PHYSICOCHEMICAL CHARACTERISTICS OF UNDRAINABLE WATER DAMS UTILIZED FOR FISH REARING IN THE SEMI-ARID NAROMORU AREA, CENTRAL KENYA

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Abstract

Naromoru is a semiarid area in Central Kenya, occurring on the leeward side of Mt. Kenya. Its water sources include a few permanent rivers such as Nairobi River, intermittent streams and a large number of undrainable water reservoirs. Most of the undrainable water resources have been stocked with fish but their utilization for fish rearing has generally remained very low. The purpose of this study was therefore to examine the water quality status of the dams to assess their suitability and potential for fish production. pH, electro-conductivity and total dissoved solutes (TDS) were measured *in-situ* from three reservoirs (Gathathini, Lusoi and Kianda dams) differing in their habitat characteristics. Water samples were collected for determination of the ionic concentartions of the reservoirs. Water quality status differed markedly between sites, with electric conductivity ranging from 350µScm^{-1} at Gathathini dam to over 1350µScm^{-1} at Lusoi dam. pH however showed only a slight variation from 8-9.6. Water temperature and transparency varied significantly between the sites, while cationic constituents (Ca^{2+}, K^{+}, Mg^{2+} and Na^{+}), anions (SO_4^{2-}, HCO_3^{2-}, and Cl^{-1}), heavy metals (Pb^{2-} and Cu^{2+}) and nutrients (NO_3^{-} and PO_4^{2-}) were all within the recommended WHO levels for fish production. Generally the water quality status was within the standards recommended for fisheries production.

Key words: Mt. Kenya, limnology, fisheries, productivity

1.0 Introduction

Undrainable dams in general are relatively small, perennial water bodies, varying in size from 0.02 to 25ha in area, with depths rarely exceeding 2.5 m. They have been constructed in many countries that lack natural lakes to trap run off water to meet future water demands and enhance food security (Sena de Silva, 1988). Because of their location in semi-arid areas, they experience extensive water level fluctuations due to water run-off, direct precipitation, ground water discharge, evaporation and most importantly human interference (Kemdirim, 2005). Their fisheries productivity is mainly influenced by prevailing physical and chemical characteristics (Chapman, 1996). Chapman (1996) and Dorstch (1981) noted that water temperature in dams affects their physical, chemical and biological processes. Different types of pollutants that end up in dams can also influence water by changing its temperature, light penetration, pH and electrical conductivity (Kinyua & Pacini, 1991). Similarly, high concentrations of certain minerals in water bodies cause problems both to the ecosystem and human health (Chapman, 1996; Masloomi *et al.,* 2009). In semi-arid areas, water bodies are largely affected by high evaporation rates that may result in high concentration of mineral salts.

The Naromoru area is generally a semi-arid area with few natural water bodies, although there are numerous small community owned dams. In the year 2003 for example, a project initiated by Waterman Foundation and Self Help Centre constructed several large reservoirs (25,000 m^3) and three sub reservoirs (5,000 m^3) to supply farmers with water for irrigation. The older dams were however constructed by white settlers to provide water for irrigation and domestic use. Some of the constructed undrainable dams have been stocked with fish, mainly tilapias, although fisheries development has remained low. This paper assesses the suitability of these dams for future fisheries production by presenting data on their physical and chemical characteristics.

2.0 Materials and methods

Naromoru area is located on the western leeward side of Mt. Kenya (Figure 1) and upper Ewaso Ng'iro River basin (Gichuki *et al*., 1998). The area receives a bimodal rainfall pattern with the long rains received from March to May and the short rains from October to December. Rainfall received is usually low averaging 800 mm with a range of 500 mm to 1200 mm per annum. Because of the low rainfall, the main economic activity in the area is marginal mixed farming. Temperatures in the area vary from 20°C to 25°C during the day and from 10°C to 15°C at night (Mathooko, 1992). Fisheries development in the area is largely practised on small aquaculture ponds with little focus on the large undrainable water dams in the area.

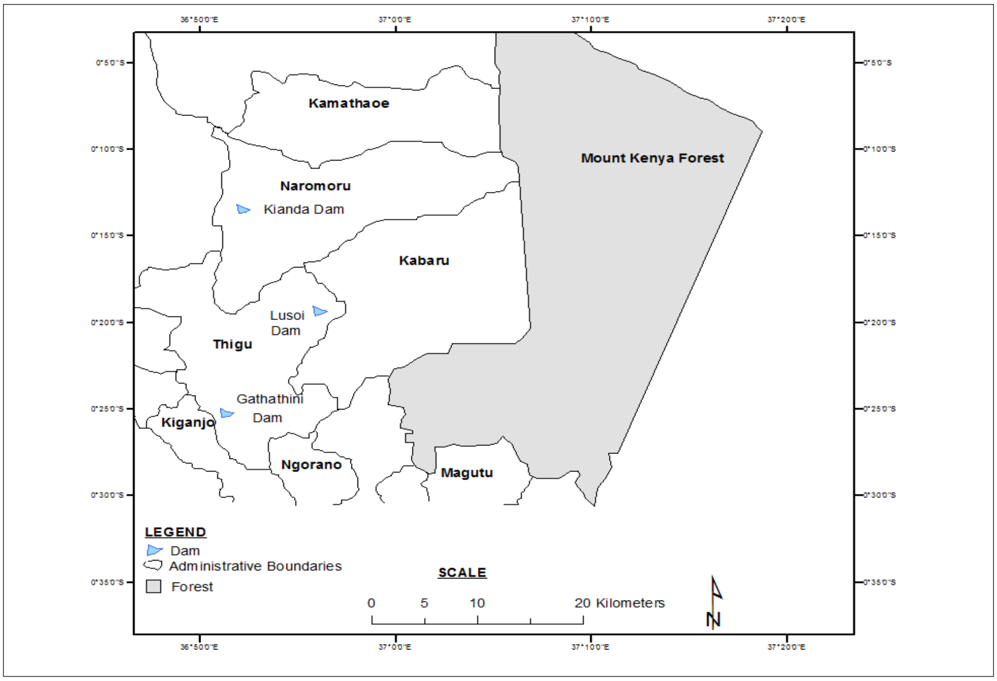

Figure 1: Location of the undrainable water reservoirs (Gathathini, Lusoi and Kianda) in Naromoru area, Central Kenya

Sampling was carried out bi-monthly from September, 2008 to February, 2009. Three dams were purposively selected for sampling, representing the different localities of Naromoru, namely Gathathini (co-ordinates S00°22.173' and E037º00.699'), Lusoi (co-ordinates S00°16.528' and E037°03.096') and Kianda dams (co-ordinates S00°05.713' and E037°00.107'). Gathathini dam (1782m asl) was developed from a disused quarry but had broken down three years prior to the start of the study and was subsequently rehabilitated. Much of the banks had been overgrazed although the western shores were more vegetated with tussocky grass. The dam is fed by water from Nairobi River, which passess through irrigated vegetable farmlands. During the dry season, the dam's water volume declines significantly due to low inflows although it never dries out completely. Lusoi dam (1989m asl) recieves water from a permanent stream and its water level remains largely constant. The dam was constructed in the early 1960s but had been recently desilted. It is well protected with heavy tussocky grass and shrubs growing along the shores. The dams' inlet is characterized by massive growth of emergent macrophytes such as *Typha* species, which prevents excessive inflows of pollutants from the surrounding farmlands.

Kianda dam (1880m asl) is located in a more dryer area. It was recently renovated having broken down in 2003. The dam is fed by a seasonal stream which similarly flows through an intensive agricultural area. During the dry season the inflowing stream dries up and the dams' volume decreases massively. The dam's shores are bare with little grassy vegetation although large acacia trees surround the dam. The local community has started farming around the dam posing a great danger to the water quality of the dam.

In each of the three dams, the major physical and chemical descriptors of water quality were measured. Water temperature was measured using a pocket thermometer while transparency was estimated by a 20-cm diameter secchi disc (Wetzel, 1983). The secchi disc was gently lowered into the water until it disappeared and then slowly raised until it reappeared. Secchi depth was computed as an average of the depth at which it disappeared and reappeared. Maximum depth of each reservoir was measured using a long straight pole and a tape measure. Water pH, conductivity and total dissolved solids (TDS) were measured in-situ using a calibrated portable pH/Conductivity/TDS probe meter (model PCT: 40). Dissolved oxygen (DO) was measured using a calibrated portable HI 9146 dissolved oxygen meter. Duplicate water samples were collected from the inlet, the shores, dam centre and outlet for analysis of major cations and anions. In total, five samples were collected from dam during the sampling period. Samples were transported in well-rinsed sample bottles to the Department of Mines and Geology, Kenya Government, where concentrations of all ions were determined using an electron spectrophotopheter (APHA, 1998).

3.0 Results

Surface water temperature, averaged for the whole the study period, was generally higher at Gathathini dam, averaging 21.9±0.52°C as compared to 20.3±0.43°C and 20.8±0.49°C at Lusoi and Kianda dams, respectively (Table 1) although the differences were not significant (K=3.638, $P>0.05$, Kruskall-Wallis test). The water temperature remained fairly stable at Gathathini dam, ranging from 21.0 to 24.3ºC, while at Lusoi dam, water temperature showed greater fluctuation ranging from 19.3 to 21.3ºC.

Water transparency was lower at Kianda dam as compared to Lusoi and Gathathini dams (Table 1), but the differences were not significant (K=4.028, $P<0.05$, Kruskall-Wallis). Gathathini dam was significantly deeper (K=6.25, $P<0.05$, Kruskall-Wallis) than Lusoi and Kianda dams, with an average depth of 1.7±0.38m. The increased depth of water at Gathathini dam was due to the desilting that occurred after the 1997-98 El Nino rains. Kianda dam recorded the least mean depth of 0.8±0.08m as compared to Lusoi dam with a mean of 0.9±0.03m. Water depth at Gathathini dam was also noted to experience high fluctuations which ranged from 1.21m to 4.91m, while Lusoi and Kianda dams had relatively stable water depths.

Water pH was higher at Lusoi dam averaging 9.6±0.05, as compared to Gathathini and Kianda dams with mean pH values of 8.3±0.11 and 8.6±0.05, respectively (Table 1).

Table 1: Physical-chemical characteristics of the three reservoirs of Naromoru

Reservoir	Temp (ºC)	Transparency (cm)	Depth (m)	pH	TDS (mg/l)	Condu-ctivity (µS/cm)	DO (mg/l)
Gathathini	21.9±0.52	20.4±0.87	1.7±0.38	8.3±0.11	221±4.41	312±41.3	5.3±0.01
Lusoi	20.3±0.43	20.5±0.98	0.9±0.003	9.6±0.05	833±35.3	1283±48.1	6.7±0.06
Kianda	20.8±0.49	7.4±0.03	0.8±0.08	8.6±0.05	530±50	730±10	5.9±0.06

However, the differences were not significant (K=5.139, P>0.05, Kruskall-Wallis test). Gathathini dam recorded high fluctuations in water pH ranging from 7.53 to 8.64. Lusoi and Kianda dams had stable water pH that ranged from 9.46 to 9.73 and 8.5 to 8.69, respectively. Lusoi dam had significantly higher TDS (K=6.25, P>0.05, Kruskall-Wallis test) than Gathathini and Kianda dams. TDS at Gathathini dam was low and fairly constant throughout the study period, probably because of low entry of solutes into the dam as the dam is entirely dependent on rain water and its banks are well protected. Lusoi and Kianda dams, however, received stream inflows from extensive agricultural catchments. Water electrical conductivity was significantly higher at Lusoi dam (K=6.25, P<0.05, Kruskall-Wallis), averaging 1283µS/cm, with a range of 1190 to 1350µS/cm, probably because of ionic concentration due to the long period it has existed as it was constructed in 1960’s. At Gathathini and Kianda dams, electrical conductivity was low averaging 312±1.11µS/cm and 730±10µS/cm, respectively. These dams were newly constructed.

Dissolved oxygen (DO) concentration was generally high (Table 1) in the three dams and did not differ significantly between the dams (K=1.111, P>0.05, Kruskall-Wallis test). Lusoi dam had the highest DO concentration that averaged 6.7±0.06 mgl^{-1}, and relatively higher fluctuations ranging from 5.13 to 8.31mgl^{-1}. The high level of oxygen concentration is attributed to the low water temperatures and the location of the dam at high altitude (1989 m) as oxygen solubility increases with decreasing temperature as altitude rises (APHA, 2005). Gathathini and Kianda dams were located at lower altitudes (1782 m and 1880 m) and consequently had higher water temperatures and lower DO concentrations, averaging 5.3±0.01mgl^{-1} and 5.9±0.06 mgl^{-1}, with ranges of 4.91-5.50 mgl^{-1} and 5.15 to 6.67 mgl^{-1}, respectively.

Mean concentration of calcium ions (123.9±41.71 mgl^{-1}) was significantly higher at Kianda dam (K=6.14, P<0.05, Kruskall-Wallis test), with Gathathini and Lusoi dams having means of 18.2±0.79 mgl^{-1} and 77.4±14.99 mgl^{-1}, respectively (Figure 2).

Unlike calcium, however, sodium ion concentration was significantly higher in Lusoi Dam (K=19.65, P<0.05, Kruskall-Wallis test), averaging 202.2±9.86 mgl^{-1} than at Kianda (105.9±8.25mgl^{-1}) and Gathathini (21.2±0.89 mgl^{-1}). Potassium ion concentration at Kianda dams was significantly higher (K=12.75, P<0.05, Krukall-Wallis test) than the concentrations at Gathathini and Lusoi dams (Figure 2).

The concentrations of heavy metals commonly used in agricultural chemicals and equipment (mainly copper and lead) were generally very low in all the three dams, ranging from 0.001 to 0.134 mgl^{-1} (Figure 4). Like the major cations, however, Lusoi dam had significantly higher concentrations (Kruskall-Wallis test, K=10.66, P<0.05), averaging 0.01±0.002 mgl^{-1}, 0.007±0.002mgl^{-1} and 0.003±0.002 mgl^{-1} of copper at Lusoi, Kianda and Gathathini dams, respectively. Similarly, lead concentration averaged 0.048±0.05mgl^{-1}, 0.02±0.003mgl^{-1} and 0.04±0.009 mgl^{-1} at Lusoi, Gathathini and Kianda dams, respectively. All the three dams were generally rich in nutrients, particularly phosphates which ranged from 1.2 to 6.0mgl^{-1} (Figure. 5). Nitrate levels were significantly higher at Gathathini dam (K=14.17, P<0.05, Kruskall-Wallis test), averaging 2.0±1.66 mgl^{-1}, 1.3±0.27 mgl^{-1} and 0.07±0.01 mgl^{-1} at Gathathini, Lusoi and Kianda dams, respectively. The concentrations of phosphate ions however had no significant differences (K=3.362, P>0.05, Kruskall-Wallis test) between the three dams, with averages being 6.0±2.75 mgl^{-1}, 4.7±1.42mgl^{-1} and 1.2±0.81 mgl^{-1} at Kianda, Lusoi and Gathathini dams, respectively.

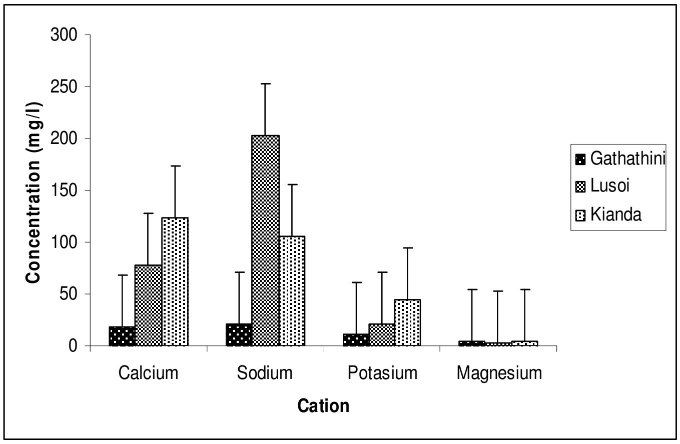

Figure 2: Mean concentration of the major cations in the three undrainable reservoirs of Naromoru

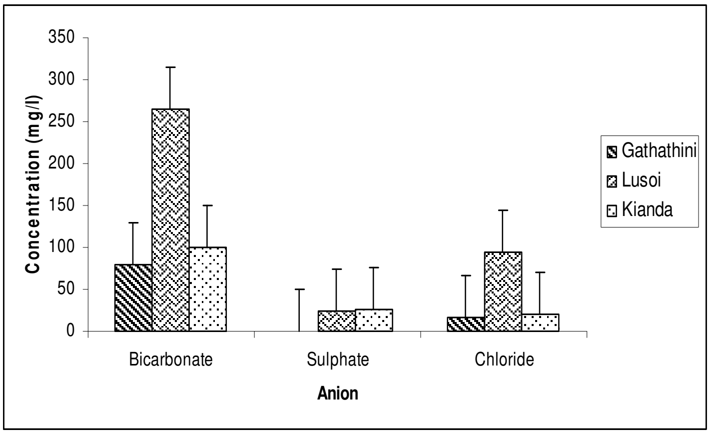

Figure 3: Variation in concentrations of the major anions in the three undrainable reservoirs of Naromoru

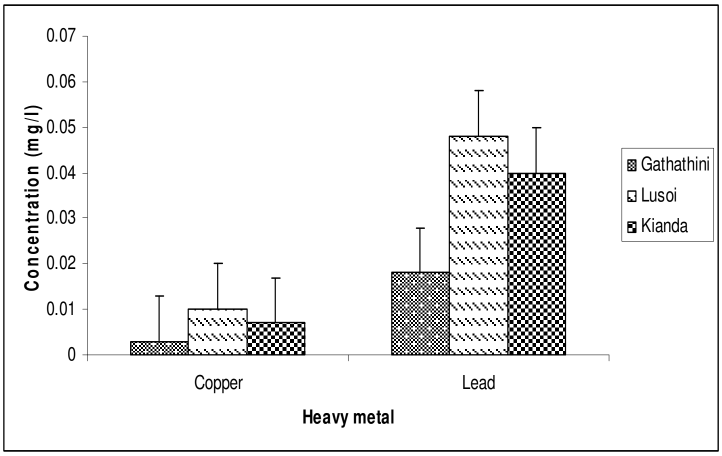

Figure 4: Variations in concentration of heavy metals in the three reservoirs of Naromoru

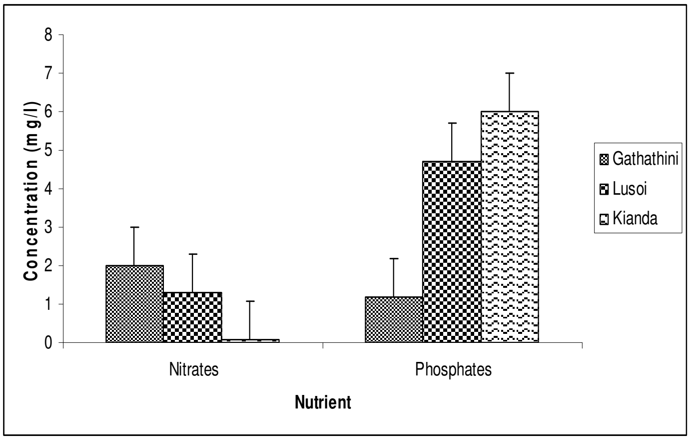

Figure 5: Variation of the major nutrients in the three dams of Naromoru

4.0 Discussion

Undrainable dams generally differ in their characteristics based on location, form and operations (Chapman, 1996). The three undrainable dams differed markedly in their physical and chemical characteristics in relation to their location. Gathathini dam, for example, located at an altitude of 1756m, experienced in average higher temperatures than Lusoi and Kianda dams, which were located on higher altitudes of 1960m and 1852m, respectively. Water dams in Naromoru were generally highly turbid, with turbidity's ranging from 7.32cm at Kianda dam to 22.5cm at Lusoi dam, due to siltation from surrounding catchment areas. Among the three dams, Kianda Dam had more turbid waters than Lusoi and Gathathini dams, as it was open to extensive erosion by surface run-off and disturbance by catfish, *C. gariepinus*. The shores of the dams had extensively cleared shoreline, which had been subdivided by the local community for agricultural purposes. Catfish are bottom dwellers, which extensively stir the bed sediments of a water body while searching for benthic invertebrates, which are their key food items (Koekemoer and Steyn, 2005). High turbidity prevents light penetration into the water thereby reducing primary productivity (Bruckner, 2009). According to Datta (2010), transparencies ranging from 20 to 40cm are suitable for fish production. And while Gathathini and Lusoi dams were within this range, Kianda dam fell below the range. The undrainable dams of Naromoru were generally very shallow, possibly because they have been in existence over a long period and have therefore suffered from extensive siltation. Recently, however, the Government began renovating them and Gathathini dam was reconstructed after the 1997/1998 El Nino rains. As such, Gathathini dam was the deepest of all the three. Kumar (1992) also reported that most undrainable dams in India have shallow depths arising from siltation. Siltation rates of undrainable dams in semi-arid areas are generally high as such areas potentially generate and transport large quantities of sediments during rainy seasons as they are characterised by scanty vegetation cover (Ampofo *et al.,* 2001).

Dissolved oxygen (DO) concentration in the three undrainable dams of Naromoru ranged from 5.0mgl^{-1} at Gathathini dam to 8.71mgl^{-1} at Lusoi dam, which was greater than the minimum concentration of 5mgl^{-1} required for survival of aquatic organisms (Chapman, 1996). The low DO concentration at Gathathini Dam was attributed to the high water temperatures that were experienced in the dam, reducing DO solubility (Ebbert, 2003). Lusoi dam on the other hand had high DO concentration, due to strong waves that occurred in the dam constantly aerating the water. The three undrainable dams of Naromoru had slightly alkaline waters with pH ranging from 7.53 at Gathathini dam to 9.73 at Lusoi dam, which was within the reported ranges of undrainable dams (Chapman, 1996). Kumar (1992), for example, studying the undrainable dams of India found their pH ranging from 7.0 to 9.0. The pH range recorded in all the three dams is within the tolerance levels of most aquatic organisms (Mukherjee *et al.,* 1992), with maximum fish production occurring with the pH ranges of 6.5 to 8.5 (Alabaster and Lloyd, 1980).

Measurements of total dissolved solutes showed Lusoi dam to have significantly higher ionic concentration, indicating that the dam was much more fertile than the other two. Similarly, the dam also had significantly higher conductivity than the other two, again confirming the higher fertility status of the dam. TDS and conductivity have been shown to have a positive and significant correlation (Kutty, 1987), which supports the findings reported in this study. The high concentration of TDS and electrical conductivity at Lusoi dam was attributed to accumulation of ions in the dam over a long period of time (since the creation of the dam in early 1960's). Gathathini and Kianda dams, which were constructed later recorded lower TDS and electrical conductivities. Generally, undrainable dams tend to have high salinities and conductivities due to lack or less outflow of water (UNEP, 2006), and high evaporation rates, which tend to concentrate dissolved minerals (Gordy, 2001). The predominant ions in all the three dams were sodium and calcium, although highest concentrations were recorded in Lusoi dam. The observation is in agreement to the measurements of conductivity and TDS, which were also highest in Lusoi dam. Studies by Purandara *et al.* (2004) along Malaprabha River in India reported that water bodies with high electrical conductivity values are predominant with sodium and chloride ions. Unexpectedly, the dams though occurring in intensively cultivated areas, had very low heavy metal concentrations, far below the recommended WHO guide for safe water levels (WHO, 2008). This result was surprising as most farmers around the area frequently use pesticides to spray their vegetables against pests. Nitrate levels were significantly higher in Gathathini Dam as expected as the reservoir had been recently fertilized using farm manure. It is concluded that the water quality of the dams is suitable for fish farming.

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