Investigating the Pollution of Lake Mofole (Cameroon) Using Field Studies, It’s Water, Sediments, Fish Content and Nearby Well Water

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Abstract: The pollution of lake Mofole, the main water source for the entire village was evaluated by conducting a field study on surrounding population, evaluating the physico-chemical properties of water and sediments from the lake and nearby well water and identifying the presence of heavy metals on the lake and nearby well waters, lake sediments and on five parts of the fish (head, bones liver, skin and flesh) by qualitative analysis. Results show a decrease in volume of this lake, extinction of many fish species and a rise in bilharzia and filarial in the community due to intense agricultural, occupational and domestic activities on the lake. All physico-chemical properties were within standards, except for temperature and EC of well water that were higher. High temperatures recorded for all the media studied probably enhanced the growth of microorganisms. Pb and Cd were present in lake water; As, Cd and Fe in well water; Fe, Cd, Hg, Pb and Zn present in sediments and Cd, Hg, Zn in all organs of the fish with Fe present in bone alone and Zn absent on the skin. This shows fish feeds directly from sediments and the combined effect of two or more poisons (Fe, Cd, Hg, Pb and Zn) may probably have contributed to extinction of some fish species. Proper management of this lake is necessary to avoid epidemics and improved economics of the community.

Key words: Aquatic environment • Heavy metals • Mofole • Pollution • Physico-chemical • Tilapia nilotica

INTRODUCTION

According to a World Health Organization fact sheet and other sources [1-2] the overall fresh water that is available for use is 1 % or 0.007 % of the total water on earth, which is really very little. Unfortunately, some 2 million tons of waste per day are disposed of within these fresh water sources (negatively modifying their physico-chemical properties), including industrial wastes and chemicals, human waste and agricultural wastes [3]. Freshwater resources which include Lakes and ponds, rivers and streams, reservoirs, wetlands and groundwater provide the majority of drinking water resources, for agriculture, industry, sanitation, tourism, educational and scientific researches as well as food including fish, amphibians, aquatic plants and invertebrates [4-6]. Fate of wastes in the aquatic environment and the community responses is summarized in Fig. 1.

Potentially harmful substances such as heavy metals are considered as dangerous pollutants because of their persistence in the environment, toxic in trace amounts, ability to induce severe oxidative stress and bio accumulate in aquatic organisms [6-8]. Unfortunately, they are present in virtually every area of modern consumerism from construction materials to cosmetics, medicines to processed foods; fuel sources to agents of destruction; appliances to personal care products [6]. Heavy metals reach the aquatic environment, by human action, atmospheric transport and as a result of erosion phenomena by action of the different edaphic factors [6]. In these aquatic environments, there are adsorbed on the suspended particles and then they accumulate at the level of sediments constituting an important source of contamination. Aquatic organisms also absorb the pollutants directly from water and indirectly from food chains [9,10]. Fish is one of the most important aquatic
communities concerning man [11]. Some of the toxic effects of heavy metals on fishes are; reduction of the developmental growth, increase of developmental anomalies, reduction of fishes survival- especially at the beginning of exogenous feeding or even cause extinction of entire fishes population in polluted reservoirs [9].

Several researchers [4, 10, 12-16] have used the identification of heavy metals in fish organs and physico-chemical parameters of the aquatic environments in controlling the pollution of this milieu. But literature review shows no such study on Lake Mofolé, located in the Far North region of Cameroon. In the present study, a field study on surrounding population was carried out. Some physico-chemical properties and qualitative analysis of some heavy metals was carried out on the Lake, nearby well water and the fish in the Lake. Results will help the people and local authorities of the area to be conscious of the dangers of dumping waste in the Lake and using water from the Lake and a nearby well which are the main sources of water in the area.

MATERIALS AND METHODS

Study Area: Mofolé Lake locally called petit barrage de Mofole is situated about 1 km from the town of Mokolo (geographical coordinates: 10°44’25”N and 13°48’10”E) which is the head quarter of the Mayo-Tsanaga division of the Far North region of Cameroon. Mokolo has a surface area of 1650km² with a population estimated at 310000 habitants distributed in 106 villages (Mofole included), with a population density of 188 inhabitants/km² and a growth rate of 3 %. The relief of Mokolo is dominated by plains and hills [17]. This locality has a Sudano–Sahelian climate characterized by a rainy season of about four months (June to September). But this Lake is not developed, with its surroundings being inhabited by farmers, villagers and sometimes fishermen as this location in environmental terms makes it a wetland, a place for agriculture, livestock and household and other domestic activities and development of some aquatic animals. Consequently, this Lake is the seat of intense human activity (washing of motorcycles, cars, laundry,
dishes, agriculture, fishing...) leading to various types of wastes being discharged in to it. Principal activity of the population is agriculture, livestock and motorcycle riding.

This study was conducted on three different sites (S1 and S2) of the Lake and S3, a well as shown in Fig. 2. The geographical coordinates of these sites are: S1: E013°46.796, N10°43.918, altitude 841m; S2: E013°46.742, N10°43.903, altitude 842m and S3: E013°46.732, N10°43.825, altitude 841m, determined by GARMIN etrex10 GPS.

The main activities carried out on S1 include washing of motorcycles and cars principally as well as laundry, dishes, livestock and gardening. While laundry, dishes, livestock and gardening are carried at S2. S3 is a well situated about 10 m from the Lake and is the principal source of more than 90 % water used for drinking and cooking in the Mofole village. S1 and S2 are the easiest access ways to the Lake due to the mountainous nature of its surroundings. The nearly 80 % of the 310000 inhabitants of Mokolo town depends on water from the Lake for agriculture and livestock, washing of motorcycles, cars, laundry and drinking during their different activities around the Lake. Motorcycles are the principal means of transportation of goods, persons and services.

Sample Collection, Treatment and Analysis: Prior to sampling, a preliminary study was carried out through the administration of questionnaires. This was aimed at having more knowledge on the changes undergone by the Lake with the evolution of time.

The sampling of water was carried out on the three sites while that of sediments and fish was done on S1 and S2 (on the Lake). Sampling was carried out during the dry season in the month of March and April with temperatures varying from 40-45°C generating intense activity on and around the Lake. Sampling was carried out by adapting the methods described by Demirak et al. [18] and Tabinda et al. [19]. Water samples and sediments were collected in polyethylene bottles (washed with detergent, then with deionized water, 2M nitric acid, then deionized water again and finally with water from S1 S2 and S3 and moist sediments from S1 and S2). Samples were acidified with 10 % HNO₃, placed in an ice bath and brought to the laboratory and the pH, temperature, TDS, electrical conductivity analyzed same day. The water samples and portions of sediments (washed with deionized water) were filtered respectively through a Whitman filter paper N°1 and the pH, temperature, TDS, electrical conductivity determined by an Extech pH-conductibility EC 500. The rest of the water was kept in a refrigerator while the sediments were dried at 120 °C for 24 hours and used for metal analysis. Sediment samples from a depth of 0.5-1 m from the surface were collected using a shovel. At each sampling time, 1–2 fish (Tilapia nilotica) was caught using a local fishing net. They were transported to the laboratory in a thermos flask with ice on the same day and stored in a refrigerator for 24 hours. The Fish was dissected and separated in to five organs: head, bones, liver skin and flesh. These organs were then dried at ambient temperature for two weeks, grinded to powder for metal analysis. The fish organs were digested (1g) with Conc. HNO₃ and H₂O₂ (1:1 v/v) [20]. The digestion flasks were heated until dissolution on heating plate and then diluted with water for analysis. For sediment metal analysis, 0.5g dried sample was taken in digestion tube. 4 mL conc. HNO₃ was added and sample was heated for 1hr at 120°C and 4mL H₂O₂ was added and digested until it was colorless [19]. A qualitative analysis of As, Pb, Cd, Cr, Cu, Fe, Hg, Zn, PO₄³⁻, NO₃⁻ was carried out on water from S1, S2 and S3 sites, sediments from S1 and S2 and on five organs of the fish (head, bones liver, skin and flesh) from S1 and S2 using standard methods [21,22].
RESULTS AND DISCUSSIONS

Through questionnaires administered, it was revealed that 40% of people interviewed have lived in Mofole village for a period of 4 to 5 years, 35% for 5 to 10 years and 25% for more than 10 years. This was intended to have viable information about the Lake such as changes in its volume, evolution of activities around it and the evolution of different species of fish present. Those who have lived around this Lake for less than 10 years constitute the majority. These are mostly people who migrate to this area with the aim of using water from the Lake for their respective activities (agriculture, washing of motorcycles, livestock, bathing etc.). These activities coupled with climatic changes have resulted in the decrease in water volume of the Lake. This decrease is often compensated during the rainy season by villagers and farmers who construct pathways that channel water from farmlands into the Lake (a major source of polluting the Lake). According to those interviewed, the drying of this Lake and the large quantity of waste disposed in it has resulted in the disappearance of some fish species and the quantity. This Lake today contains only Tilapia nilotica and in very small quantity. But according to the villagers, it used to be the main source of fish in Mofole some 20 years ago as it used to contain many other fish species.

The fact that a well (the source of drinking water, cooking and bathing in the village) was located some 10 meters from the Lake led us to carry an enquiry on the main illnesses suffered by the inhabitants of Mofole. This revealed that 80% of the inhabitants suffer from Bilharzia, while 20% suffer from filarial. They also revealed that sometimes water from the Lake overflows into the well. This study also revealed that, the lone health center of the village called TADA has sensitized the villagers on the risk of using water from the well as well disposing waste in the Lake. Unfortunately, 100% of our respondents say they are aware of such risks but have no choice since they dependent on the Lake and well water for their livelihoods.

The dominance of Bilharzia or Schistosomiasis amongst the population of Mofole is to be expected because it affects mostly poor and rural communities during routine agricultural, domestic, occupational and recreational activities which expose them to infested water. Transmission occurs when people suffering from schistosomiasis contaminate freshwater sources with their excreta containing parasite eggs which hatch in water. People become infected when larval forms of the parasite released by freshwater snails penetrate the skin during contact with infested water. Because it is the main water source for many activities, migration to this areas and population movements probably contributed in introducing the disease or parasite to the Lake and well water (through overflow of Lake water). Considering that high water temperatures enhance the growth of microorganisms, it is evident from this study that temperatures of 30-32 °C obtained for water and the sediments (Table 1) probably favoured the multiplication of the parasite that causes Bilharzia and filarial.

Physico-Chemical Parameters of Water and Sediments of Lake Mofole and Well Water: These results are presented in Table 1.

From Table 1, water from two sites on the Lake S1 and S2 showed a basic pH of 8.5 and 8.23, respectively. The sediments from these sites also had pH values of 7.5 and 7.62, respectively. However water from the well (S3) had a more acidic pH of 6.74. Though there is a variation in pH of the different sites of the Lake, these values are within acceptable limits as shown in Table 1. The low pH of well water (S3) may be attributed to discharge of acidic water by agricultural and domestic activities [20]. Acidic pH of water may also be due to acid rain that originates largely from mines and burning of coal and oil [11]. The basic pH may be due to the presence of carbonates of calcium and magnesium [20] as this Lake is located in a rocky terrain. Generally fish usually live at pH levels between 6.0 and 9.0, although they may not tolerate a sudden change within this range [11].

The underground drinking water quality can be checked effectively by controlling conductivity of water [24]. Water from S1 and S2 sites and their sediments showed EC within standards (Table 1). However, water from the well (S3) had EC values (408 ìS/cm) higher than the standard for drinking water (Table 1). This definitely resulted from the fact that chlorine is added to this well water twice a month as revealed by the local inhabitants. Higher values of EC and TDS may be contributed by Na⁺, K⁺, Ca²⁺, Mg²⁺, CO₃²⁻, HCO₃⁻, Cl⁻, SO₄²⁻ and NO₃⁻ [25]. EC in water is generally due to ionization of dissolved inorganic solutes or mineralization of organic matter in the bottom water [24].

Total dissolved solids indicated that the salinity behavior of groundwater. The increase in TDS is due to presence of K, Cl, Na, Cd, Pb and nitrates. High levels may produce undesirable taste. Leaves, silt, industrial wastes and sewage and pesticides and inorganic materials may raise the level of TDS in the water body [24].
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Site 1</th>
<th>Site 2</th>
<th>Site 3</th>
<th>Site 1</th>
<th>Site 2</th>
<th>Reference values [23]</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>8.50</td>
<td>8.23</td>
<td>6.74</td>
<td>7.50</td>
<td>7.62</td>
<td>6.5-8.5</td>
</tr>
<tr>
<td>CE (μS.cm⁻¹)</td>
<td>208</td>
<td>198</td>
<td>408</td>
<td>208</td>
<td>216</td>
<td>250 μS/cm</td>
</tr>
<tr>
<td>TDS (mg.L⁻¹)</td>
<td>184.0</td>
<td>175.2</td>
<td>374.0</td>
<td>184</td>
<td>192</td>
<td>500 mg/L</td>
</tr>
<tr>
<td>Temperate (°C)</td>
<td>31.7</td>
<td>31.5</td>
<td>32.2</td>
<td>30.7</td>
<td>30.4</td>
<td>NM</td>
</tr>
</tbody>
</table>

NM: not mention

### Table 2: Heavy metals present in water (S1, S2, S3) and sediments (S1, S2)

<table>
<thead>
<tr>
<th>Metal</th>
<th>Site 1</th>
<th>Site 2</th>
<th>Site 3</th>
<th>Site 1</th>
<th>Site 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe²⁺</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Pb²⁺</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Cd²⁺</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>As³⁺</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hg²⁺</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Zn²⁺</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

*: heavy metal absent +: heavy metal present

Water containing more than 500 mg/L of TDS is not considered desirable for drinking water supplies, but in unavoidable cases 1500 mg/L is also allowed [26]. Highly mineralized water may be used where better quality water is not available [27]. TDS values in the study area varied from 175 mg/L to 374 mg/L which were found within the permissible limits of 500 mg/L. High values of TDS in ground water are generally not harmful to human beings but high concentration of these may affect persons, who are suffering from kidney and other diseases.

Surface temperature showed almost constant values within the period of study. Temperatures of 31 °C were obtained for water from S1 and S2 with a corresponding low temperature of 30 °C for sediments from these sites. But a 32 °C value was obtained for well water (S3). These values are to be expected because the average environmental temperature during the study was 35-40 °C. Unfortunately, high water temperature enhances the growth of microorganisms and may increase problems related to taste, odour, colour and corrosion [28]. Thus, the Lake and well water probably contain more microorganisms than sediments. Babu and Selvanyagam [24] also reported that temperatures over 30 °C can cause regression in growth and decay in plants.

**Heavy metals present in water and sediments of Lake Mofole and well water:** Results of the heavy metals present in water and sediments of Lake Mofole and well water are presented in Table 2.

Table 2 shows the presence of Fe in the well water and the sediments from the Lake (S1, S2) but it is absent in the water from the Lake. Pb is also present in the water and sediments from the Lake but absent from well water. Cd is present in the well water (and As), water and sediments of the Lake while Zn and Hg are present in the sediments of the Lake. The agricultural drainage water containing pesticides and fertilizers, livestock activities, washing of motorcycles and cars, bathing and other domestic activities on the Lake, supplied the water bodies and sediments with heavy metals [29].

The presence of arsenic in well water may be due to natural sources (involving the dissolution of minerals or rock deposits containing inorganic arsenic) and could also be related to atmospheric deposition originating from the use of pesticides for agricultural activities. Arsenic is also found in large quantities on the surface zones of water sources, between 30 to 130 m depth [30]. The origin of the accumulation of arsenic in this well water may also be due to mountainous terrain of this area.

These results highlight the prevalence of many metals in the sediments. But the water from the Lake exhibited an opposite pattern in relation to the metals present; containing only Cd and Pb. This variation is because, Lake Sediments are normally the final pathway of both natural and anthropogenic components produced or derived to the environment [29]. This stems from the fact that sediments have a certain limited capacity to absorb different ions from waters percolating through it. This capacity is lowest for carbonate-sandy fractions of
Heavy Metals Present in Fish Organs from S1 and S2 on the Lake: Results of the different heavy metals found in fish organs are shown in Table 3.

Table 3 present results of heavy metals (Fe, Cd, Hg and Zn) found in the different fish organs. They show that the metals present in fish organs (head, muscle, bones, liver and skin) of Tilapia nilotica are closely associated with metals present in water and sediments of the Lake (Table 3) with Cd, Hg and Zn present in almost all organs. Fe is only present in the bones. This may be attributed to the presence of these metals in water and sediments and absorbed by aquatic organisms. A remarkable relationship between heavy metals concentrations in aquatic organisms and sediments were observed by Ibrahim et al. [36] and Ibrahim and El-Naggar [37]. Studies have shown that freshwater fish can concentrate cadmium to levels 10-1,000 times higher than levels in ambient water [38]. According to Soliman [39], nearly all of the mercury in fish muscles occurs as Methyl mercury, the most toxic form of Hg.

Although these analyses were qualitative; additive, antagonistic or synergistic effects [15] can lead to toxicity despite been present within tolerable limits. An example of an additive interaction is the combined toxicity of zinc and cadmium to fish. Also metals such as Cd, Pb and Hg have no known physiology to organisms. Because of their very high toxicities their presence within living organisms is a serious threat to their survival especially in the long term. Before further studies are performed on these metals presence and the extinction of some fish species in Lake Mofole, Cd, Pb and Hg present in the fish from this Lake may probable have contributed to this extinction.

CONCLUSIONS

Results of this study indicate that the physico-chemical properties studied of water and sediments from Lake Mofole as well as water from a well around its surrounding are within acceptable limits, except for the EC of well water which is slightly higher than accepted limits and the high temperatures in the Lake and the well. These high temperatures probably favoured the growth of many microorganisms particularly those causing bilharzia and filarial, thus affecting the health of the population. The presence of As in drinking water as well as presence of Pb, Cd and Hg within the Lake water, its sediments and on different parts of fish in this Lake is a course for concern. Because these metals occupy top positions on the ATSDR's Top 20 list (ATSDR’s = Agency for toxic substances and disease registry). As is number 1, Pb is number 2, Hg is number 3 and Cd is number 7 [40]. Lead accounts for most of the cases of pediatric heavy metal poisoning.

While waiting for detailed study to be carried out on this Lake owing to its importance to the local population, this paper should contribute in encouraging the Cameroon government to quickly apply the Minamata Convention (to which she is signatory) whose aim is to protect human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds and it sets out a range of measures to meet this objective [41].
REFERENCES


