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Review

Water quality problems, related challenges and their impacts on Ethiopian fishery

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The purpose of this review article is to explore the drivers of the water quality problems and associated impacts and mitigation schemes of the fishes and fisheries in Ethiopia. Data were obtained from both published and unpublished online documents as well as from different Ethiopian universities and institutions. The country has the potential to produce more fish yield (94, 500 ton/year. The published and unpublished documents stated that the fishes and water bodies utilized are under stress such as textile industry, floriculture industry, tannery industry, high population growth, irrigation, application of agrochemicals, deforestation around the watershed, types of fishing gears, fishing methods, socio-economic factors, lack of facilities and infrastructure, ineffective administration setup, invasive weeds, land use around the fish habitats. However, the demand for fish is increasing at an alarming rate time to time. For this reason, good management setup for stakeholders particularly those communities settled around the watershed awareness is critical to sustain fish and water resources for the upcoming generation in the country.

Key words: Ethiopia, fishery, management, watershed, water quality.

INTRODUCTION

Ethiopia is endowed with inland aquatic ecosystems including lentic and lotic water bodies namely the Rift Valley, Abay, Awash, Baro-Akobo, Omo-Gibe, Tekeze and Wabishebele-Genale drainage basins (Awoke, 2015; Utaile and Sulaiman, 2016). Ethiopian important commercial fishes were widely distributed in the aforementioned drainage basins (Golubtsov and Mina, 2003). Besides this, these drainage systems consist of diverse indigenous fishes; they are highly productive and contribute to the local and national economy (Reyntjens et al., 1998; Tudorancea and Taylor, 2002). In addition to fish production, the water bodies are the habitats of aquatic biota like plant (flora) and animal (fauna) biological communities. However, recently the aquatic lives including fishes are affected due to the alteration of water quality. Water pollution is a global problem and it needs urgent attention (Abrehet et al., 2015; Ali et al., 2008). Human induced activities that lead to aquatic pollution, number of industries, agricultural and commercial chemicals discharged into the water bodies cause various deleterious effects on the aquatic biota (Ali et al., 2008). Fishes can accumulate pollutants directly

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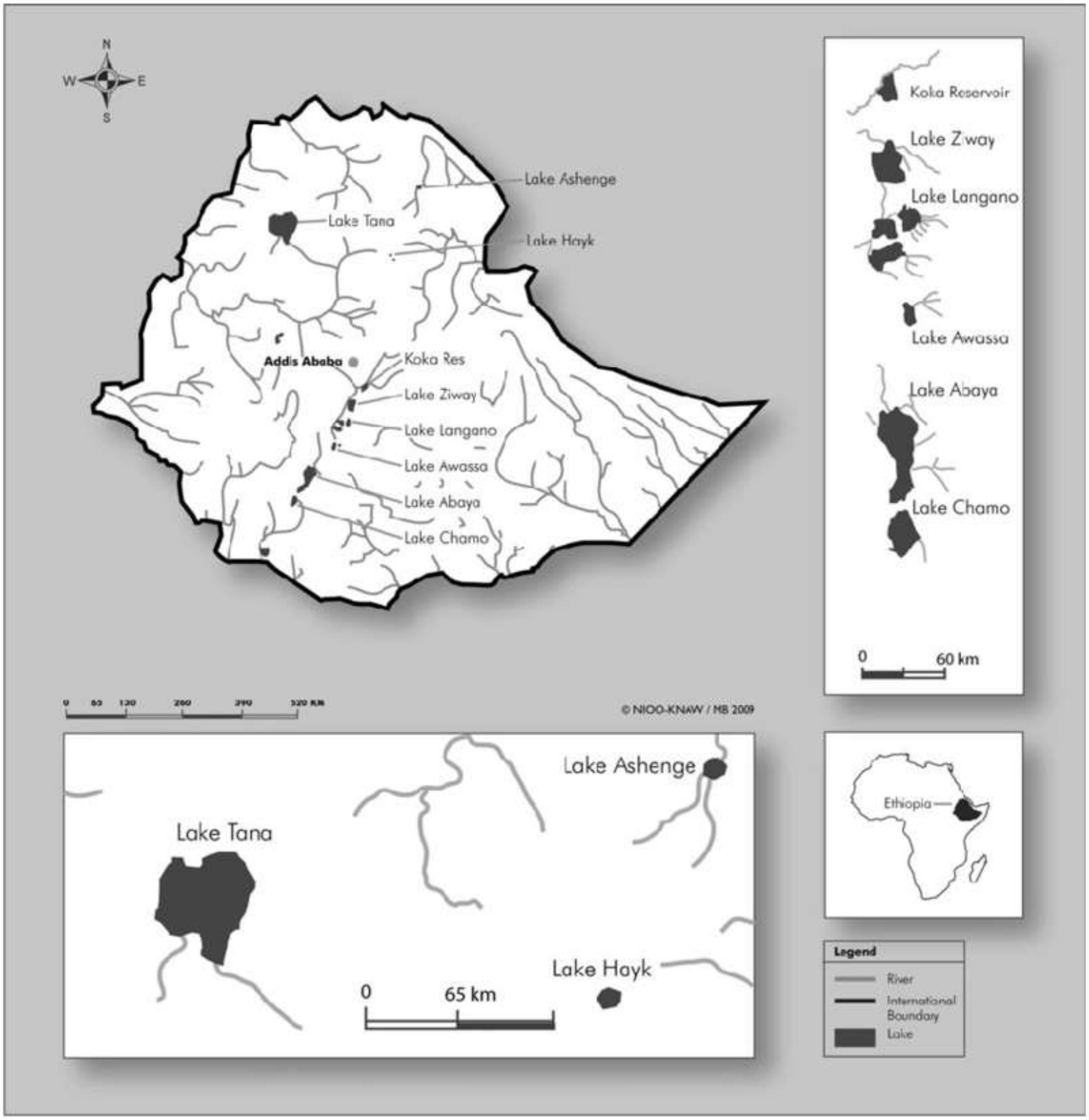

Figure 1. Some of the Ethiopian lakes.
Source: (Tesfaye and Wolff, 2014).

from the water sediment or indirectly from contaminated water and through the food chain (Dawodu et al., 2015; Desta et al., 2006). In other words, the water quality parameters such as salinity and turbidity reveal increasing trends due to anthropogenic activities within the catchments and having drastic effect on fish production (Utaile and Sulaiman, 2016). Various studies have been conducted on human activities and their impacts in Ethiopian water bodies (Yohannes et al., 2013; Worako, 2015; Berehanu et al., 2015) such as Lake Hawassa (Utaile and Sulaiman, 2016), Lake Chamo, (Desta et al., 2015; Desta et al., 2017), Lake Ziway (Goshu and Aynalem, 2017; Gebremedhin et al., 2018), Lake Tana, (Abrehet et al., 2015), Blue Nile River (Minuta and Jini, 2017), and Walleme River Southern Ethiopia (Figure 1). Good water quality plays an important role in wild fishes and aquaculture development in the country (Utaile and Sulaiman, 2016). There is little or no compiled information on the causes of water pollution and its impacts on Ethiopian fisheries. Therefore, this review paper aims to fill this gap and provide useful information for the proper management of water bodies and fishes for

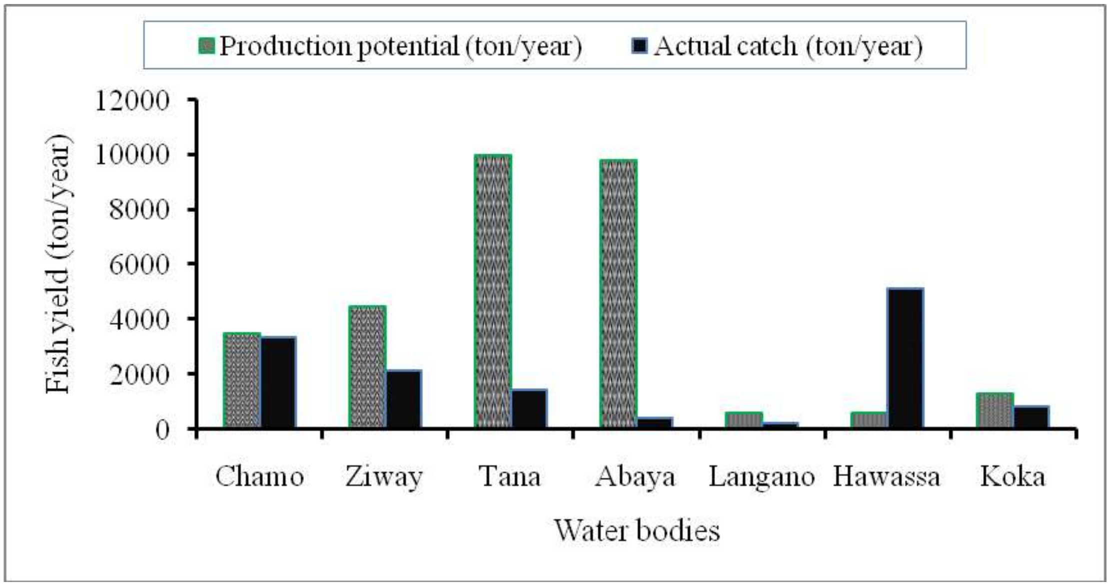

Figure 2. The production potential and the actual exploitation rate (ton/year) of fish in major Ethiopian lakes. Source. (Janko, 2014).

continued fishing in Ethiopian water bodies.

MATERIALS AND METHODS

A range of literature sources used for this review were collected from August 2018 to October 2018; they include journal articles (from the Internet data bases), workshop proceedings, FAO reports, bulletins, legal documents, (from University libraries and Ethiopian Ministry of Livestock and Fishery).

Production potential, catch and challenges of fishes in the water bodies of Ethiopia

Fishery in Ethiopia only depends on inland water systems (Janko, 2014). Accordingly, the country has the potential to produce 94,500 ton/year (FAO, 2012). However, the actual exploitation of fish production is 15,389 ton/year (Janko, 2014). In other words, only 31% is being utilized. For instance, Lake Abaya and Lake Tana have the potential to produce 9800 ton/year and 10,000 ton/year of fish yield respectively (Figure 2). However, the exact exploitation of the capture fishery is less when compared to the production potential of Ethiopian water bodies. This is might due to several reasons. Vijverberg et al. (2012) pointed out that habitat degradation and destruction are the main causes of fish stock depletion of freshwater fishes and this why fish population differs per water body, even from habitat to habitat. Sustaining species richness is one of the main issues of conservation in fisheries biology. So, that site specific management is vital in fishery biology and fish community conservation.

Major lakes contribute a total of 23,342 ton/year production potential and catch 10,598 ton/year. Major reservoirs and dams have production potential of 4399 ton/year and 1366 ton/year of catch. Rivers have the potential to produce catch of 21,788 ton/year and 3121 ton/year. Even, small water bodies have the potential to produce 1952 ton/year and 303 ton/year of the actual exploitation fish stock (Janko, 2014) (Figure 3). According to Goshu and Aynalem (2016), the drawbacks of unsustainable fisheries utilization in Lake Tana were the introduction of monofilament gillnet that has a mesh size less than the recommended one (less than 10 cm mesh size), habitat destruction, targeting spawning aggregation of migratory fishes at river mouths, pollution from the basin, sedimentation, hydrological regime change, invasive weeds, urbanization, and use of fish poisonous plants like *Millettia ferruginea*, which massively kills fishes of different type and age groups. Moreover, the challenges of Ethiopian fisheries and fishes are summarized as types of fishing gears, fishing methods, socio-economic factors, lack of facilities and infrastructure, ineffective administration setup, lack of expertise, land use around fish habitats, and lack of scientific data (Temesgen and Getahun, 2016).

Causes of water pollution, related challenges and the consequences on Ethiopian fisheries

Aquatic ecosystems are important for different communities such as irrigation, livestock watering, fisheries and recreational purposes. Moreover, greater than 183 fish species are found in Ethiopia. The production potential of the Ethiopian water bodies is

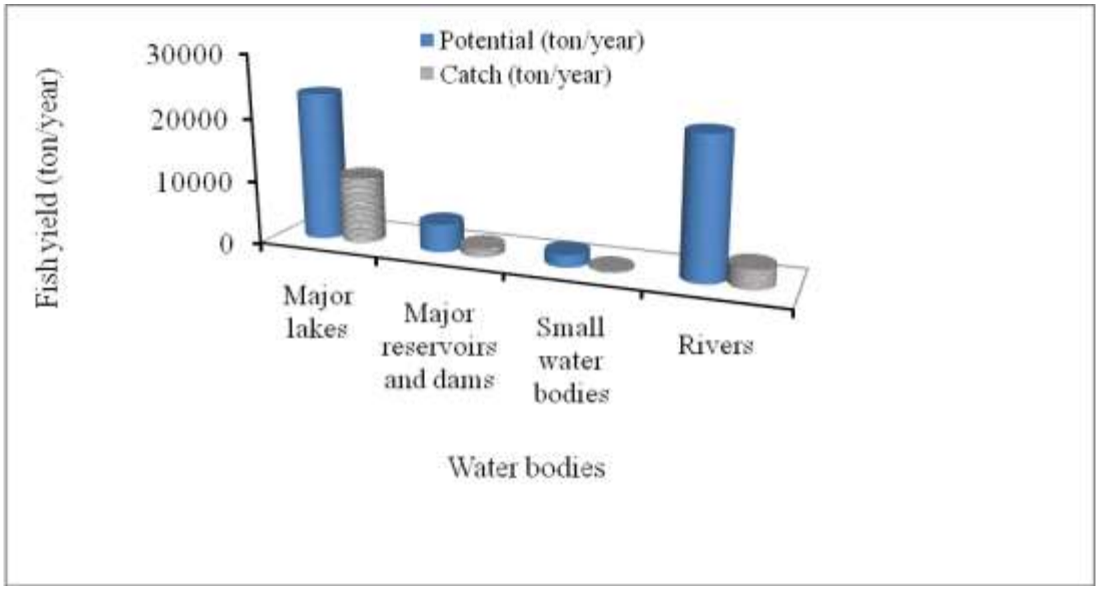

Figure 3. The production potential and the actual exploitation rate (ton/year) of fish in major and small Ethiopian water bodies.
Source: (FAO, 2012; Janko, 2014).

assumed to be 94,500 tone/year (Tesfaye and Wolff, 2014). However, only 31% is being utilized. Here are some of the major findings in this review that water pollution challenges in Ethiopia lead to less utilization and accessible with regard to fish and fisheries.

Effluent discharges from the textile industries

Textile industries play significant role as domestic and national economy in the country. The effluents from the textile factories contain high amount of organic and inorganic chemicals and are attributed to high Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Dissolved Solids (TDS), pH, Total Suspended Solids (TSS) values, and low dissolved oxygen (DO) values as well as the color change of the given water body as reported by Abrehet et al. (2015). These make the textile industries one of the main sources of water pollution problems (Berehanu et al., 2015). For instance, a study made in Blue Nile River with respect to water quality parameters showed that the mean value of dissolved oxygen (DO) ranged from 3.7 mg/L at the site of waste water outlet of the Bahir Dar textile factory (Abrhet et al., 2015). Several studies also showed that dissolved oxygen level of textile effluents is low and varies from 0.42 to 4.60 mg/L, with mean values of 2.36 (Mohabansi et al, 2011), 4.8 - 8 mg/L (Sultana et al., 2009), 0.4 mg/L (Knat, 2012), and 0.28-5.12 mg/L (Abraha et al., 2014). The high value of the Biological Oxygen Demand (BOD) at the site of waste water outlet of the Bahir Dar textile factory is probably due to high content of organic load, and the high levels of BOD are also indicators of water pollution as documented by Abrehet et al. (2015) (Table 1). The authors have concluded that the textile factory (Bahir Dar) causes serious pollution to the aquatic habitat of the head of Blue Nile River. Therefore, there is a need to monitor (treatment) of the effluents before releasing into water bodies because these water bodies are important for the socioeconomic purposes such as drinking, fishing, bathing, and irrigation. Similar study was conducted at the Hawassa Textile Industry. The effluent contains severe toxic organic and inorganic compounds and this in turn can damage the aquatic biota including fishes. Based on the report of Lake Hawassa textile factory, effluent contains high COD (3 times higher), and TDS (19 times higher); moreover, PO_4^{3-}(39 times higher) was recorded in the textile effluent compared to the maximum permissible limit standardized by the Environmental Protection Agency (EPA, 2003) (Table 1).

The evidence is, the effects of textile factory effluents (5, 10 and 20% concentration levels) on the survival of tilapia fish fry killed high proportions of fish (65, 86.8 and 88.7%, respectively) compared to 16.1% mortality at 1% concentration level of the textile effluent. However, this is not quite different from that of the mortality rate in the control pond containing lake water of 9.4% (Berehanu et al., 2015). Besides, the consumption of the African big barb *Labeobarbus intermedius* whose catch is mainly from the rift valley lakes like Lake Hawassa and Lake Koka has declined. Desta et al. (2006) noted that the fish is found to be unsafe for human consumption due to its high mercury concentration, and the authors recommended

Table 1. Mean values of chemical parameters and some heavy metals in textile effluent reported by different investigators in relation to the maximum permissible limit prior to discharge to the environment (Zinabu and Pearce, 2003; Berehanu et al., 2015; Abay, 2007) at Hawassa textile factory and (Abrehet et al., 2015) at Bahir Dar textile factory.

Parameter	Berehanu et al., 2015	Abay, 2007	Abrehet et al., 2015	Maximum permissible limit (EPA, 2003)	Parameter	Berehanu et al., 2015	Gebre-Mariam and Desta, 2003	Maximum permissible limit (EPA, 2003)
Chemical Oxygen Demand (COD) mg/L	400	5183	-	120	Co (µg/L)	10.7	0.3	1000
Dissolved Oxygen (DO) mg/L	0.75	-	3.7	NS	Cr (µg/L)	2.3	17.7	1000
Nitrate (NO^{3-}) mg/L	5.3	17.8	-	50	Pb (µg/L)	28.1	0.4	500
Total Nitrogen (TN) mg/L	40	353.8	-	40	Cd (µg/L)	0.12	1.6	1000
Electrical conductivity (µS/cm)	3030	5455	1050	1000	Zn (µg/L)	41,000	8.9	5000
Phosphate ($Po^{3-}{}_4$) mg/L	386	9.84	-	10	Fe (µg/L)	1500	131.9	1000
Sulphate ($SO_4{}^{2-}$)	0.052	136.3	-	200	As (µg/L)	0.69	10.6	250
pH (pH Units)	-	-	8.4	5 – 9	Hg (µg/L)	0.32	3.8	1.0
Temperature (°C)	-	-	25.2	40	-	-	-	-
Total hardness (mg/L)	-	-	88	NA	-	-	-	-
Total dissolved Solid (TDS) mg/L	1530	3818.5	612.3	80	-	-	-	-
Biological Oxygen Demand (BOD) mg/L	-	-	40.3	40	-	-	-	-

*NS-not specified, NA-not Available.

that higher Hg burdens significantly cause neurotoxin connected with human health and this is a result of poor water quality (pollution) caused by textile, ceramic and soft drink factories waste effluents discharged near the watershed of Lake Hawassa. Probably, high accumulation of mercury is associated with food chain. This dietary study on big barbs in different water bodies showed that the ingestion of detritus, sand particles and benthic food items indicates the ability of the species to live in benthic habitats and ingest sediments.

Effluent discharges from the tannery industries

The leather industry makes significant contribution towards economic growth, development, employment and generally poverty alleviation in the field of leather manufacturing. Nevertheless, it contributes huge amount of pollutants to the environment. For instance, total dissolved solid (TDS), Chromium (Cr), Sulphide, Chloride, total suspended solid, COD and BOD contribute 17000-21000 mg/L, 200- 250 µg/L, 240-300 µg/L, 9000 -11000 mg/L, 8000-10000 mg/L, 11000-13750 mg/L, 4600-5000 mg/L of the total pollution load of the Ethiopian tanneries per year respectively (Birhanu, 2017). The mean value of the parameters of the wastewater have shown that, majority of them were above the standard permit limit set by Environmental Protection Authority (EPA, 2003) (Table 2). Accordingly, excess pH of wastewater is not tolerable, e.g high pH values were recorded at Hora (10) and Gelan (11) tannery factories. Excess pH causes problems for aquatic life to survive in aquatic habitats (Birhanu, 2017) and fishes may die if 5 > pH > 10. The remaining factories such as China - Africa, Friendship, Modjo, Farida, Colba, and Bahir Dar have pH values ranging from 6-9 based on the EPA standard guideline. The discharge of the total suspended solid (TSS) is higher in all factories compared to the maximum limit set by EPA (50 mg/L). In the same way, it is extremely higher at Friendship Tannery accounting for 3687.5 mg/L followed by Modjo Factory (2100 mg/L). Suspended solids are floating substances and have the ability to remain in water bodies under suspension. They can reduce the net primary production by blocking solar radiation (Utaile and Sulaiman, 2016). Phosphorus or phosphates are the main factors that influence the water quality, and the standard limit set by EPA is 10 mg/L. But, large amount of Phosphates is recorded at all tannery factories; it is extremely higher at Modjo estimated to be 215 mg/L

Table 2. Mean values of chemical and physical parameters in nine tannery factories effluent reported by different investigators in relation to the maximum permissible limit prior to discharge to the environment (Abrehet et al., 2015; Birhanu et al., 2017).

Parameter	Tanneries									Maximum limit (EPA, 2003)
	China- Africa	Friendship	Modjo	Hora	Mesako	Farida	Gelan	Colba	Bahir Dar	
pH	6.5	7.4	8.5	10	9	7.5	11	7.3	7.15	6-9
Total suspended solid (mg/L)	265	3687.5	2100	1520	690	1150	240	740	339	50
Phosphate (mg/L)	20.6	41	215	183	90	185	30	135	-	10
Ammonia (mg/L)	126.3	63.75	174	69	476	416	684	352	228	30
COD (mg/L)	1424	1700	6450	2605	3775	5950	3740	3650	850.8	500
BOD (mg/L)	1280	580	960	1840	1670	1900	2000	1480	342	200
Temperature (mg/L)	-	-	-	-	-	-	-	-	25.2	40
Sulphides (mg/L)	1.161	4.54	25.3	4.88	106.5	159	100.3	194	16.05	1
Conductivity (μS/cm)	-	-	-	-	-	-	-	-	3953	1000
Total dissolved solids (mg/L)	-	-	-	-	-	-	-	-	2003	80

followed by Farida comprising 185 mg/L and Hora consisting of 183 mg/L. The Ammonia (NH_3) values of the effluent discharges of the tannery industries are extremely higher than the EPA standard permit limit (30 mg/L). The recorded values range between 63.75 - 684 mg/L; however, higher values are obtained at Gelan factory estimated at 684 mg/L followed by Mesako accounting for 476 mg/L and Farid consisting of 417 mg/L of the total NH_3 load. The Biological Oxygen Demand (BOD) values range between 580-2000 mg/L; higher values were recorded at Gelan (2000 mg/L) and Farida (1900 mg/L) of the total pollutants discharged. The implication is the recorded high values of (BOD) are due to high concentration of organic pollutants. Discharging of the high BOD level into the environment has severe impact on aquatic biota including altering of water quality. This is because it promotes the growth of bacteria, which increase the demand of oxygen. This in turn decreases the concentration of dissolved oxygen, leading to mass mortality of aquatic organisms including fishes. Generally, the effluent from the tannery industries shows that the waste water effluents discharged into the aquatic environment are without or little adequate treatment. Excessive discharge of physic-chemical parameters like BOD, COD, TSS, phosphate and ammonia into the environment causes pollution in lakes, reservoirs and rivers. The potential environmental associated impacts include algal bloom (over algal biomass) and extreme poor water quality for the survival of river or lake aquatic system (Wosnie and Wondie, 2014; Birhanu, 2017) (Table 2).

Anthropogenic activities around water bodies and fish habitats

The Ethiopian lotic and lentic water systems are being exposed to serious ecological problems in relation to human activities (Temesgen and Getahun, 2016). Micro or macro habitat degradation is an urgent problem in most catchments of Ethiopian lakes and rivers. For example, 68.8% respondents around Lake Ziway said that the pollution of Lake Ziway is correlated with human activities (Desta et al., 2017). Of these, irrigation close to the shores or littoral zone of the lake (62%), deforestation at the watershed (57%), waste discharged into the lake (33%) particularly from Ziway floriculture industry, poor watershed management practices, particularly soil and water conservation activities (23%) are sources of water pollution. Based on the finding, the lake's fish stock is depleting through time and the possible challenges are water volume reduction due to water abstraction for irrigation and water supply (72%), siltation of the lake through soil erosion due to deforestation (71%), chemical pollution due to runoff from irrigated lands (65%), uncontrolled and excess fishing practices (54%) due to the increasing fishing population over time (86%), use of small mesh fishing nets (53%), lack of government control over fishing (31%), and lack of community involvement and sense of ownership of the lake (26%) (Desta et al., 2015). A study made in North-south gradient of Ethiopian lakes suggested that the major threats that contributed to the depletion of fish communities were overfishing, high sediment load and degradation of habitats (Vijverberg et al., 2012). Comparably, the diversion of River Awash for irrigation purposes (Abegaz et al., 2010), and water abstraction in Lake Zeway (Yohannes, 2003) and in Koka Reservoir (Hailu et al., 2010) for irrigation (during winter season) and floriculture are adversely impacting the water bodies. Moreover, municipal effluents (wastes) can affect the fish stock in Lake Hawassa (Fetahi, 2007). The sewage effluents consist of mixtures of chemicals like natural and synthetic hormones, alkyl-phenols, phthalates, bisphenol, pharmaceuticals and some pesticides (DDT). These chemicals interfere with the endocrine system of the fishes. Several adverse health effects in aquatic organisms have been attributed to developmental, neurological, endocrine and reproductive alterations (Dawodu et al., 2015).

Lake Hawassa has been exposed to environmental and ecological modification due to population growth and natural events. This is because around 50% of the water bed is filled with silt deposit and the lake’s storage capacity has decreased by 4%. The morphometric changes of the lake are caused by anthropogenic activities like urbanization and agricultural activities around the watershed of the lake (Abebe et al., 2018). In the same way, the head of Blue Nile River is facing serious problem of waste effluents (discharges) from Bahir Dar City. Agricultural activities, deforestation, soil erosion, sedimentation, wetland degradation, eutrophication, toxigenic bacteria, invasive weed, over-exploitation of fishes, fecal pollution, climate change, improper solid and liquid waste management, stakeholders’ conflict, lack of data base system, lack of environmental related policies and strategies and hydrological alteration are the recent challenges of Lake Tana (Gebremedhin et al., 2018; Goraw and Ayalem, 2017; Anteneh et al., 2010; Wondie, 2010). This is indirectly affecting the spawning site of *Laboebarbus* fish species that are endemic to Ethiopia (Anteneh et al., 2010; Wondie, 2010; Gebremedhin, 2014).Wetlands are a good site for fish production and they can also support other various aquatic organisms. Though, recently these water bodies are endangered due to several factors including human pressures, improper agricultural activities, nursery ground degradation, urbanization and industrialization and water diversion for irrigation throughout the Ethiopian wetlands (Hirpo, 2017).

Conservation of fishes and water bodies

Several authors documented that Ethiopia has 12 river basins, more than 9 lakes, more than 10 reservoirs or dams, more than 3 small water bodies or swamps (Janko, 2014; Hirpo, 2017). As seen above water bodies of more than 183 fish species harbor and collectively have the potential to produce 94, 500 ton/year (Tesfaye and Wolff, 2014). Of these, 31% is being exploited. The most common commercially important fish species are Nile tilapia, *Oreochromis niloticus*, the labeo *Labeo hori,* the African catfish *Clarias gariepinus, Barbus species* and the Nile perch, *Lates niloticus* (Tilahun et al., 2016). It is possible to observe that the expected fish yield exceeds the actual harvested fish product and therefore, management step up is critical to sustain fish products as well as the water bodies. Avoiding fishing during spawning grounds (Gebremedhin et al., 2014), mesh size restriction, reduced number of fisher men, balance catch quotas, banning beach seines, regulate illegal fishermen, equipment or chemicals, control of illegal fish traders, awareness creation on fish welfare and production through training, extension service by the concerned bodies are best management options for a better fishing strategy (Keliel, 2002; Temesgen and Getahun, 2016).

Conclusion

The Ethiopian fishery has faced multiple challenges. Challenges are caused by human induced and natural problem like the expansion of industrialization, poor land use practices, fish nursery (spawing) habitat destruction and agricultural practices. These challenges and problems should be addressed in order to sustain the fish and water resources for now and the next generation. The Government of Ethiopia needs to prepare and implement integrated water resources and fisheries management plan in the drainage basin of Ethiopia with full participation of all relevant stakeholders including the riparian community to sustain the water system in the basin.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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Full Length Research Paper

Modelling and simulation of atmospheric conditions impact on photovoltaic production in Saint Louis area

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In this study, we worked on the modelling and the simulation of atmospheric conditions impact on photovoltaic production in Saint Louis area. Using Ineichen's model based on the disorder factor of Link, an assessment of sunshine in the study area was made. A characterization of the irradiation is elaborated by modelling the radiation and by simulating outputs of a photovoltaic power plant. We can estimate aerosols impact on photovoltaic production in the river area thanks to results obtained. We evaluated the sunshine rate of this area by using the modelling process. We chose an irradiation model to estimate the outputs of a photovoltaic power plant subjected to an atmosphere disturbed by aerosols. This work enabled us to set up a system of alerts and specific warnings for populations benefiting from this type of resource.

Key words: Photovoltaic output, atmosphere, aerosol, sunshine, alert, Saint Louis area.

INTRODUCTION

In Saint Louis, the atmosphere is influenced by desert dust (D'Almeida 1986). This Sahelian area near Sahara Desert is a climatic area, which is subjected throughout the year to dust episodes (Kaly, 2015). During the rainy season, heavy clouds appear which unfortunately produce few rains (Chamani et al., 2018) and can disturb the area insolation. During the dry season, Saint Louis area is exposed to dust occurrences. These dust occurrences in most cases are mineral aerosols commonly called "desert dust", have a very marked seasonal cycle and whose timing coincides partially with that of Harmattan (Martiny et al., 2016). Thus, if the dry season extends from October to March, we can distinguish a period "without" dust from July to December and a period "with" dust from January to June. The latter can be split into two sub-periods: from January to March and from April to June (Martiny et al., 2016). It is in the dry season that the continental trade winds in the North / Northeast direction speed increase in the lower atmospheric layers and bring with them significant amounts of desert dust from the Sahara to the Sahel (Senghor, 2017).

With the advent of photovoltaic energy and the urgent need to control global warming (Arent et al., 2011)

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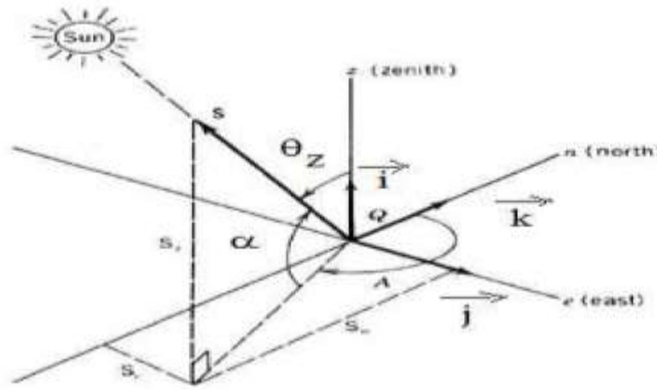

Figure 1. Horizontal coordinates system for the S position vector identified by the coordinates α , θz et A.

power plants are being created everywhere (Laines-Canepa et al., 2017), including in Saint-Louis area, with the 20-megawatt solar center of Bokhol (Maillard, 2017).

However, a major problem remains with the use of photovoltaic energy. This technology uses solar radiation to produce energy (Gratzel, 2005). These radiations must cross the atmosphere before reaching the sensor. Saint Louis area is an area with high concentration of dust and cloud cover more or less important depending on the period of year and seasons. This radiation will necessarily be subject to disturbances (Dickinson 1975) that have been discussed in this work.

So the objective of this work was to correlate the impact of certain atmospheric conditions, notably aerosols and the variability of photovoltaic production in Saint Louis.

MATERIALS AND METHODS

According to the Bouguer-Lambert law, better known as Beer's Law, the attenuation of light through a medium is proportional to the distance covered in the medium and the radiation flux where k is an attenuation coefficient (Abitan et al., 2008).

$$I_{Bn} = I_0 \exp(-kx) \quad (1)$$

Where, I_{Bn} is the radiation attenuated; I_0: is the incidental radiation; K is the attenuation coefficient;
X : is the covered distance.

The diversity and multiplicity of radiation prediction methods require a critical look at the accuracy, the performance and even the validity of some models.

It is for this reason that we studied a model proposed in the literature, which is the model of Ineichen (Ineichen, 1992; Kasten 1996) based on disorder factor of Link.

Several models of direct radiation determination based on disorder factor of Link are mentioned in the literature. The difference between these models lies in the factor approach and / or in the formulation of direct solar radiation. This factor is used to characterize the atmospheric disturbance caused by water vapor, mist, fumes, dust, etc. The advantage of these models is that factors attenuating radiation are given according to a single easy-to-use index. For this model, the direct solar radiation is given by Bouhadda and Serrir (2006):

$$I_b = I_0 \exp\left(-\frac{T_L}{0.9+9.4\sin\alpha}\right) \quad (2)$$

Where I_b is the direct solar radiation; I_0 is the incidental radiation and α is the solar height that is the angle between the star and the horizontal plane (Figure 1). As an alternative, the altitude of the sun can be described in terms of the zenithal solar angle θz which is simply the complement of the solar elevation angle,

$$\theta_z = 90^{\circ} - \alpha(degrees) \quad (3)$$

$$\sin\alpha = \sin\sigma\sin\phi + \cos\phi\cos\omega\sin\phi \quad (4)$$

Where ϕ is the latitude of the place to study; ω is the hour angle is the angular distance between the meridian of the observer and the meridian whose plane contains the sun. This measurement is made from the South turning towards the West.
T_L is the the disorder of Link coefficient is expressed by (5):

$$T_L = 2.4 + 14.6\beta + 0.4(1+2\beta)\ln(P_v) \quad (5)$$

With β as the Angström coefficient that expresses the amount of aerosol in the atmosphere; P_v is the atmospheric pressure of the place; σ: is the declination. It represents the angle between the sun direction and the equatorial plane. It varies throughout the year (Figure 2).
It is given by the relation (6):

$$\sigma = 23,45\sin\left[\frac{360}{365}(284+d)\right] \quad \text{(Figure 3)} \quad (6)$$

$$\omega = 15(TSV - 12) \quad (7)$$

With TSV as the True solar time is defined in relation to the sun.

$$TSV = TSM + ET/60 \quad (8)$$

ET is the equation of time which is the gap between the TSV and the TSM is called the time equation. Indeed, the variation of the earth speed on its trajectory around the sun introduces a corrective term called noted equation of time:

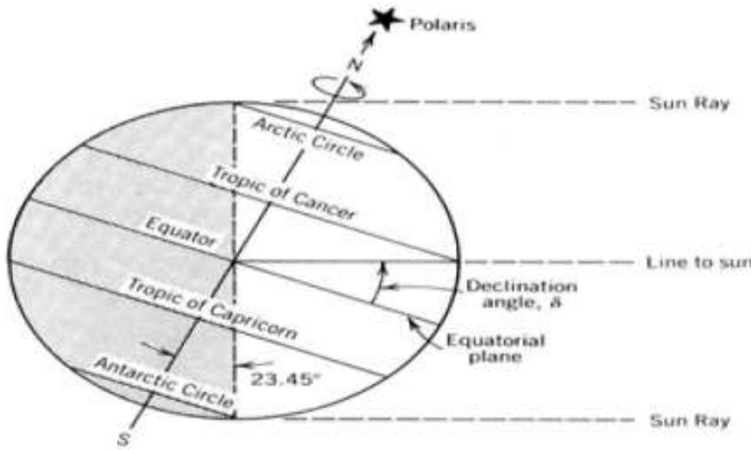

Figure 2. The declination.

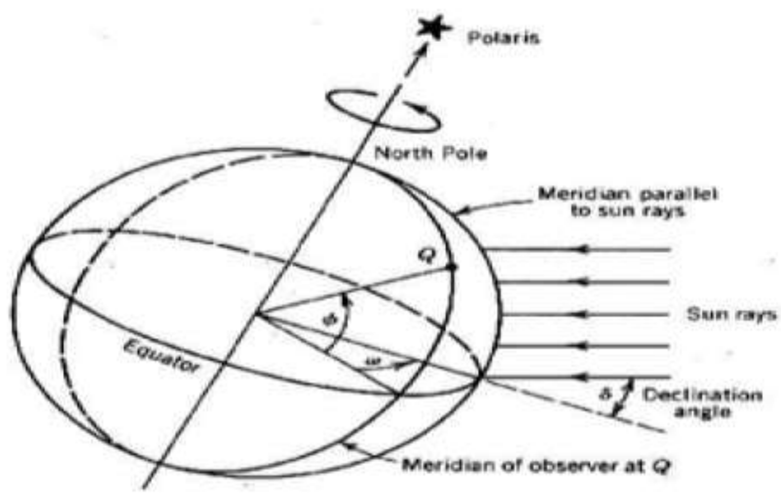

Figure 3. The hour angle.

ET=9,9sin [2(0,986d+ 100)] − 7,7sin (0,986d – 2) (9)

TSM is the mean solar time.

$$\mathbf{TSM} = \mathbf{TU} + \frac{\lambda_{\text{greenwich}-\lambda}}{15} \quad (10)$$

$$\lambda_{\text{greenwich}=0}$$

TU s the universal time is the mean solar time of Greenwich. The mean solar time of a longitude location λ (counted in positive numbers towards the west) is related to universal time by Equation (11):

$$\mathbf{TU} = \mathbf{TFH} + \frac{\lambda_{st}}{15} \quad (11)$$

TFH is the time zone is an area of the earth's surface within 2 meridians 15° longitude distant.

The time for the TFH time zone is the mean solar time of the reference meridian (of longitude λ_{st}) located in the center of the spindle.

TFH= TL – C (12)

TL is the legal time TL in a state is usually the time of the time zone but it may differ for convenience and C varies according to the country. In Senegal, C equals zero.

In this study, a modelling of the irradiation has been done by varying the Angström coefficient which expresses the quantity of aerosol in percentage from 0 to 1 in steps of 0.05.

A photovoltaic cell is modelled by the electrical diagram made up of a current generator Isc, a diode D1 and two resistors (shunt Rsh and series) (Edouard and Njomo, 2013).

We modelled the physical model on LT Space, and in a second time we included that physical model in a behavioral model to assign it the irradiation input values obtained by varying the Angström coefficient for the model of Ineichen and by collecting the output voltage of the current or the power received by a possible

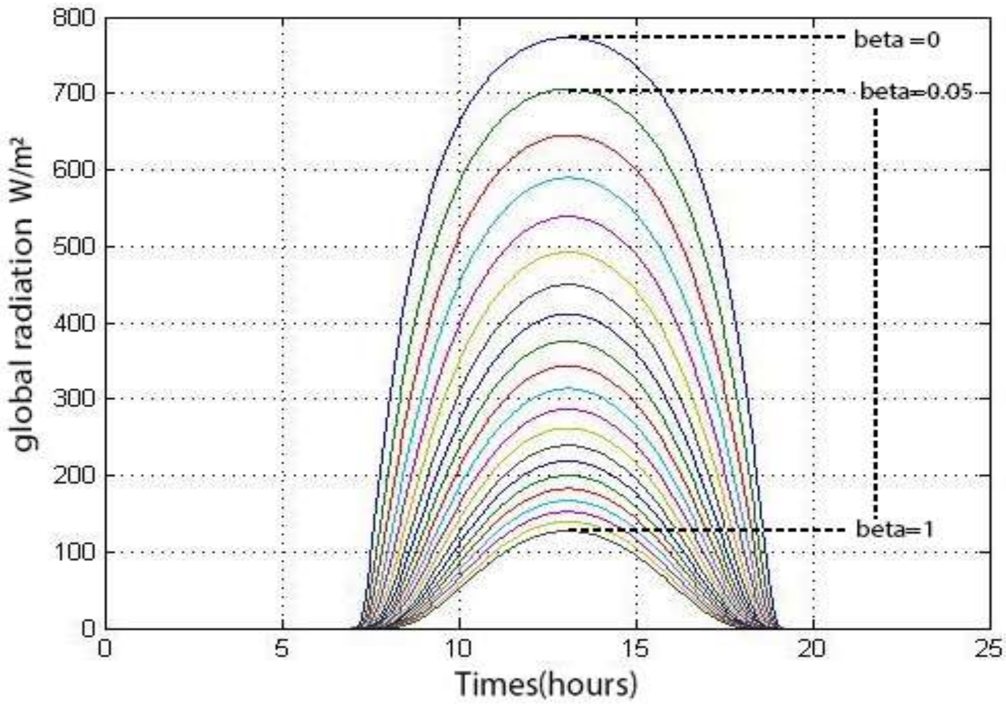

Figure 4. Global radiation variation as a function of time for beta from 0 to 1 in steps of 0.05.

load.

RESULTS

After doing the modelling on Matlab by varying the Angström coefficient which expresses the quantity of aerosols in percentage from 0 to 1 in steps of 0.05, we have the variation of the global radiation as a function of the Angström beta coefficient (Figure 4).

Figure 4 shows the variation of the radiation power as a function of time for different Angström coefficients. We find that the maximum radiation for a beta equals zero and the order is 772.8525W / m^2. The minimum value of the radiation is 127.2792 W / m^2 for a beta equals one (Dyer and Hicks, 1965).

These maximum and minimum values given in Figure 4 are obtained at around 12 Am.

Table 1 gives us the variation of the global radiation max as a function of the Angström beta coefficient. We notice in this table that there are strong values for weak coefficients.

Figure 5 reflects the variation of the maximum radiation as a function of the Angström coefficient. There is a decrease in the maximum power as a function of beta.

Figure 6 reflects a photovoltaic cell. That cell is modelled by the electrical diagram made up of a current generator Isc, a diode D1 and two resistors (shunt Rsh and sériers).

This physical model is in a second time included in a physical model to assign it values of irradiation inputs and temperature, as well as to collect the voltage output of the current or the power received by a possible load.

Figures 7 and 8 show the curves obtained from the simulation of different values of angström beta coefficient.

In the abscissa, there is the duration of the day. In ordinate, there are the powers in Impp (maximum power current) and in Vmpp (maximum power voltage). Note that the maximum power is obtained at about 12 Am and the voltage as well as the current is in phase opposition.

Figures 7a and 8a which show the current evolution indicate the beginning of the current growth at about 7 Am. We noticed that around 6 Pm we have a near zero current.

In Figures 7b and 8b, there was a decrease from 7 Am with a minimum at about 12 Am.

For Figures 7.c and 8.c, the maximum power is obtained at about 12 Am and the voltage as well as the current is in phase opposition.

Similar phenomenon occurs for beta and for all other Beta values. Figure 9 shows for a cell of 10 cm^2 the outcome variation as a function of beta. We notice that there are outcomes higher than 0.7 for beta less than 0.05.

There is outcome decrease. It seems normal that the atmosphere is milder with a high beta.

From this point, an operation mode of the photovoltaic cell is drawn as a function of the aerosol quantity in the

Table 1. Variation of the global radiation max as a function of the Angström beta coefficient.

Beta	0	0.05	0.1	0.15	0.2	0.25		
IB max (W/m²)	772.8525	706.2032	645.3015	589.65196	538.8015	492.3363		
Beta	3	3.35	0.4	0.45	0.5	0.55	0.6	
IB max (W/m²)	449.8781	411.0815	375.6306	343.2369	313.6368	286.5894	261.8744	
Beta	0.65	0.7	0.75	0.8	0.85	0.9	0.95	1
IB max (W/m²)	239.2909	218.6549	199.7985	182.5683	166.8239	152.4373	139.2914	127.2792

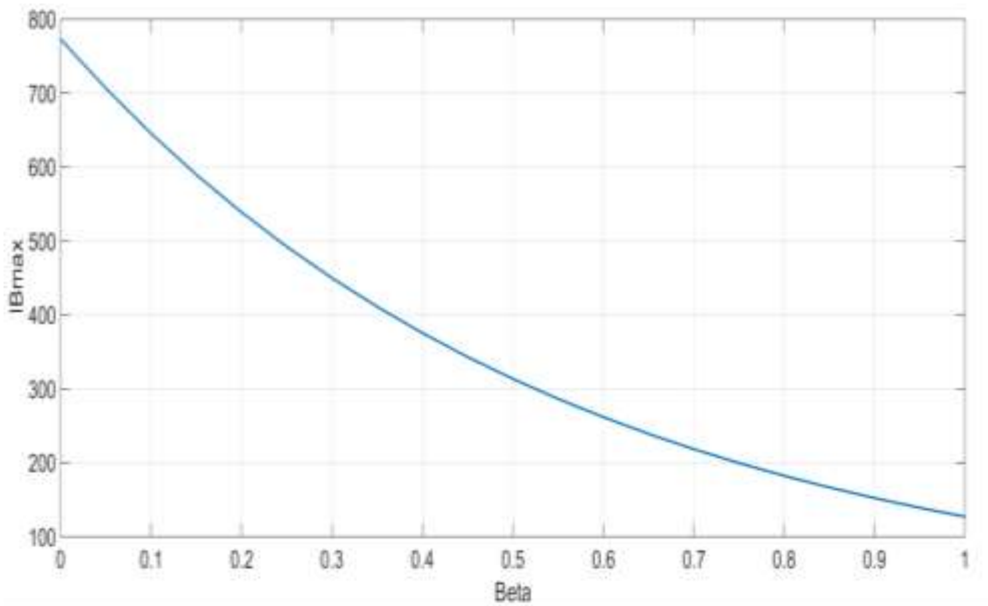

Figure 5. Curve of variation of the global radiation max as a function of the Angström coefficient.

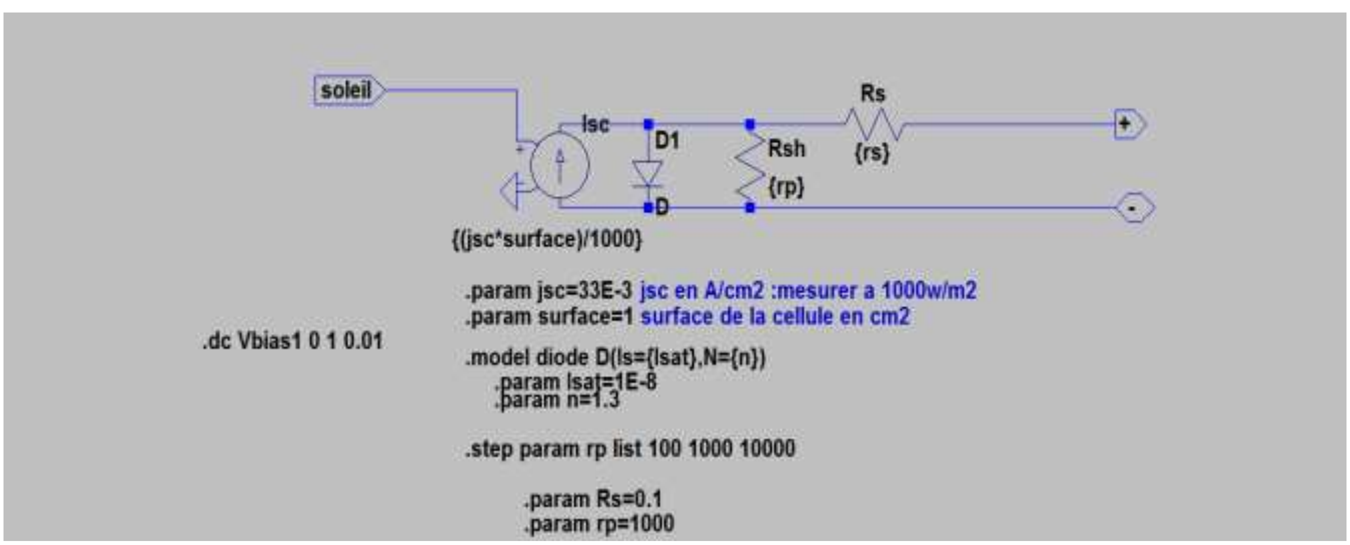

Figure 6. Behavioral model of a photovoltaic cell.

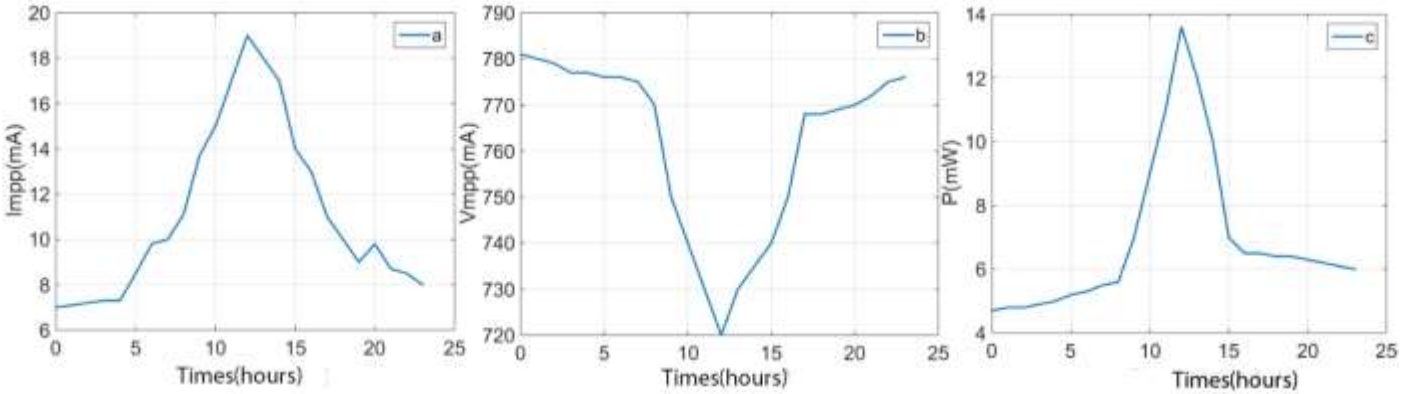

Figure 7. Current voltage and power for beta equals.

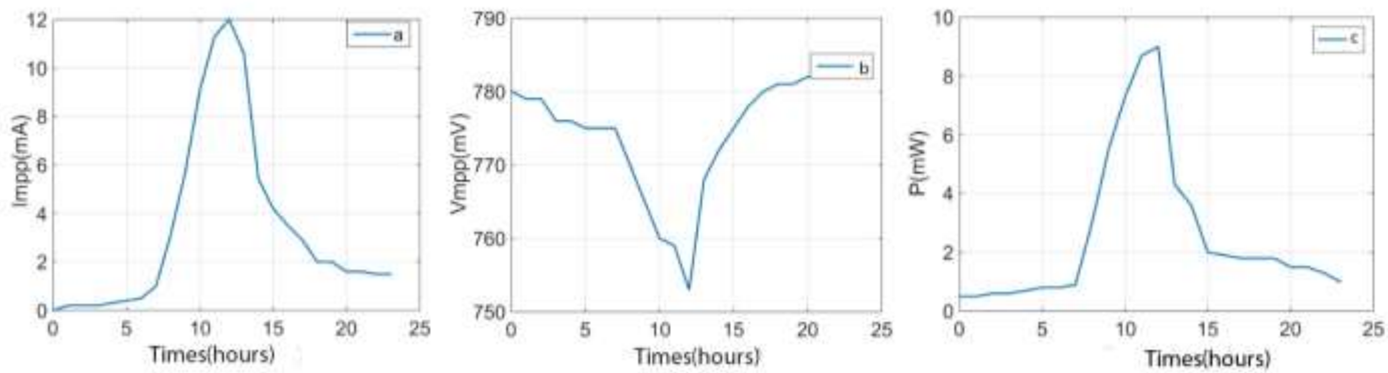

Figure 8. Current voltage and power for beta equals 0.25.

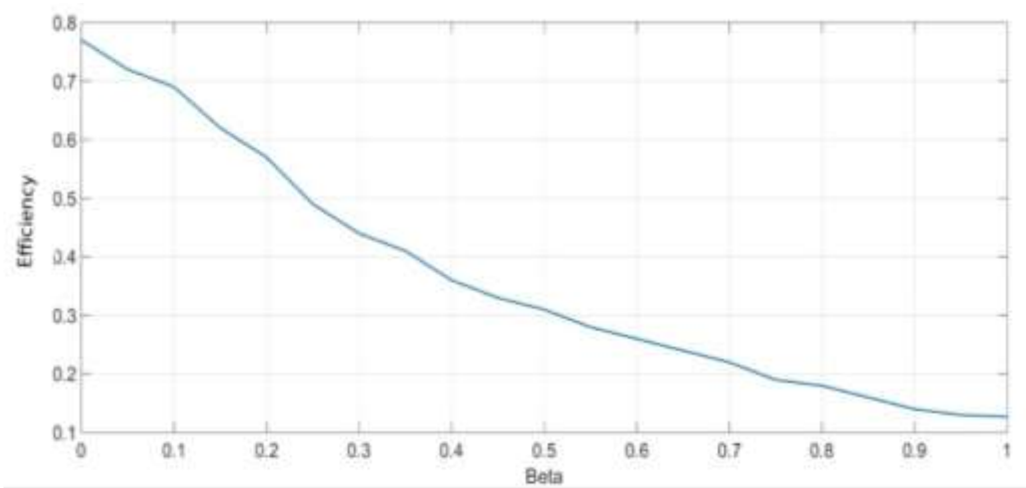

Figure 9. Outcome variation as a function of beta.

atmosphere (Table 2).

We modelled a town of 40 houses, with an extension to 50 houses, 1 hydraulic pump, a mosque (Figure 10).

The solar energy potential of the area is provided by RESTSCREEN (Figures 11 and 12).

The energy needs of the town are estimated at 255.53

Table 2. Variation of photovoltaic cell as a function of aerosol amount in the environment.

Beta	0	0.05	0.1	0.15	0.2	0.25		
Functioning%	100	93.5	89.61	80.51	67.02	63.64		
Beta	3	3.35	0.4	0.45	0.5	0.55	0.6	
Functioning%	57.14	53.25	46.75	42.85	40.26	36.36	33.77	
Beta	0.65	0.7	0.75	0.8	0.85	0.9	0.95	1
Functioning%	31.17	28.51	24.67	23.37	20.78	18.18	16.89	16.50

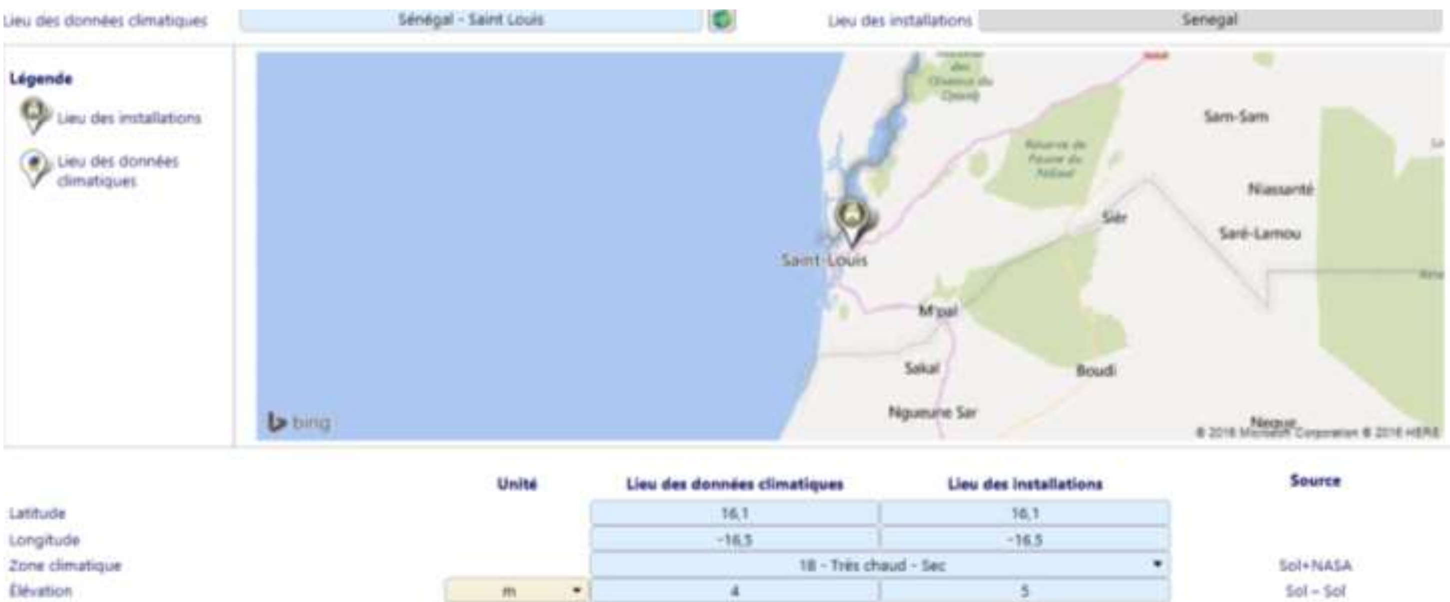

Figure 10. Ndiawdoun-Pont.

Figure 11. RESTScreen Saint Louis.

Mois	Température de l'air	Humidité relative	Précipitation	Rayonnement solaire quotidien - horizontal	Pression atmosphérique	Vitesse du vent	Température du sol	Degrés-jours de chauffage 18 °C	Degrés-jours de climatisation 10 °C
	°C	%	mm	kWh/m²/j	kPa	m/s	°C	°C-j	°C-j
Janvier	22,3	49,2%	3,72	4,97	101,3	3,9	24,9	0	381
Février	23,2	52,8%	1,67	5,48	101,2	4,3	26,9	0	370
Mars	23,7	59,1%	0,51	6,72	101,0	4,8	29,0	0	425
Avril	23,1	68,6%	0,41	7,27	100,9	5,3	31,4	0	393
Mai	23,9	72,2%	0,49	7,07	100,9	5,1	33,6	0	431
Juin	25,8	79,5%	4,89	6,34	101,0	4,5	34,1	0	474
Juillet	27,3	80,8%	35,87	6,28	101,1	4,3	33,1	0	536
Août	28,2	81,7%	101,76	6,24	101,0	3,8	32,0	0	564
Septembre	28,6	81,5%	84,81	5,80	101,0	3,3	32,2	0	558
Octobre	28,3	72,4%	21,56	5,67	101,0	3,4	33,5	0	567
Novembre	26,0	59,3%	1,26	5,04	101,1	3,5	30,8	0	480
Décembre	23,3	52,0%	1,40	4,72	101,2	3,5	26,8	0	412
Annuel	**25,3**	**67,5%**	**258,35**	**5,97**	**101,1**	**4,1**	**30,7**	**0**	**5 592**
Source	Sol	Sol	NASA	NASA	NASA	Sol	NASA	Sol	Sol
Mesuré à					m	10	0		

Données climatiques

Figure 12. RESTScreen Saint Louis data.

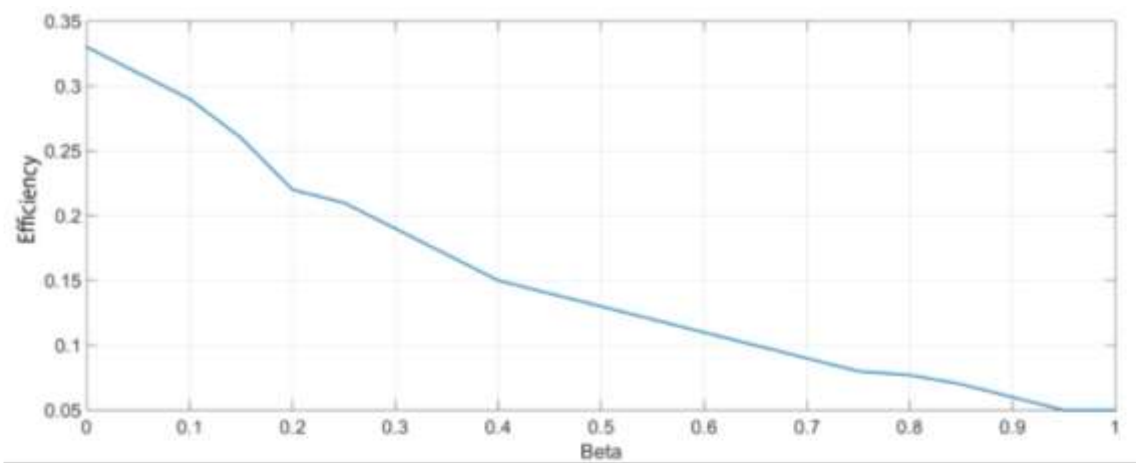

Figure 13. Variation of photovoltaic field outcome as a function of aerosol amount in the environment.

KWh for a total power of 24.16 KW. The peak power (PC) required for the photovoltaic system is 71.34 KWp. The number of 250W / 24V panels required is 288.

The photovoltaic field outcome under optimal conditions, without aerosols, is 0.33.

By applying the photovoltaic cell operation to the photovoltaic field and considering the field as a much larger cell, we have the Figure 13 which expresses the variation of the photovoltaic field outcome as a function of beta.

Analyses and interpretations of the results

The results obtained allowed us to highlight the evolution of the irradiance compared to the atmospheric disorders, characterized by the Link factor, in which the Angström coefficient, which we called beta, is found.

Step 1

In Figure 4, we have the variation of the global daily radiation as a function of time for beta ranging from 0 to 1 in steps of 0.05. We are left with a "superposition of 21 curves" of different colors. Minimum was seen for each curve around 6 am and 6 pm; maximums around 12.

A difference of 645.5733 W / m2 between beta = 0 and beta = 1 is noted at the maximum overall radiated level (Figure 4). This difference shows the influence of the Angstrom coefficient in the radiative transfer.

The first results show the reduction of irradiance according to the beta coefficient increase, which is nothing other than a Link Factor variable which gives us information on the quantity of aerosols in the atmosphere. This is consistent with the literature (DIOP 2012) because solar energy is attenuated (diffusion and absorption) by the presence of dust in the atmosphere.

Step 2

We modeled a CdTe cell on LTspace with the characteristics as shown in Figure 6. It is assigned the irradiation values obtained in "step 1". Note that the efficiency of cadmium telluride cell (CdTe) after simulation decreases. We go from an R (efficiency)> 0.7 to a R <0.2. The efficiency of the cell is affected by the presence of aerosols in the atmosphere. This is evidenced by the evolution of the maximum overall irradiation with respect to the Link factor.

The impact of aerosols on solar radiation results in lower cell efficiency. From the yields obtained, an operating mode of the photovoltaic sensor is obtained (Table 2) as a function of the Angstrom coefficient.

Step 3

The photovoltaic power plant that we have developed from a sizing of the village of Ndiawdoun-Pont provides for an atmosphere free of aerosols (beta = 0) a yield of 0.33 corresponding to a power of 71.34 KWc sufficient to supply Ndiawdoun-Pont.

By applying the operating mode (Table 2) to the photovoltaic field, considering the photovoltaic field as a macroscopic sensor, we observe:

For beta greater than 0 and less than 1 the yields are between 0.21 and 0.08. The plant operates less than 63.64%. This will impact the comfort of the village and concessions.

We have shown that atmospheric conditions impact photovoltaic production in the river region. The sunshine in the study area was made with an interactive beta coefficient. A characterization of the irradiation elaborated by modeling the radiation and a simulation of the yields of a photovoltaic power plant showed that there is a correlation between the output of the model and the renderings of the simulation.

The beta coefficient here makes it possible to determine the impact of aerosols on photovoltaic production in the area in question; the maximum sunshine rate of this zone is of the order of 127.2792 W/m^2 for beta equals 1. For low Beta we have a maximum of 772.825 W/m^2. This highlights the effect of aerosols. The link between the outputs of the irradiation model for two values of beta (1 and 0) when considering the maximums gives estimated yields at 0.05 and 0.33 of the photovoltaic plant subjected to a more or less disturbed by aerosols.

With known limit values it is possible to allow the informed population to make arrangements with regard to the devices consuming electrical energy at their disposal.

Conclusion and perspective

It is important to note that climate change will be one of the biggest environmental issues of the 21st century. Global warming impacts, which are visible over the past few years, demonstrate the urgent need for the international community to act in a concrete way for future generations and for countries vulnerable to climate change, and this by making the decrease as quickly as possible of greenhouse gases emissions.

Fossil energies are used abusively. Their transformation steps and their use raise a lot of environmental problems such as climate change with the phenomenon of global warming, which is the increase of temperatures over most of the oceans and the Earth's atmosphere, measured globally over several decades, and reflecting an increase heat retained on the earth's surface.

Senegal has a medial electrification level (Kande, 2018), with a good coverage in urban areas while it remains low in rural areas.

Thus, the issue raised is in relation with the improvement of people's living conditions by avoiding fossil fuels. The promotion and the use of renewable energies as well as photovoltaics are good solutions since we have an area with very strong sunlight.

The fact that photovoltaic technology uses solar radiation to produce energy is mentioned in this study. The atmosphere impacts affected by aerosols on radiation are also discussed in this study.

We highlighted the atmospheric conditions on photovoltaic production in the river area. An assessment of sunshine in the study area has been made. A characterization of the irradiation is elaborated by modelling the radiation and a simulation of photovoltaic power plant outcomes.

Based on the results obtained, we can estimate aerosols impact on photovoltaic production in the river area; we evaluated the sunshine rate of this zone through modelling. We chose an irradiation model to estimate the photovoltaic plant outcomes subjected to an atmosphere disturbed by aerosols.

Thanks to this work, it is possible to launch alerts and specific warnings to population benefiting from this type of resource concerning their consumption and their electricity consumption devices.

Perspective

On one hand, for a more effective alert model, we will have to consider the evolution of atmospheric conditions (clouds, rain). An advanced study of the factor of Link in the day, the month or even the season will refine the recommendations and tips for the use of electrical devices powered by the plant.

On the other hand, the plant outcome will be better apprehended by considering meteorological parameters and aerosols deposit on the plant solar panels. The study will also continue on production and costs.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Conditions of available sources of water for domestic use in selected communities in Ado-Ekiti, Ekiti State, Nigeria

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The challenges of high quality water for domestic use and particularly for potability must be overcome in its entire ramification for health and ecological environment. The aim of this study is to identify the conditions of domestic water sources in Ado-Ekiti. One water sample was drawn from the two different sources of water, that is, shallow well and Ureje River at Ureje, and two samples from one water source, that is, borehole at Ilupeju and ABUAD in Ado-Ekiti. Water samples were analyzed in the Laboratory. Parameters including turbidity, pH, jar, hardness, calcium hardness and alkalinity were determined. Results revealed that the water samples drawn from borehole were of good quality following WHO reference guidelines, whereas, for water from well in Ureje and from river in Ureje, the concentration of these parameters exceeded WHO reference guidelines. It can be concluded that water obtained from Ureje River and that from well in Ureje are unsuitable for drinking (based respectively on colour, turbidity, odour, jar and hardness as well as pH, jar, turbidity, colour, and odour). However, pH, calcium and alkalinity are good following WHO reference guidelines. Further, well in Ureje contained water which is suitable for drinking and domestic uses. Samples drawn from borehole were the most suitable following WHO reference guidelines. However, further improvement is required. Detailed studies revealing the underlying reason for drop in quality of deep groundwater in the study area are required.

Key words: Ecological, potability, groundwater, borehole, parameters, wells.

INTRODUCTION

Water is an essential constituent for human life. Access to safe water supply has great influence on the health, economic productivity and good quality of life. Water of the earth is enormous but only about 0.62% of it is naturally good for drinking, occurring in surface sources (rivers, lakes etc.), ground water (shallow and deep), soil moisture and vapour in atmosphere (Gaur, 2008). Access to this available quantity of good water is a major challenge for humans today, with many countries of the world plagued by it, Nigeria not exempted. Nigeria is the most populated nation in Africa with an estimated population of over 190 million. Annual increase is

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estimated to be 2.61% (Worldometers, 2017). Estimates have shown that about 54% do not have access to safe drinking water (FMWR, 2013). This implies that more than 90 million people are exposed to non-potable water sources. The three levels of government (state, local, and federal government) are responsible for the provision of municipal and domestic water supply. Despite the effort of the government, good water is only available to very small fraction of the population. This made the rest of the people to seek alternative water source, where the most available are waters in streams, wells, and boreholes. In locations where the stream is easily accessible because of its surface flow, the waters in wells and boreholes are accessed by boring a hole in the ground. These sources of water receive some levels of contamination and are therefore rendered most times, unfit for domestic usage and for drinking. Lack of access to good water will no doubt impinge on the population and on the economy. Study conducted by the United Nation's Children Fund (UNICEF)/WHO Joint Monitoring Program for Water Supply and Sanitation analysis on Nigeria proved the inadequacy of safe water to the entire population and it was linked to the prevalence of water related diseases such as guinea worm, cholera, diarrhea, dysentery, etc. Premium Times Nigeria of October 6, 2017 report by the federal government showed that over 59,000 Nigeria children under the age of five die annually from preventable water and sanitation related diseases. Water and sanitation in Ekiti State suffer continuous neglect by past and present administration which has led to many indigenes suffering serious health challenges. It is therefore important that adequate check be carried out on the various available sources of water in various communities in the State to know the level of contamination in them and have awareness of the level of treatment required for safe consumption.

Research purpose

The practice of open defecation alongside improper waste handling and disposal suggests the possibility of drop in quality of water available to the people of Ado-Ekiti. The three main water sources (stream, well, and borehole) available in this area have the potential of receiving direct influence of the washing of wastes and contents to the surface water and infiltration into the groundwater. The people of the communities are left with no choice than to find a way of dealing with the contamination in their water and its consequence, hence, they suffer one health issue or the other. This project deals therefore wholly on providing information on the quality level of the water that these people use, which will guide their understanding of the needed treatment for safe and healthy consumption. It is clear that an awareness of a problem informs possible solutions. This research is therefore aimed to examine the purity conditions of the various water sources and determine the most viable water treatment for people in Ado-Ekiti, Ekiti State, Nigeria. The objectives of the study therefore are to provide advice on the best sources of safe drinking water in the community, to determine the physio-chemical composition of domestic water at selected locations, to describe the functions of each treatment process in treating drinking-water, to highlight the environmental and health implications of unsafe drinking water, and to determine safe drinking water treatment/purification management strategies.

Some of the issues driving the interest in decentralized systems, apart from declining local water sources, are financial efficiency, installation timeframe of infra-structures, water security, water loss derived from long distance transport, environmental degradation of aquatic habitats and local community empowerment (Domenech, 2011; Makropoulos and Butler, 2010; Wilderer, 2004).

Most studies have shown that the operational phase of the life cycle has the largest environmental impact, and that electricity consumption for pumping and treatment is a significant contributor to the system's impacts. Assessments of decentralized and/or source separation systems are less common, but have become more frequent in recent years (Gardels, 2011; Glick and Guggemos, 2013; Lam et al., 2015; Lehtoranta et al., 2014; Lemos et al., 2013; Matos et al., 2014; Shehabi et al., 2012; Thibodeau et al., 2014).

Research limitation

This research is specifically limited to the water samples collected from water sources in the study area; Ureje River water, Ureje well water, Ilupeju borehole water and ABUAD borehole water within Ado-Ekiti; their constraints and prospects. It comprises the most common and important water tests which are used to examine water for safe domestic consumption. These fundamental drinking water tests include: turbidity, hardness, colour, jar, odour, pH and alkalinity.

Historical background

The United Nations (UN) set a goal in their Millennium Declaration to reduce the amount of people without safe drinking water by half in the year 2015 (UN, 2000). For water to be safe for human consumption, it should meet the standard guidelines for taste, odour, colour, and chemical concentrations, and must be available in adequate quantities for domestic purposes.

Water sources

The extent of treatment carried out on water depends on the quality of the source of supply and the desired quality in the finished product. The sources of water majorly available in the area of this investigation can be classified into two general categories namely: Groundwater sources (accessible through wells and boreholes) and surface water sources such as rivers, lakes, and impoundments on rivers and streams.

The availability of adequate water supply both in quality and quantity is essential for human existence. With the exponential increase in population, access to improved water remains an important pre-condition for sustaining human life, maintaining eco systems and for achieving sustainable development (Oyebode and Oyegoke, 2015).

Groundwater

The water that fall from rain several decades, hundreds, thousands or in some cases millions of years ago move through layers of soils before getting into the saturated regions in the subsoil. These waters are naturally filtered by soil and rock layers to a high degree of clarity before they get to the saturated zone where they are stored as groundwater. Groundwater emerge as any of springs, artesian springs, or may be extracted or explored through boreholes or wells. Deep ground water is generally of very high acceptable bacteriological quality (that is, pathogenic bacteria or pathogenic protozoa are typically absent), but the water may be rich in dissolved solids, especially of carbonates and sulfates of calcium and magnesium. Improper subsoil repository practice may lead to discharge or ingress of contaminants into the groundwater thereby impairing its quality.

Surface water

Any water that exists on the surface of the ground is called surface water. It is the water that did not seep into the ground where it flows or exists. It exists and/or flows over impermeable ground surfaces normally existing in lower surfaces from the natural human habitable ground level. Surface water exists as stored water in reservoir, ponds, springs, and lakes, as or flowing water in rivers, streams, wetlands, seas and oceans. Other forms of surface water include canals and lowland reservoirs. Surface water is normally recharged by precipitation, runoff from adjoining surfaces, and near-surface subsoil water that could no longer permeate the ground due to meeting impermeable rock. They are usually are more subjected to contamination making the presence of some bacteria, protozoa or algae to be in high level. Surface washing from the ground, and unhealthy practice of release or discharge of waste into the surface water contaminate it.

The impact of water use on our ecosystems should be an intricate issue of special concern in every area of the world as water is the one resource we cannot live without. Also, the financial implication of water loss can be minimized if the management method is improved for maximum effectiveness and optimal benefit (Oyebode, 2014).

Water tests

Turbidity

Turbidity refers to the cloudiness of water sample which is mostly caused by the presence of suspended solids. It is a measure of how ray of light shone on the water is scattered or absorbed. More turbid water sample will scatter and absorb more light than less turbid water sample. According to Spellman (2003), high turbidity causes problems for waterworks operator; components that cause high turbidity can cause taste and odour problems and will reduce the effectiveness of disinfection. Turbidity is undesirable for aesthetic considerations as solids may contain heavy metals, pathogens or other contaminants, and turbidity decreases the effectiveness of water treatment techniques by shielding pathogens from chemical or thermal damage, or in the case of UV (ultra violet) treatment, absorbing the UV light itself (Cheremisinoff, 2002). Turbid water has the tendency of posing health challenges, causing symptoms like nausea, cramps, diarrhoea, and associated headaches. Treatment of water against turbidity requires flocculation, sedimentation, filtration and disinfection process. Alternatively, the water can be boiled at 100°C for at least 30 min, allowed to cool down, filtered, and stored in a clean covered container for consumption. The turbidity is not expected to be greater than 5 NTU.

pH

The pH of a water sample is a measure of the amount of hydrogen ion (H^+) content of the water sample and indicates the acidity and alkalinity of that water. pH value is a scale of 0 to 14 with 7 indicating neutral point while pH less than 7 depicts acidic water and that above 7 depicting basic water. The pH is a very vital content of water as it can dictate chemical activities such as coagulation and corrosion, and can affect how microorganisms thrive in water. pH adjustment is required where the pH level falls outside the permissible range, and such adjustment may include the addition of sodium ash or sodium hydroxide through an injection system to raise the pH level of the water or addition of alum, ferric chloride or ferric sulphate to reduce the pH. Required pH value is between 6.5 and 8.5.

Alkalinity

Alkalinity is the amount of basic content of a water sample; a measure of the extent of acid needed to neutralise the basic content of water. The alkaline contents act as the buffer to changes in the pH; too low

Figure 1. Map of study area (from Google Earth).

alkalinity of value below 80 ppm can allow rapid fluctuations in pH implying insufficient buffer to the pH while high alkalinity of any value above 200 ppm results in the water being too buffered (Spellman, 2003). Acid salts (alum, ferric chloride or ferric sulphate) or basic salts (lime, soda ash, or caustic soda) can be used to regulate the alkalinity of water sample. Alkalinity in water is expected to not be more than 200 mg/L.

Colour and odour

Colour and odour in water are indication of presence of dissolved contents in water. They may be due to metals, minerals from soils, microorganisms (algae and cyanobacteria) and biological reactions, decaying organic contents, and contents of effluents from the industries e.g. phenol, formaldehyde, petrochemical wastes etc. The colour and odour in water can be removed by activated carbon filters, sometimes marketed as taste and odour filters. Applications of oxidizing agents such as chlorine, chlorine dioxide, ozone, and potassium permanganate can also serve right. Another treatment method is coagulation and sedimentation using alum or other chemicals while aeration can remove those due to dissolved gases and volatile organic materials. This process is normally used only in large plants since its complexity often requires the care of a trained water treatment plant operator.

Hardness test

Hardness is said to exist in water when the water fails to form lather with soap; it is known to be caused by the presence of metal ions particularly, magnesium ions (Mg^{2+}) and calcium ions (Ca^{2+}). Hardness in water is mostly due to washing of rocks into groundwater. Hard water is characterised by problematic phenomena for domestic usages like causing skin irritation after bath, taking longer time before boiling, increasing fading of fabrics, producing deposits as scales that could clog hot water pipes and kettles among others. Water required to be available for domestic users is therefore expected to be of no or low hardness; to reduce the amount of soap used, increase the life of water heaters, and to reduce encrustation of pipes. Chemical precipitation (involving pH adjustment) and ion exchange (use of sodium zeolite) are the two hardness removing processes that are most commonly used. While chemical precipitation converts calcium hardness and magnesium hardness to calcium carbonate and magnesium hydroxide respectively through the addition of the lime-soda ash or the caustic soda, ion exchange replaces calcium and magnesium with a non-hardness causing cation, usually sodium by passage through a solids interface (matrix). The permissible hardness is between 80 and 100 mg/L.

METHODOLOGY

Study area

The study area consists of selected communities in eastern Ado Ekiti. This is a city in Southwest Nigeria and is the State capital and administrative headquarters of Ekiti State. It falls within the Ekiti sub-ethnic group of the Yoruba having its geographic location being unique as it is almost equidistant from Nigeria's economic capital, Lagos and the Federal capital, Abuja. It lies approximately between 7°37′16″N and 5°13′17″E 7°31' with an altitude of 455 m above sea level and a population of 308,621 (NPC, 2006). Ado-Ekiti is characterised with low relief and gentle gradient which favours groundwater depth and access. It has a tropical climate which varies between 70°C and 95°C during the coolest and hottest month of the year with rainfall that is highly seasonal, marked with wet and dry seasons having mean annual rainfall of the area as 1367 mm that is concentrated between the months of April and October with a break in August.

Table 1. Turbidity test result for different samples.

Samples	1	2	3	4	5	Average
Ureje river water	5.58	4.01	8.35	6.19	11.0	7.03
Ureje well water	4.01	5.45	4.83	4.65	4.63	4.71
Ilupeju borehole water	2.27	2.43	2.01	1.90	1.96	2.11
ABUAD borehole water	1.32	0.87	1.56	1.98	1.87	1.52

Table 2. The pH test values of water samples.

Samples	Temperature °C	pH Value
Ureje river water	26.8	**7.33**
Ureje well water	26.8	6.45
Ilupeju borehole water	26.8	6.08
ABUAD borehole water	26.8	6.53

This study was conducted on four water samples of different sources; they are water from Ureje River (latitude 7°37'4.76"N and longitude 5°16'26.88"E), borehole in Ilupeju (latitude 7°36'56.75"N and longitude 5°14'59.83"), well in Ureje (latitude 7°36'55.40"N and longitude 5°15'27.92"E), and borehole in ABUAD (latitude 7°36'18.04"N and longitude 5°18'26.95"E) within Ado-Ekiti. The location map of the study area is presented in Figure 1.

The communities considered for this study were chosen because they are among the most populated in the area (one of which is an institution with a large number of residents), with the sources being in the centre of the communities for good representation; implying that the water sources serve a good number of the people in the study area. Representative samples were taken in good quantity for the various water sources; one from a well that is well utilized, one each from two boreholes and one from a river that is accessible by almost all the people in the area. The collection was done in clean bottles and the samples were taken such that they were in their purest form as the people will want it ensuring that no external contamination was possible. The various tests were then carried out to check the suitability of the water for domestic usage and compared with the World Health Organisation (WHO) standard for good water supply.

RESULTS AND ANALYSES

The results of the various tests that were carried out are thus presented. Turbidity test conducted on five portions from each of the samples taken from all sources are presented with their corresponding averages. The pH values, result of jar test, total hardness, calcium hardness, and alkalinity tests for the samples examined are as presented in Tables 1 to 6.

Summarily, the laboratory experiment conducted showed that, following the WHO standard for drinking water, water from borehole at ABUAD is satisfactory in all tests except in turbidity, that from borehole at Ilupeju satisfied all except for pH and turbidity, while water from well at Ureje and the river water from Ureje showed most unsatisfactory constituents as the water from the well at Ureje only meet requirements in jar test, hardness, and alkalinity, and that from the river water at Ureje satisfied in pH, calcium hardness, and alkalinity, but both failed in all others.

Conclusion

The expected physical and chemical tests for checking the quality of water for potability and safe domestic usage have been carried out. Based on these tests, the most suitable water source for drinking is the borehole; samples from ABUAD borehole water and the Ilupeju borehole water meet the permissible constituent level, meaning satisfactory; notwithstanding, a little more treatment is still required for borehole water in this study area particularly to correct suspended solids and ensure appropriate pH.

To consider water from the other sources for domestic use, we recommend that, further treatments be carried out on them, healthy environmental practice be ensured, and that activities in the study area should minimize contamination of the surface water, open defecation and discharge of waste into the river should be discouraged.

RECOMMENDATIONS

In the following tests, the following should be considered:

Turbidity: The four samples should undergo further flocculation, sedimentation, filtration and disinfection process. Alternatively, the water can be boiled at 100°C for at least 30 min, allowed to cool down, filtered, and stored in a clean covered container for consumption.

Jar test: The Ureje River, Ajebamidele well water and the ABUAD borehole failed in this test because of their turbid level; thus, the amount of coagulant added to the

Table 3. The jar test.

Samples	**Amount Of coagulant (g) $Al_2(SO_4)_3$**	**Turbidity (NTU)**
Ureje river water	0.5	5.56
Ureje well water	0.5	1.67
Ilupeju borehole water	0.5	0.93
ABUAD borehole water	0.5	1.08

Table 4. Hardness classification of the water samples.

Sample	**mg/L as $CaCO_3$**	**Classification**
Ureje river water	122	Hard
Ureje well water	86	Moderate
Ilupeju borehole water	68	Soft
ABUAD borehole water	57	Soft

Table 5. The content of calcium in the water samples.

Sample	**Calcium in mg/L $CaCO_3$**
Ureje river water	25.23
Ureje well water	26.83
Ilupeju borehole water	18.82
ABUAD borehole water	6.01

Table 6. The alkalinity level of the water samples.

Sample	**Alkalinity mg/L $CaCO_3$**
Ureje river water	318
Ureje well water	162
Ilupeju borehole water	114
ABUAD borehole water	134

water sources should be increased or instead a different coagulant e.g. alum, ferric chloride and ferric sulphate should be introduced to the water samples.

An efficient drinking water treatment plant that is suitable for the community should be provided. Research on potable water should be funded by every nation of the world and environmental sustainability should be given optimal priority.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Waves-waves collide induced by different wind directions caused high exchanged in the water level at the open area Shallow Lake, China

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Wind from different directions induce waves-waves to collid at the central zone of Taihu Lake. It causes exchange in water bodies and release of internal nutrients which increases algal bloom. This study aims to analyz the impact of the interactions between waves-waves collision from different directions and different sources such as traveling ships and explored factors, causing sediment resuspension. The results were achieved to collect high-frequency data for measuring wind speeds, currents, waves, and suspended solid concentration (SSCs). The results indicate that the water exchange and the turbidity highly escalated when wind speeds reached 5 m/s. The surface flow velocities are very high, about 80 cm/s or more according to the raw data after calibrating the instruments. This finding is very important in the processes of sediments dynamic. Maybe in these wide area, high waves –waves collide leading to constructive interference from different sources generate waves. Sediment processes were categorized into three period A, B, and C corresponding to three shear-stress thresholds. Period A: Sediment bottom particals was stable with $\tau w < 0.01$ N/m^2. It did not change through this period and the averaged suspended solid concentration (SSCs) was approximately 50 mg/L. Period B: Sediment resuspension was small with a range between $0.01 \leq \tau w < 0.1$ N/m^2. It jumped up slowly and the averaged was in the range of 50 to 70 mg/L. Period C: Sediment resuspension was moderate with shear stress $0.1 \leq \tau w < 0.8$ N/m^2. The form of the sediment bed was changed at the second period, this shows that increase of the shear stress activated the sediment in this period. The bottom SSCs increased quickly from 60 to 350 mg/L in average. Outcomes of this paper presents the main factor causing sediment resuspension, which may assist further studies and estimate the real reasons for internal nutrient release from different waves induced waves-waves to collide in Lake Taihu.

Key words: Eutrophication, central zone, shear stress, different direction wind, waves-waves collide, constrictive interference.

INTRODUCTION

Excess nutrient loading in shallow lakes, reservoirs as well as freshwater bodies have become a critical

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environmental issue which is resulting in increased algal blooms and affects the water quality negatively (Paerl et al., 2001; Paerl and Huisman, 2008; Qin et al., 2010). The factors effect on water eutrophication include nutrient enrichment, hydrodynamics, and environmental factors. The prevalence of water eutrophication is actually a difficult function to evaluate amongst the affecting factors (Martin et al., 2008; Yang, 2008). Excessive nutrient loading into surface water system is considered to be one of its main factors (Fan et al., 2004; Tong et al., 2003; Xiao-e and Yang, 2008; You et al., 2007). Eutrophication phenomena are excessive nutrient loading especially in shallow lakes. It is considered as a result of internal nutrients release from sediments (Qin, 2009; Qin et al., 2006; Zamparas and Zacharias, 2014).

Sediment resuspension by waves-waves collides that work on the water-sediment results in internal nutrient release. The main dynamic steps considered to be the key of transporting solid particles and nutrients. Wind-induced waves are the forces which sediment re-suspension in shallow water bodies (Li et al., 2017; Qin et al., 2006; Stone, 2011; Wang et al., 2014). The changes in habitat of aquatic organisms may be attributed to a few storm events, waves-waves collide from different sources influence on transmission, nutrient and sediment transport (Barros, 2005; Davis et al., 1982; Mazumder and Ojha, 2007; Skilleter, 1996).

In addition, other research used numerical experiments to analyze the impact of hydrodynamic force on the sediment resuspension in lakes (Qin et al., 2004; You et al., 2007). Other researchers have worked on the impacts of currents and waves on sediment resuspension processes (Li et al., 2017; Pu et al., 2000). Observations on sediment dynamics resuspension were carried out in open-channels, rivers resuspension, and the results showed that it is primarily caused by current-induced shear stress (Jin and Ji, 2004; Li and Sheng, 2011). However, it is clear that the sediment resuspension consider a result of wind-induced waves in shallow lakes, ponds, and nearshore of the lakes (Chung et al., 2009; Ji and Jin, 2014; Qin et al., 2004; Mian and Yanful, 2004). The shear stress is responsible for sediment resuspension in shallow lakes (Hamilton et al., 1996; Sheng and Lick, 1979).

The current study about sediment resuspension in shallow lakes, for example Lake Taihu in China assistance to sediment resuspension is from current and waves, mainly associating to wind effects, were not measured (Qin et al., 2004; Qin et al., 2006). In the present study, real-time measurements of high-frequency sediment concentration and hydrodynamics data from Lake Taihu were achieved under complex actions of wind-induced waves and currents. The aims of this study were to: (1) explore the changes of the current speed, wave parameters and nutrients loads under different wind speeds and directions in Taihu Lake; (2) establish the relationships between winds, current, wave, and suspended solids concentration (SSC); and (3) estimate the effects of sediment dynamics processes to critical shear stress. The outcomes of this paper will contribute to realizing the factors and mechanisms of sediment resuspension such as waves-waves collide from different direction in the open area of Lake Taihu.

MATERIALS AND METHODS

Study site

Lake Taihu is located in the lower Yangtze River Delta in China between 30°56′-31°33′ N and 119°53′-120°36′ E in the south part of Jiangsu province. The depth ranges from 1 to 2.5 m with a mean of 1.9 m and the total water surface area is about 2,338 km^2. It is an essential source of drinking water for local cities around the lake, and has experienced severe eutrophication and harmful algal blooms. Sediment resuspension has caused nutrient released, which is one of the most important factors of algal growth in the lake. It has been continually monitored until now. Field observations were conducted in Pingtaishan, the central part of the Lake with depth 2.7 m (Figure1).

Instruments pattern

Synchronous, high-frequency measurements of wind, currents, waves, and SSC were carried out in this study. The observation tools included a RBR duo T.D wave tide gauge, PH-II Handheld weather stations, PHWD wind direction sensor, a bottom-mounted holder equipped with an Acoustic Doppler current profiler (ADP Argonaut-XR), Acoustic Doppler Velocimeter (ADV Ocean, Son Tek Inc.), and Optical Backscatter Sensor (OBS) turbidity meter. The wind parameters were measured using PH-II Handheld weather stations and a PHWD wind direction sensor fixed on a bracket 5 m above the surface of the lake (Figure 2). The records gathering interval was 5 min and it used automatic wind speed with direction recorder (10 meter above the water surface, 10 min monitoring interval). Also, the vertical velocity profile was measured using an ADP Argonaut-XR (operating frequency of 1500 kHz) fixed above the sediment-water interface (Figure 2). The ADP blind height was 50 cm and the instrument height was 30 cm, so the first layer of the monitoring cell was 80 cm above the lake bottom. The water bodies was classified into four diffision. The ADP measured the variance in every 10 min, average current profile at a resolution of 0.1 cm/s, signal-to-noise ratio (SNR) in the water profile, correlation coefficient, and echo intensity (EI).

Velocity was measured at two fixed points using two ADVs. The First was 5 cm overhead the lakebed. The second was 50 cm under the water surface. Surface ADV had an operating frequency of 10 MHz a monitoring frequency of 10 Hz (Figure 2). Temperature wave tide gauges RBR duo TD wave was used for measuring 3-D velocities. The instrument was fixed 50 cm below the water surface (Figure 2). It measured significant wave height and wave period. OBS-3A instruments were used for measuring Turbidity.

Analysis methods

Laboratory analysis of SSC

The turbidity (NTU) measured by the OBS was calibrated with SSC samples, and measuring the concentration (in mg/L) according to Luo, (2004) method.

Wave data gathering

The Equation 1 showing wave parameters was used:

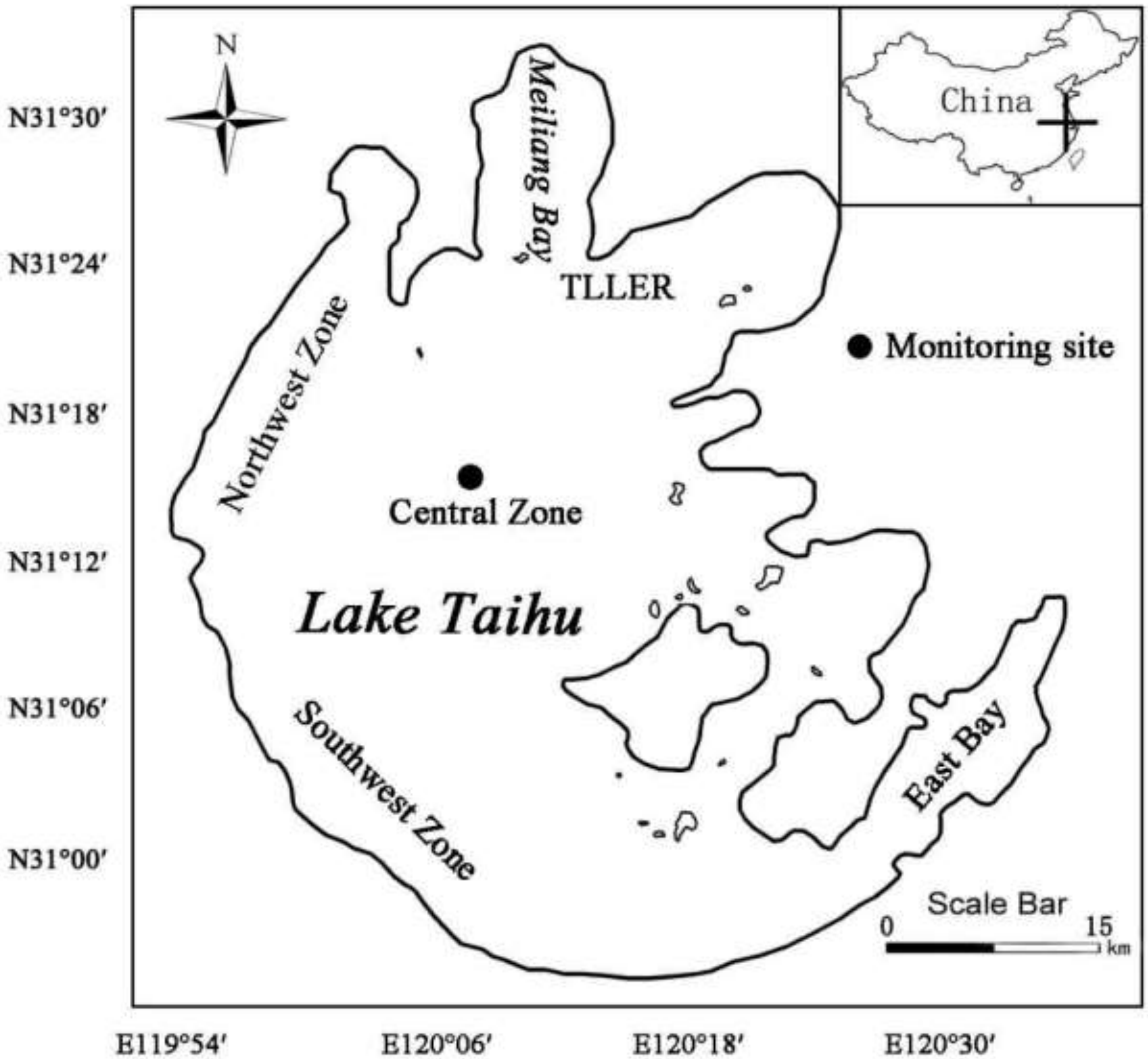

Figure 1. Location of the monitoring site at central zone in Taihu Lake.

$$L_s = (\frac{gT_s^{\ 2}}{2\pi})\tanh(\frac{2\pi h}{L_s}) \qquad (1)$$

L_s referes to the significant wavelength, T_s means the significant wave period, and h means the depth points we observed.
The maximum orbital velocity of wave near the bottom layer u_w (m/s) can be expressed as (Madsen, 1976; Whitehouse, 2000):

$$u_w = \frac{\pi H_s}{T_s \sinh\left(\frac{2\pi h}{L_s}\right)} \qquad (2)$$

The letters refers to the following: H_s means the effective wave height (m), L_s the wavelength (m), T_s is wave period, and h is the depth pionts in meter.

Shear stress gathering

Shear stress produced by wave-current interactions consider the dynamic force for sediment resuspension in the Lake (Chung et al., 2009). To differentiate the different contributions of waves and currents, the shear stress generated by waves and currents at the water-sediment interface was calculated based on the linear wave theory and Karman-Prandtl logarithmic velocity distribution law.

Shear stress produced by waves can be calculated by the following equation (Li et al., 2017; Grant and Madsen, 1979) :

$$\tau_w = 0.5\rho f_w u_w^2 \qquad (3)$$

The abbreviation τ_w is shear stress (N/m^2), ρ indicated to the density of water (kg/m^3), u_w the maximum wave orbital velocity near the bed (calculated by Equation 2), and f_w the wave friction coefficient related to the lake bottom roughness and Reynolds number. The f_w was calculated as follows (Jiang et al., 2000):

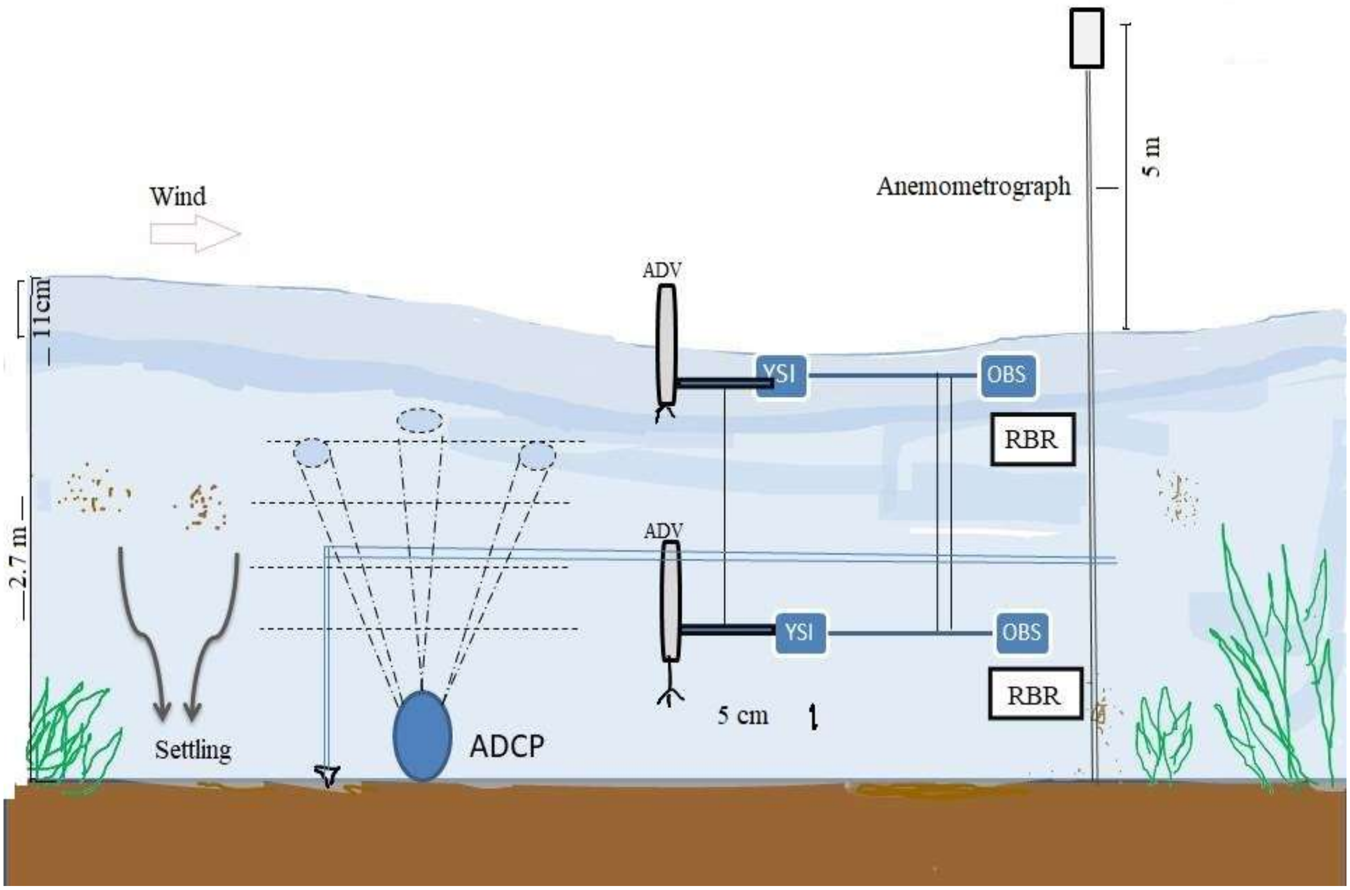

Figure 2. Diagram of the instruments layout for field observation in central zone.

$$f_w = \exp\left[5.2(A_\delta / K_s)^{-0.19} - 6.0\right]$$
$$f_{w,\max} = 0.3 \text{ if } A_\delta / K_s \leq 1.57 \quad (4)$$

The abbreviation Ks is the physical roughness of the lake bed and A_δ is the amplitude of wave-particle (m), which is determined by the linear wave theory. A_δ is calculated as follows:

$$A_\delta = \frac{H_s}{2\sinh\left(\frac{2\pi}{L_s}h\right)} \quad (5)$$

The shear stress caused by current at the water-sediment interface calculated with the following (Hawley, 2000; Sheng and Lick, 1979) methods:

$$\tau_c = \rho u_b^* u_b^* \quad (6)$$

$$u_b^* = \frac{k u_z}{\ln \frac{z}{z_0}} \quad (7)$$

The abbreviation τ_c indicates the shear stress affected by currents (N/m^2); u_b^* is friction velocity (m/s); *k* is the Kaman constant (0.4); u_z represents the velocity, which is the height, *z*, above the bottom; and z_0 is the bottom physical roughness (0.2 mm) (Li et al., 2017 ; Hawley, 2000; Nielsen et al., 2001).

RESULTS AND AND DISCUSSION

Physical characteristics of wind, wave and flow velocities

Wind field analysis

From 23rd to 31st July 2014 the wind variances in the observation period is recorded in Figure 1. The range of wind speed was from 0.7 m/s to 9.6 m/s with mean 3.7 m/s. The statistical analysis of the wind direction frequencies is shown in Figure 4. The frequencies moving clockwise from North to West and a little South were 14.67, 5.84, 5.71, 3.78, 4.66, 3.29, 4.07, 3.28, 4.66, 3.28, 4.07, 6.80, 4.86, 4.86, 2.77, 6.24, 3.03, 2.85, 2.465, 11.44 and 16.42%. During the observation period, the main high percent wind directions were North-north West, North, and Northwest and West-Northwest. The opposite wind directions are Southeast and Southwest. The directions of wind variables and the high percent are f the north. The result indicates the generated waves from different directions and the high waves from the north. This finding is very important to a view point on different waves from different wind directions, which should be in considered by researchers in Lake Taihu.

Physical appearance of waves

From 19:00-6:00 during July 23-31, 2014, the significant wave height ranged from 0.005 to 0.817 m with a mean value of 0.289 m; the significant wave period varied from 1.72 to 3.952 s with a mean value of 2.613 s, and the significant wavelength ranged from 0.000267 to 45.75 m with a mean value of 8.95 m. Varying tentative movements of significant wave height and period were in harmony with wind speeds (Figure 3). Wind speeds significantly influences generated wave in the Lake. Besides, the wind direction is also an important factor. Figure 4 demonstrates that there were different wind fetch lengths and wind energies which may be caused by variances in the height generated. The wave height generated by North West winds is larger than wave heights generated by South-Southeast winds with same wind speed (Li et al., 2017). Additionally, the wind fetch length is an index of wave height. The wind subdues in a forward movement to dash across the water body. (Green and Coco, 2014; Li et al., 2017; Luo, 2004). Different wave's height is very important as the waves meeting in the central zone, which is indicated for variable, collides in this area.

Physical appearance of flow velocities

At the Central Zone, the flow velocities ranged between 2.81 cm/s to more than 80 cm/s during the summer season. This is not consistent with the findings (Jalil et al., 2018; Li et al., 2017;) at Meiliang Bay, where the flow velocities ranged between 2.75 cm/s to 21.58 cm/s with a mean velocity of 13.23 cm/s. The surface flow velocities were found to be higher than the lower water layers flow velocities. Upper middle, middle, and lower current of the flow were in the same direction during wind speeds as shown in Figure 6. The current direction changed markedly in each layer, which maybe as a result of the location of the observation. In open areas, the waves maybe induced differently from diverse sources such as waves induced by different wind directions and traveling ships in the lake. The monsoon weather is characterized by southeasterly winds in the summer and northwesterly winds in winter (Qin, 2008). In the lake, surface water current flows from SE to NE and from NW to SE at the bottom of the lake, and the transition area is at the middle layer. At wind speed ranging from 5-6.5 m/s, all currents from the surface to the bottom followed the wind direction; consequently, the wind-induced water movement and energy dispersal downwards, right to the bottom of the lake. The flow velocities in the surface were unstable and greatly influenced by surface waves induced by wind. Wind directions in the central zone during the filed observation were North-northwest, North, and Northwest and West-northwest. The opposite wind directions are Southeast and Southwest. Conversely, the water flooded from Meiliang Bay to the Lake center with SE or SW winds. Maybe this flowed water exchange in this area was produced by the water level alteration. Waves caused high currents in the central zone of shallow lake Taihu.

Wind wave conditions

Important conditions of wind wave

Wind-induced resuspension of sediments was studied in the shallow. Sediment resuspension was mostly motivated by wind-induced waves. Wind-induced waves were conciderd the main energy for variations in turbidity (Li et al., 2017). Many wind speeds impact on wave factors (Figure 5). The significant and maximum wave heights were 0.34 m to 0.40 m and 0.52 to 0.45 m. In Taihu Lake, the significant wave height ranged from 0.3 m to 0.5 m when wind speed was between 1 m/s and 6 m/s. In South Taihu Lake where the wind speeds ranged between 1 m/s to 6.2 m/s, the significant and maximum wave heights were 0.2 to 0.28 m and 0.04 to 0.46 m (Wu et al., 2013; Zheng et al., 2015). In central zone, the wind speed ranged between 1.2 m/s to 8.1 m/s. The results indicated that when the wind speed increased, the wave height increased. Figure 5 shows that when the significant wave height was less than 0.3 m, the wave energy density was lesser, especially on 26, 27 of July. The mean wave periods show that the significant wave period varied around 2 s, and the mean wave periods were less than 2 s. The result is similar to that obtained by Qin et al. (2003), who described that the mean wave periods were around 1.1 to 2.6 s in the Lake. Figure 5 shows that the mean direction of wind-waves spread under different wind directions. The wave directions varied between 90 to 180 degrees, which established with the direction of the dominant wind Figure 4.

Effect of wind speed on turbidity

The turbidities in the water layers were accompanied by wind speed. Significant wind speeds conduct energy to hydrodynamic. It obstructed the constancy of suspended solids and encouraged sediment move in the water layers. The turbidity in the bottom is higher than in the surface layer. It is about 100 to 710.4 NTU and in the surface is about 50 to 254.4 NTU. The background turbidity is about

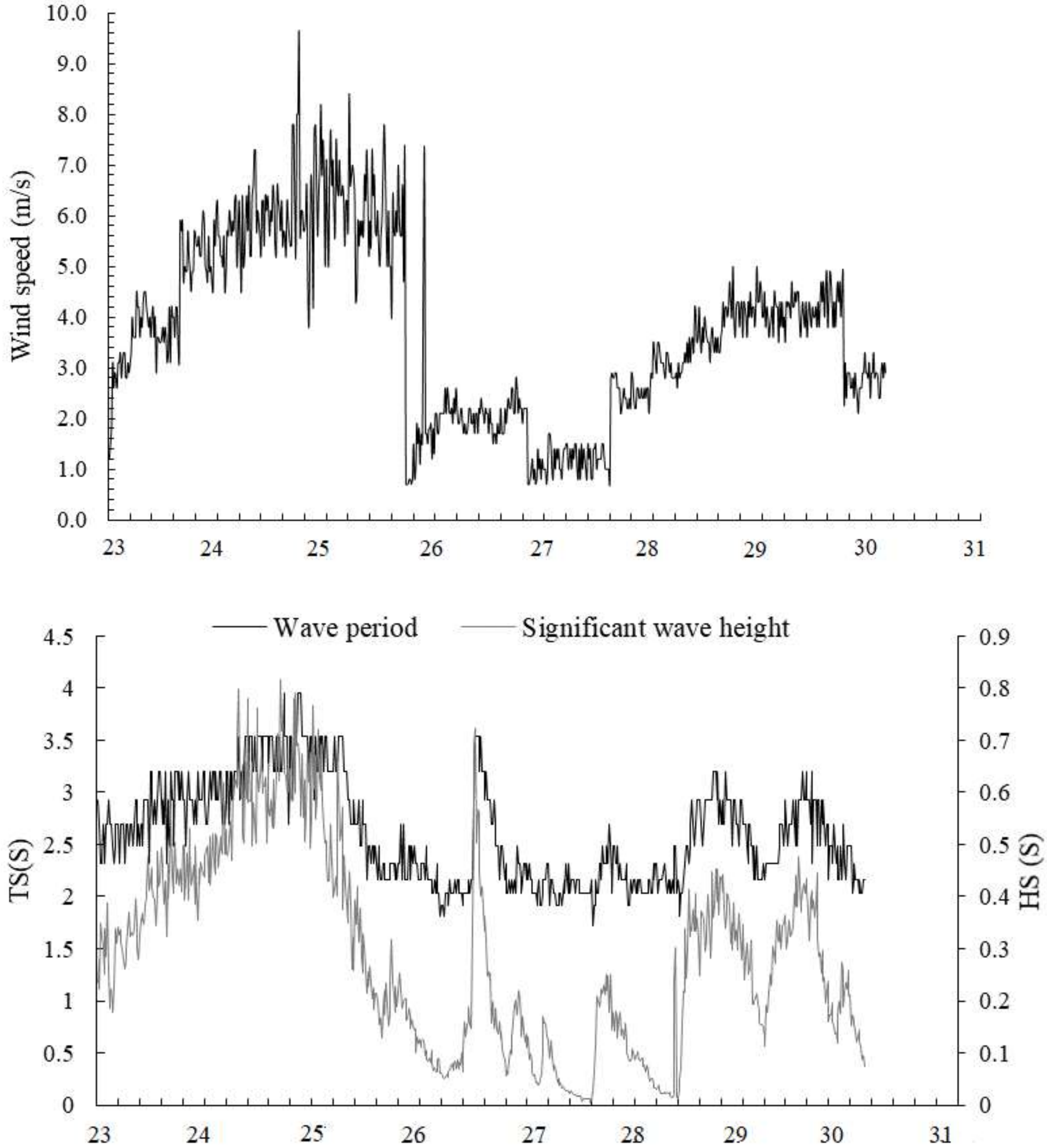

Figure 3. Varying trends of wind speed significant wave height and wave period 23-31/07/2014 19:00.

100 to 150 NTU and the surface is about 50 to 100 with a slow wind speed. Relating to Meiliang Bay during the small speed, the variance between turbidity in the surface and bottom layer was slight and the turbidity before was about 25 to 30 NTU. This finding shows that the suspended solids, which contain 50 of organics substances, can move to the surface easily of light thickness, also in the relaxed winds and hydrodynamics (Qin et al., 2000). When the wind speed increases, the bottom sediment continues to resuspend increasingly, resulting in variances in turbidity in water bodies. The realtionship between turbidity and wind speed in the

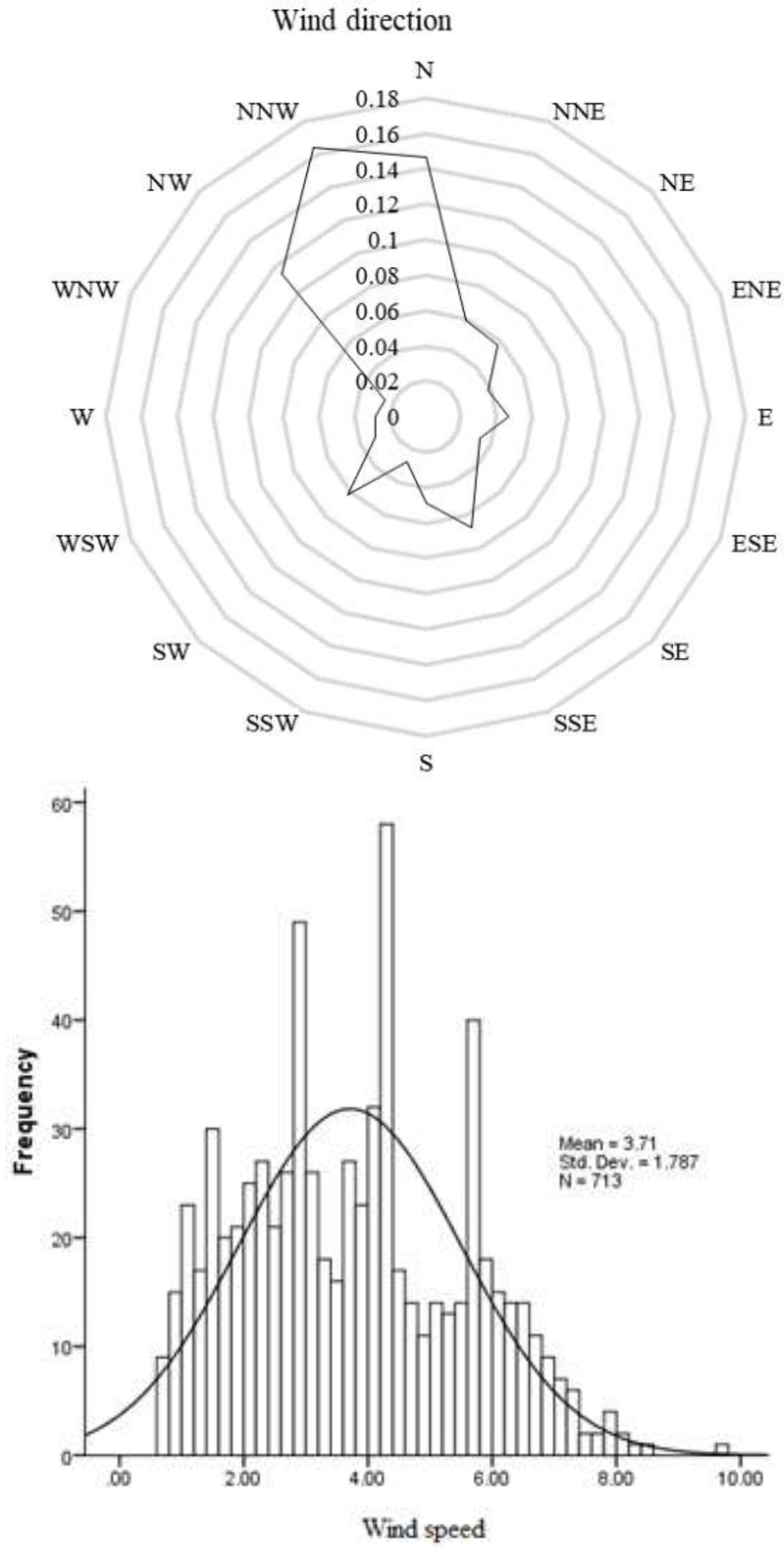

Figure 4. Wind direction and frequency of wind speed (m/s).

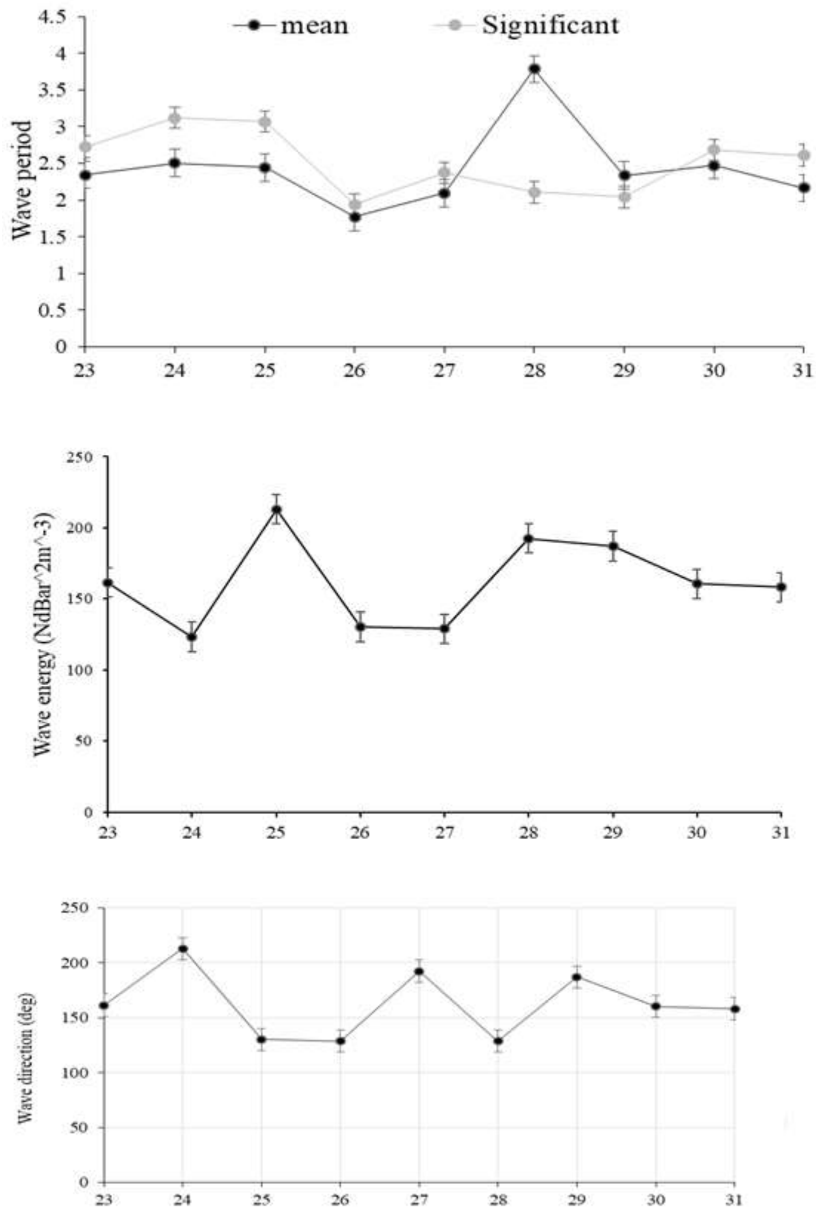

Figure 5. Mean wave energy density (a) wave period (b) and wave direction (c) under different wind disturbances.

surface and bottom layers is shown in Figure 7. The results displayed that a wind speed of 5 m/s was a point for sediment resuspension. Turbidities in the surface had moderate fluctuations, 50 to 100 NTU with wind speed 3.5 m/s; while in the bottom layer, they had large fluctuations, 100 to 200 NTU, with wind speed 4.5 m/s. Turbidity in the water column increased significantly and more unstable when wind speed ranged between 5~8 m/s. For instance, it increased in the bottom 7 to 8 times, and the surface 3 to 4 times (Figure 7). Also, these may occur because of different wind directions which generated different waves, leading to production of waves-waves collide. Hence this the main factor for sediments resuspension processes in the lake.

Impact of shear stress on the renewed suspension of sediment

The factors mechanisms influenced by sediment dynamics in open-area lakes are waves and currents (Bloesch, 1995; Li et al., 2017; Qin, 2008). They induced shear stress which influenced the SSC (Li et al., 2017; Qin, 2008). The sediment resuspension processes in

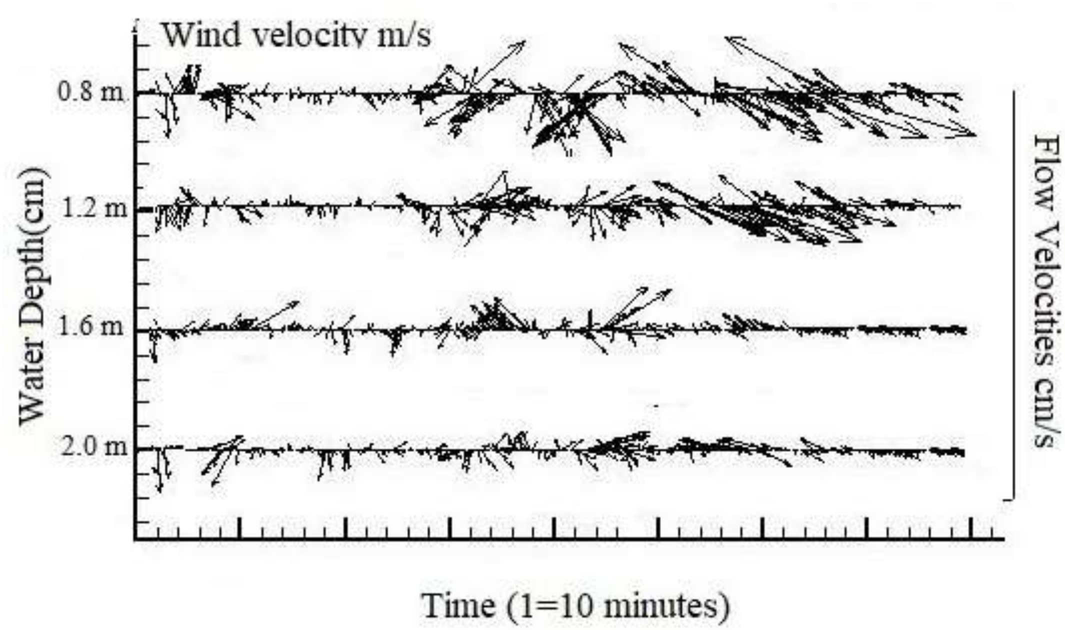

Figure 6. Comparison of wind velocities and Vertical flow velocity profiles during the present study field observations.

boundary was studied according to the bottom shear stress (Li et al., 2017; Qin, 2008).

During filed observation, the bottom shear stress generated by waves and currents displayed dissimilar tentative differences. The shear stress caused by waves was significant between 0.0008 - 1.908 N/m^2, with a mean value of 0.471 N/m^2. The bottom shear stress produced by currents was small, between 0.030 - 0.354 N/m^2, with a mean value of 0.030 N/m^2. These results given basically suggests that the total shear stress induced by waves was dominant. In most cases, in Lake Taihu, the shear stress created by waves is considered the main role in sediment resuspension. This result is close to Qin (2008) as well as Zhang and Xu (2003). The shear stress caused by wave are greater than those generated by currents. In some cases they are the same or greater than those generated by wave, when the winds or wind fetch is very small (Li et al., 2017; Qin, 2008). The bed shear stress produced by currents and waves is shown in Figure 8. There is a affirmative relationship between bed SSC and wave shear stress (Figure 8), while there is no relationship between SSC and current shear stress (Figure 8). This result indicate that waves are the main factor for sediment suspension in the Lake. The association between wave shear stress and SSC was analyzed to find out the critical shear stress value during sediment dynamic processes (Figure 8). The results revealed that the appropriate equation between Sedemint suspension concentration and shear stress generated by wave was $SSC_{OBS} = 38.161e^{1.56\tau_w}$, with R^2=0.6225. The trend appeared as three shear stress thresholds (shown as red dots in Figure 8) and sediment suspension progression divided into three phases: Phase A: Sediment remained was stable and $\tau_w < 0.01$ N/m^2. The bottom SSC was unaffected with average of about 50 mg/L; Phase B: Sediment was slightly activated and $0.01 \leq \tau_w < 0.1$ N/m^2. It increased with an average between 50 - 70 mg/L; Phase C: A sediment was moderately damaged and $0.1 \leq \tau_w < 0.8$ N/m^2. It shown that sediment and shear stress increased together and the average SSC was between 60 -350 mg/L.

The sediments in the bottom resuspended into the water column when both velocity and shear stressed exceeded the critical value. Results from this study indicate that measured influences of waves and currents depended on wind conditions; in the presence of wind speed conditions (< 4.5 m/s). in some cases, the bed shear stress was contributed equally; but this did not result in sediment resuspension process. In others cases, 95 was as a result of wave-induced shear stress. Some studies indicated that the piont of shear stress value which is important in sediment suspension ranged between 0.01 - 0.1 N/m^2 (Fang, 2004; James et al., 1997; Li et al., 2017; Lick, 1994; Lijklema et al., 1994; Sheng and Lick, 1979).

Conclusion

The present study eludicated that the factor of sediment resuspension processes during interactions between currents and waves is generated by wind. The results

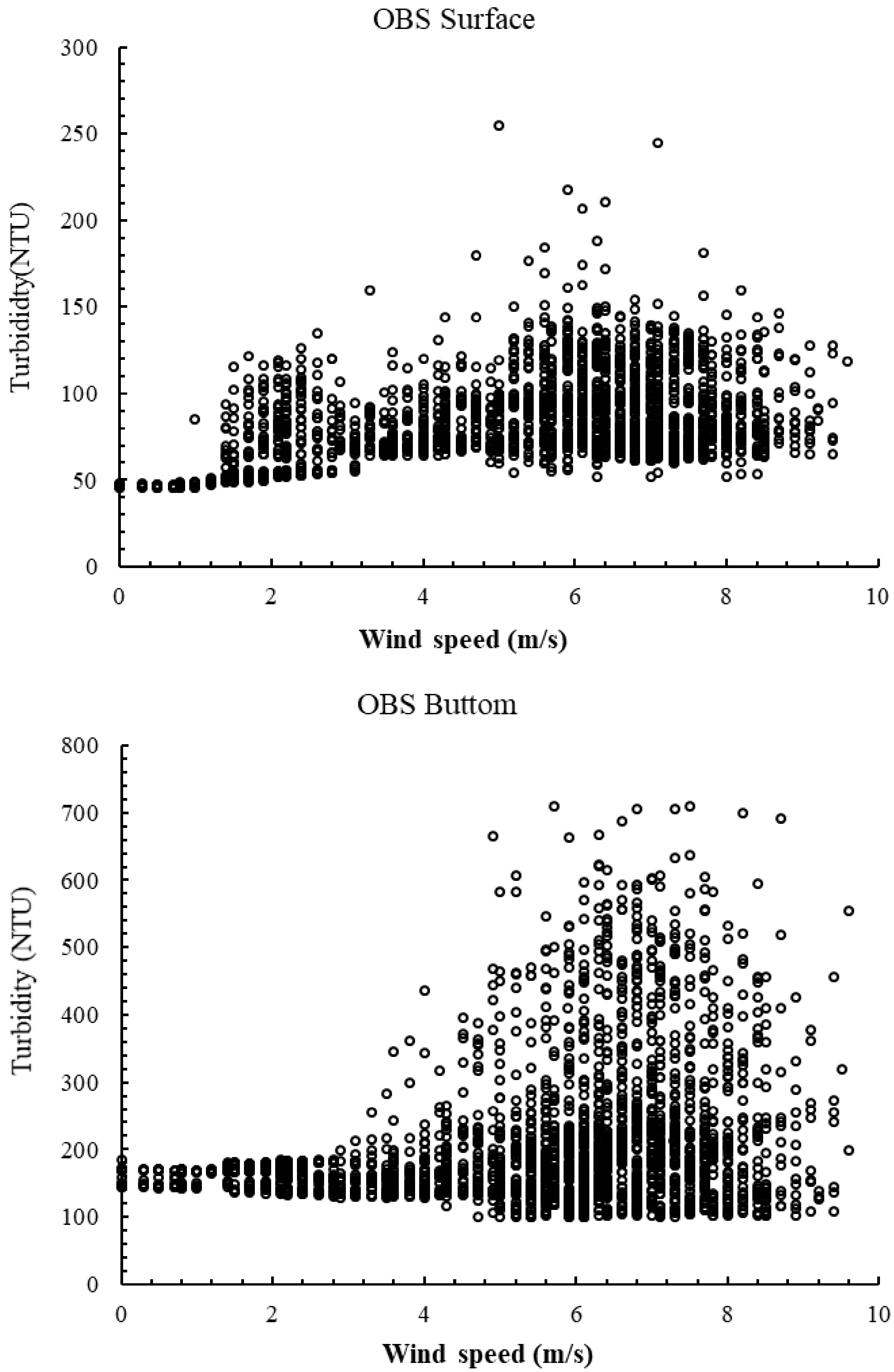

Figure 7. The relationship between turbidity in the surface and bottom with wind speed.

demonstrate that the turbidity has a relationship with wind speed and increases when wind speed reaches 5 m/s and more. In most cases, different waves induced by different wind directions collides in central zone and are resposable for the processes. The correlation between SSC and shear stress was determined using the formula

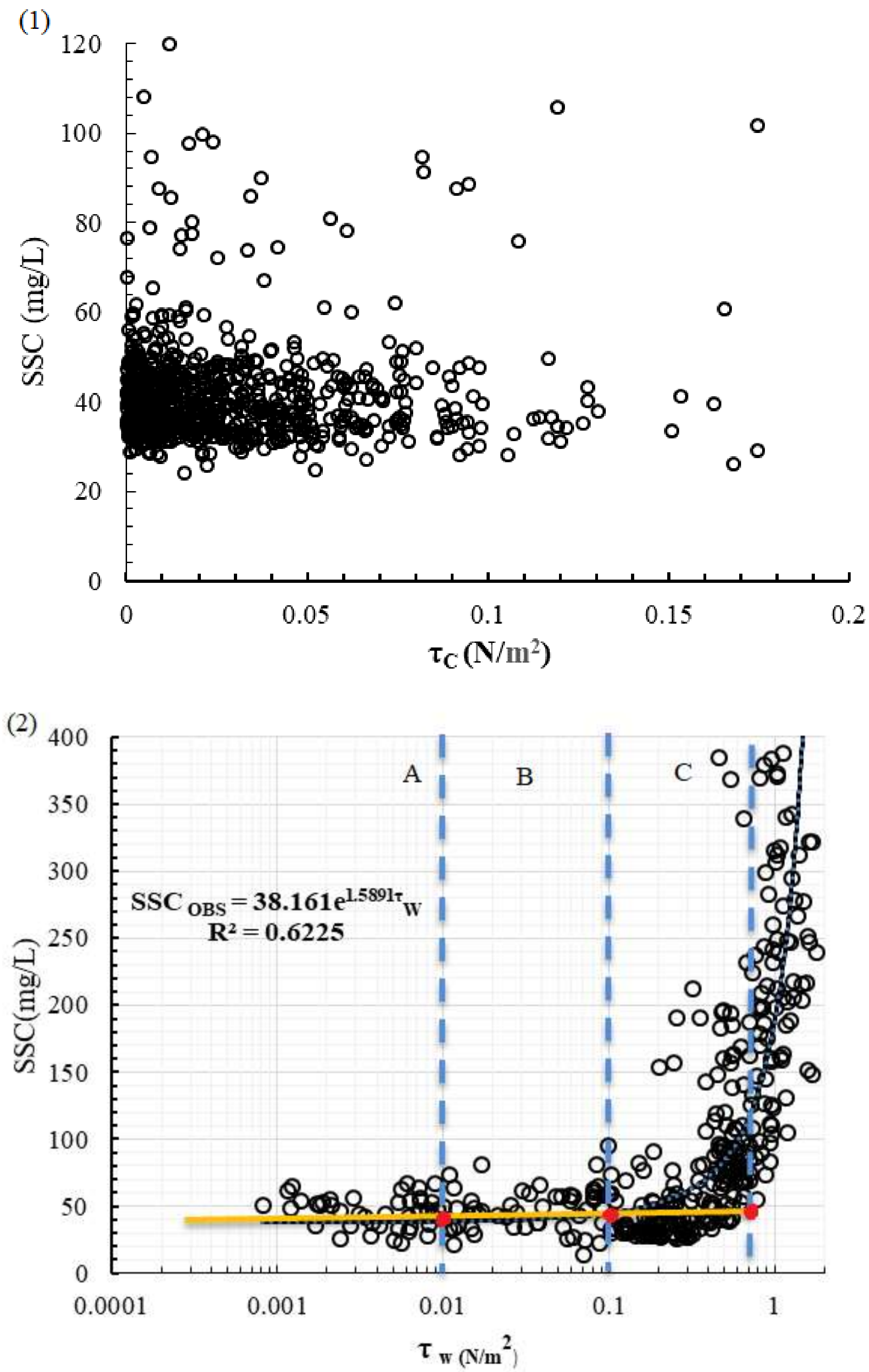

Figure 8. The relationship between SSC in the bottom layer and current-induced shearstress (1) and wave-induce shearstress (2).

SSC_{OBS}=38.161$e^{1.56\tau_w}$. The sediment movement process was classified into three stages. Stage A, SSC is constant with value 50 mg/L and τ_w was less than $\tau w < 0.01$ N/m^2. Stage B, SSC increased from 50 to 70 mg/L, and τ_w was in the range of 0.01 ≤ τw < 0.1 N/m^2. Stage C, a moderate quantity of sediment resuspension between 60 - 350 mg/L with 0.1 ≤ τw < 0.8 N/m^2. The outcomes of this paper opines that surface flow velocities may be very high in central zone of Taihu lake. This finding indicates different waves generated by different forces in the lake. When the waves-waves collided, they caused sediment resuspension processes at the bottom of Lake Taihu. Further studies should focus on the types of wave's interactions from different recourses, which encourages Algal blooms.

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CONFLICT OF INTEREST

The author has not declared any conflict of interest.

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