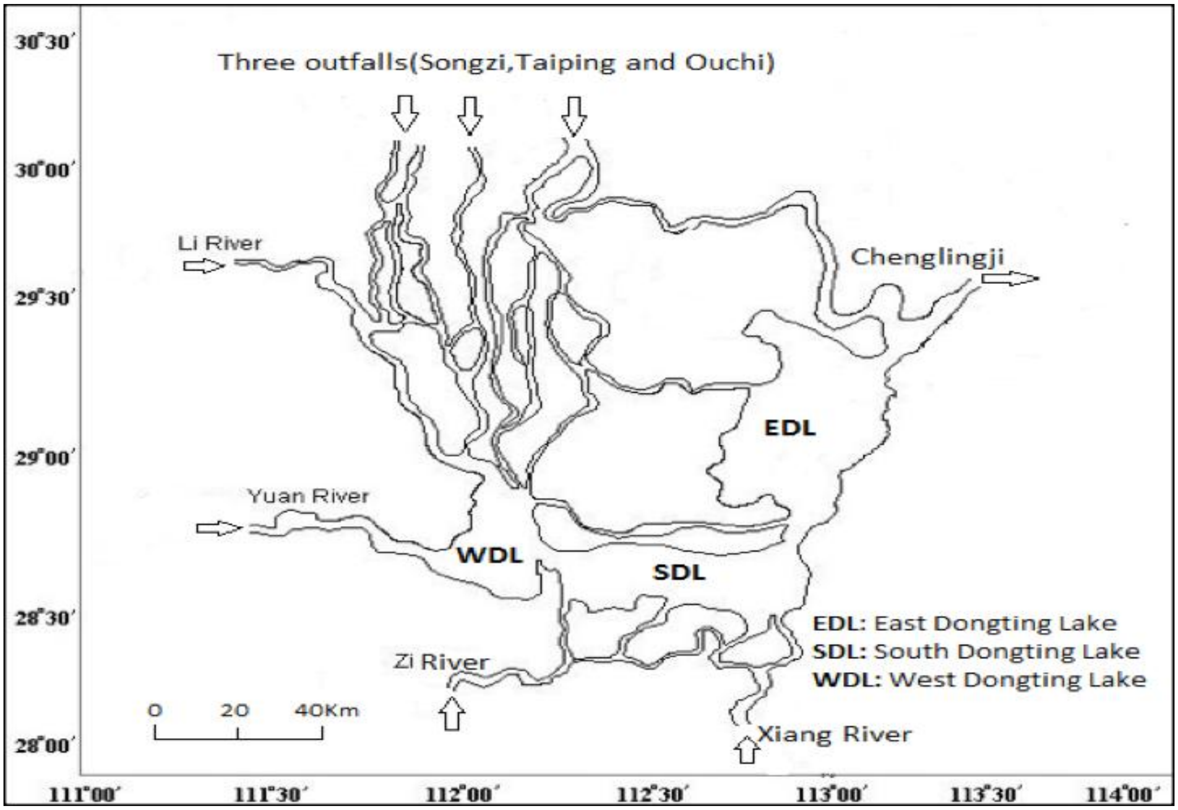

Figure 1. Dongting Lake rivers network system.

Table 1. Discharge at intake of the lake and outet of the lake in 2014.

River number	River name	Station	Annual discharge at intake (m^3/s)
1	Songzi	Songzi	318,881
2	Taiping	Gongan	478,332
3	Ouchi	Shishou	637,762
4	Li	Shimen	152,500
5	Yuan	Taoyuan	808,067.6
6	Zi	Taojiang	305,793
7	Xiang	Xiangtan	724,461
8	Chenglingji	Chenglingji (outlet)	3,164,048

Primary data review and compilation

In this study, the observation data from Dongting Lake Water Resources Administration Bureau of Hunan Province were used and 7 rivers from 1 to 7(Songzi, Taiping,Ouchi, Li, Yuan, Zi, Xiang) respectively were taken into account Figure 3. The water from Yangtze River flows into the West Lake through 3 outfalls (Songzi, Taiping and Ouchi) were collected at Songzi, Gongan and Shishou station respectively, and the flow from outlet in the Northern corner of East Lake at Chenglingji station as well as major rivers inflow to the lake: the Xiang, Zi, Yuan and Li observation data were also collected at Xiangtan, Taojiang, Taoyuan and Shimen respectively. In This paper, Daily discharge at 8: 00 AM from above Hydrological monitoring stations were used to calculate and analysis of water inlet and outlet of the lake without considering regional rainfall. From graphical analysis, the total annual inflow from Yangtze River and four major rivers were tabulated in Table 1 after compiling the daily data. This paper will also concentrate on comparison of inflow and outflow and provide annual seasonal discharge variation within Dongting Lake.

RESULTS AND DISCUSSION

The data from monitoring stations (as shown the Figure 4) were collected and analyzed. It consists of 3 outfalls as inflow from Yangtze River and inflow from other four

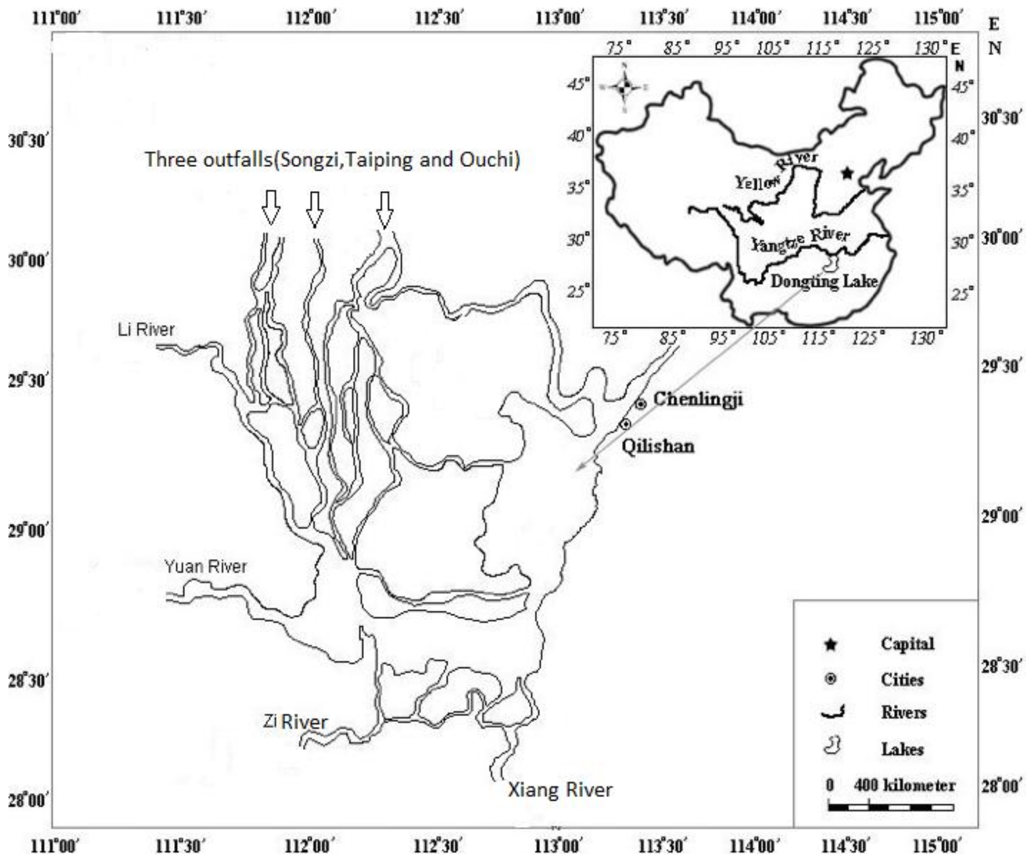

Figure 1. Dongting Lake location in China.

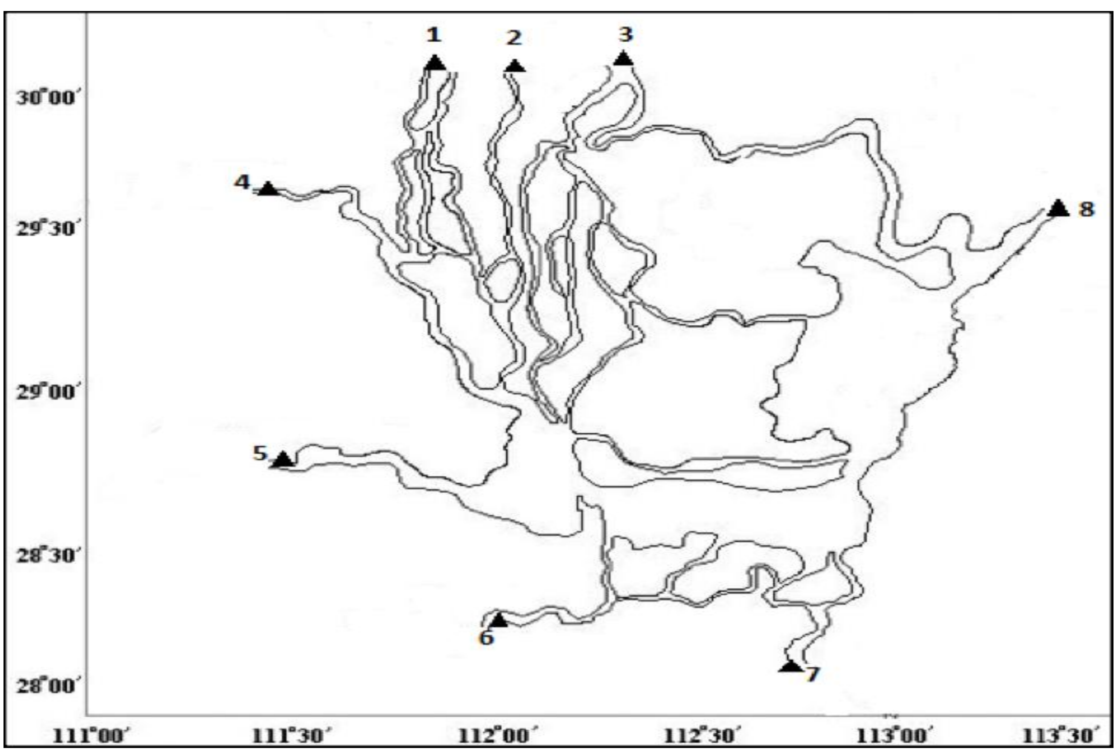

Figure 3. Location of considered monitoring stations for rivers.

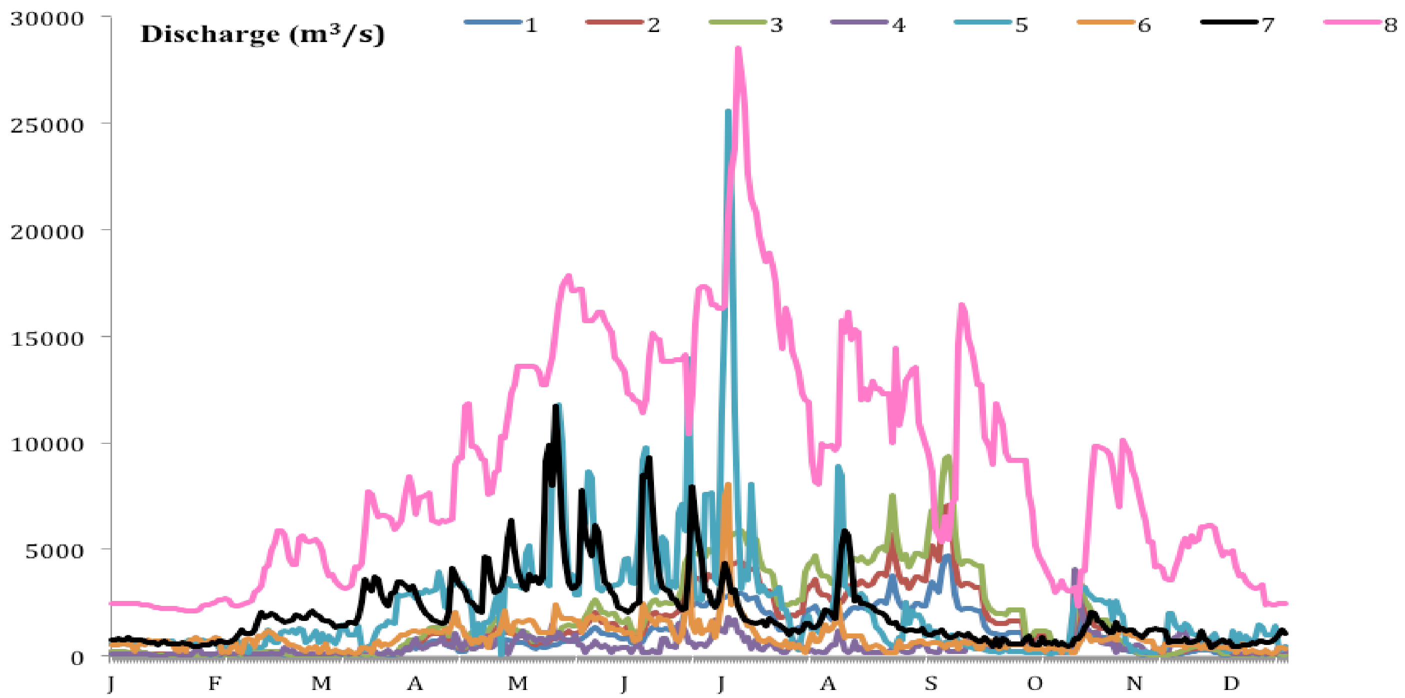

Figure 4. Annual discharge variation of the rivers in Dongting Lake in 2014.

rivers (Yuan River, Zi River, Xiang River and Li River) system.

From the Figure 4, the total inflow discharge of rivers is estimated to be 3.4 × 10^6 m^3/year. Hence, it is clear that the flood season of rivers 1 to 3 from Yangtze River is between July and October whereas the rivers 4 to 7(Li, Yuan, Zi and Xiang Rivers) is from May to August. In addition the input of major rivers (Li, Yuan, Zi and Xiang) dominates other rivers with approximately 58% of the total input though rivers. On the other hands the discharge from Yangtze River is remain very low in dry season from December to February, and it becomes high up to the maximum level of 28500 m^3/s during flood period from June to September which is approximately 42% of the annual inflow amount. Similarly, the annual variation of the total inflow and outflow discharge in 2014 is indicated in Figures 5 and 6.

The annual contribution of the inflow from Yangtze River and four major rivers (Li, Yuan, Zi and Xiang) was calculated. It is clear from the Figure 6 that the high inflow from Yangtze River is observed from June to September, which is accounted 76% of its total annual inflow to Dongting Lake. While the high inflow from major rivers was observed from May to August, which was estimated at 60% of the major rivers total annual inflow to Dongting Lake. Similarly, the Figure 5 indicated that the total inflow was high from May to August compare to the total outflow, this was due to the flood season in the region, and the inflow reduced from November to March compare to the outflow.

Conclusions

(i) The overall inflow to the Dongting Lake from the river 1 to 7 respectively flowing from the North of the lake to Southwest and then East North of the lake (Chenglingji outlet). This flows into Dongting Lake was the main driving factors related to water level variation and seasonal characteristics, and four major rivers (Xiang, Zi, Yuan and Li) occupy a major part of inflow into the lake Dongting as shown in Figure 6.
(ii) From Figure 5, it is clear that the total inflow is high from May to August compare to the total outflow; it reached 51790 m^3/s in July, this was due to the flood season in the region, and the inflow reduced from November to March compare to outflow. Therefore the water level in Dongting Lake was affected and that might cause the lake storage capacity crisis, the loss of biodiversity, Dongting Lake wetland degradation and biodiversity loss. As the region is known to be industrial area, agricultural activities with high population, to meet the water demand is critical issue. Hence, the strategies for water regulation should be put in place and maintained.

The water movement process of Dongting Lake in 2014 is then calculated using the monitoring data stations. The inflow extent in Dongting Lake fluctuates with the season. The inflow extent changes rapidly along seasonal variation, especially in the beginning of flood season. In dry season, the water inflow is mainly reduced and inflow extent reaches the yearly minimum. The Lake received a

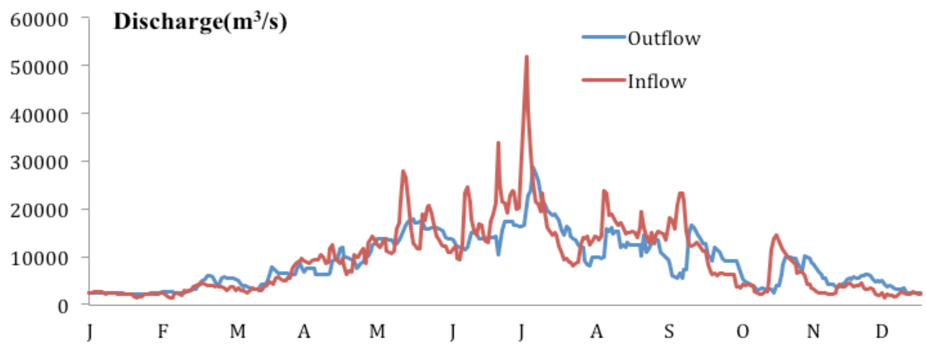

Figure 5. Dongting Lake annual inflow and outflow discharge of rivers in 2014.

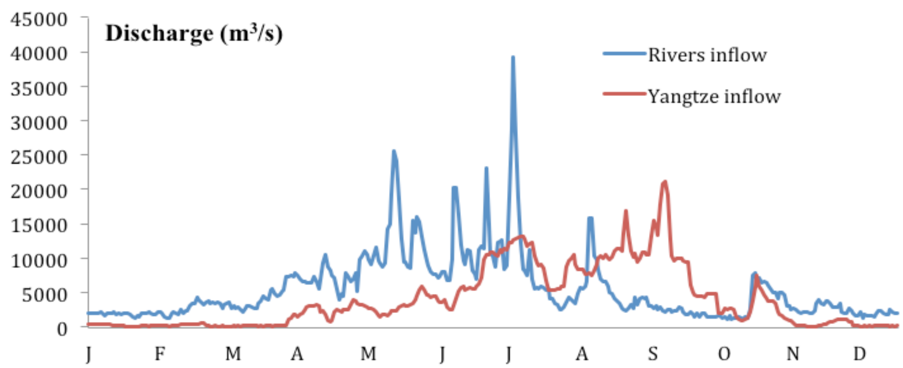

Figure 6. Annual inflow from Yangtze River and major rivers to Dongting Lake in 2014.

large amount of water in flood season and the maximum of inflow extent reaches. After the flood season, the lake exposes again with the gradual decrease of water inflow.

Conflict of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGMENTS

This study was supported by The National Science Fund of China (41272249), Research Fund for the Doctoral Program of Higher Education of China (20110072110020). Also, many thanks to the Chinese Government for a great opportunity to study in China.

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International Journal of Water Resources and Environmental Engineering