

Heavy metal and chemical uptake patterns of water and plant (*Ipomoea Aquatica*) obtained from Agodi Reservoir in Ibadan

Abstract

The basis and mode of heavy metal pollution of sampled water and plant (*Ipomoea aquatica*) obtained from Agodi Reservoir, Ibadan were investigated in this study. Of interest was possible gradient effect in the reservoir and variations that could be associated with changing climate. The aims were to determine the water quality and estimate ecological resilience of adjoining flora. Chemical analyses of the water samples were done using standard analytical methods while heavy metals in the water and plant samples were determined using Atomic Absorption Spectrophotometer (AAS). Heavy metal concentrations in sampled water were Cd 0.12, Co 0.19, Cu 12.40, Fe 43.75, Mn 64.81, Ni 0.17, Pb 0.005 and Zn 23.12 all measured in mg/L. All of these except for Cu and Pb exceeded the WHO standard. The concentration of heavy metals (mg/kg) in *Ipomoea aquatica* were Cd 0.24, Co 0.19, Cu 0.31, Fe 153.07, Mn 28.26, Ni 0.03, Pb 5.82 and Zn 35.90. The values obtained for Cd, Fe, Mn and Pb were higher while that of Co, Cu, Ni and Zn were lower to the WHO standards. Among the chemical parameters analyzed, only total hardness (TH) was higher, while SO_4^{2-} , PO_4^{3-} , NO_3^- , Cl⁻ and Alk were lower than the WHO allowable limits for drinking water. One-way analysis of variance (T-statistics) showed that the chemical contents and heavy metals recorded in the water and plant samples were insensitive to their location inside the reservoir, exhibiting no gradient effect. Also, there was no seasonal variation (wet or dry season) in the heavy metal concentration and the chemical parameters measured except for TH which is higher in the dry season. Albeit, the higher concentrations of Cd and Pb in *Ipomoea aquatica* and Cd, Cu, Fe, Mn, Ni and Zn in the water are concerns for safety when water and plants from the reservoir would, one way or the other, find their way into the food chain.

Keywords: Agodi Reservoir, water pollution, heavy metals, contaminated plant

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Introduction

Lakes and reservoirs are important sources of usable freshwater on Earth. Lakes and ponds are characterized as lentic systems, are diverse inland freshwater habitats that exist across the globe and provide essential resources and habitation for terrestrial and aquatic organisms. The study of lentic systems is embraced in limnology which Wetzel¹ defined as the structural and functional interrelationships between organisms of inland waters as affected by their dynamic physical, chemical and biotic environments. Previous workers have made clear differentiation between lake and reservoir. Bendford and Putz² described a lake as a naturally occurring body of water, with the inflow and outflow regulated by natural riverine system, while a reservoir, on the other hand constitute manmade impoundments that have control and many times subsurface outlets, these differences induce a considerably different ordering of important physical mechanisms which may in turn result in different water qualities. Perrow and Davy³ further defined water quality as the concentration of all dissolved elements and particulates as well as resident organisms. Anthropogenic activities contribute to the formation of lentic habitats. Impoundments and reservoirs are created by humans to provide water

resources for domestic use and livestock rearing.⁴ Reservoirs are those water bodies formed or modified by human activity for specific purposes including the following. Drinking and municipal water supply, industrial and cooling water supply, agricultural irrigation, power generation, river regulation and flood control, commercial and recreational fisheries, body content recreation, boating and other aesthetic recreational uses, navigation, canalization and waste disposal in some districts, No wonder, Reservoirs are often found in areas of water scarcity or excess, or where there are agricultural or technological reasons to have a controlled water facility, Where water is scarce, for example, reservoirs are mainly used to conserve available water for use during these periods in which it is most needed for irrigation or drinking supply. Where excess water is otherwise, the problem; reservoir is used for control Jorgensen and Johansen.⁵

Anthropogenic effects on aquatic ecosystem could result in pollution from contaminants, change to landscape or hydrological systems and large scale impacts such as climate change. Pollution denotes contamination of natural environments that produces deleterious effects.⁶ Water pollution, in particular occurs when undesirable substances are deposited in water and this could arise

from wastewater sludge discharge from commercial and industrial set-ups, discharges of untreated domestic sewage, release of waste contaminants including urban runoff and agriculture effluents which may contain chemical fertilizers and pesticides into surface waters. Cunningham et al.,⁷ described water pollution as any physical, biological or chemical change in water quality that adversely affects living organism or makes water unsuitable for desired use, Undue levels of pollution is capable of causing damage to plants, fish, animal and human health. Unfortunately, human activities resulting from rapid urbanization and industrialization have been linked to sophisticated technology that introduced many synthetic materials into the environment. Indiscriminate disposal of such synthetics and agricultural wastes into municipal and industrial water could find their ways into inland water bodies. Ultimately, the contaminants would create dynamics that impact the aquatic ecosystems; which enter the food chain of resident organisms which may be transferred to dependent higher organisms causing acute or chronic toxicity that may be harmful.⁸

When sewages and solid wastes are deposited in water, heavy metal toxicity can be expected. A toxic metal is any relative dense metal or metalloid that is noted for its potential toxicity, especially in the environmental context.⁹ Toxic heavy metal has particular application to cadmium, lead and arsenic¹⁰ all of which appear in the organization's list of 10 chemicals of major public concern. Other examples include manganese, chromium, cobalt, nickel, zinc and silver which have been cited in other literatures.¹⁰ Some elements otherwise regarded as toxic heavy nickels are essential, in small quantities, for human health. These elements include manganese, iron, cobalt, copper and zinc¹¹ and a deficiency of these essential metals may increase susceptibility to heavy metal poisoning.¹²

The complexity of aquatic ecosystem management and linkage within the organisms and habitat are yet to be fully understood and can make it difficult to predict the effects of undue and associated contamination, albeit, individual organisms have different capacities to adapt to different environmental conditions prompted by spot or continuous disturbances, *inter alia* to weather and climate situations or government policies and socio-cultural influence of communities changes in habited features and chemistry can favor or hold back biological distribution and or prevalence within the ecosystem. Rivers and lakes, even water reservoirs along rivers are very important habitat to various flora and fauna.¹³ Aquatic plants, also termed hydrophytes or mesophytes have adapted to living in water bodies. Such plants require special adaptation energies for living in submerged or surface waters suitable for their survival. The plants are ubiquitous in wetlands which constitute a suitable substratum.¹⁴

Physico-chemical studies are useful to get exact idea of the quality of water to make valuable decisions when results are compared with standard values. Considerable advancement has been made analyzing the physico-chemical parameters of water, significant among which are Pradhan et. al.,¹⁵; Sirvastava et. al.,¹⁶; Domothoran et. al.,¹⁷; Prasanna and Ranjan.¹⁸ Similarly, heavy metals have been used as indices of water pollution because of their high toxicity to human and aquatic life,¹⁹ while plants are also used as natural indicators of environmental pollution Trishala et. al.,²⁰

In this work, efforts were made to identify the sources of pollution at different locations in the Agodi Reservoir with the hope

of evaluating their degree of potency and regularity. The levels of pollution using chemical parameters in relation to contamination with heavy metals were determined while heavy metal pollutant threshold inside Agodi Reservoir and the relationship with plant bio-tolerance levels were studied.

Methodology

The study site

The study was conducted in the Agodi Reservoir situated between longitude 7° 2'E and 7° 40'E and latitude 3° 35'N and 4° 10'N of Ibadan, Oyo State, Nigeria. The reservoir was human created in 1980 along the path of Ogunpa River following the great flood of that year in the city. The purpose was to serve as retention basin for excess run-off from upper section of Ogunpa river, and to prevent flooding downstream of the river. Ibadan has a tropical wet and dry climate with a lengthy wet season characterized by precipitation that normally runs from March through October albeit August of the year was lull in precipitation. The lull divided the wet season into two distinct periods (March to July and September to October) with June and September having the highest precipitation values. The reservoir covers an area of 5.2hectares, stretching about 1km with a maximum depth of about 5m. The advancing Ogunpa River traverses major parts of Ibadan city where it flows through many markets, eateries, schools, residential areas, abattoirs, mechanic workshops, parking lots, waste dumps and other areas where wastes are generated before discharging into Agodi Reservoir. All of these activities result in increasing the pollution and pose environmental problems, economic and productivity loses.

Experimental plant

Ipomoea aquatica

The water and marsh plant, *Ipomoea aquatic* (Figure 1) used for this study has a creeping hollow filled stems with shining green leaves. Its stems are 2-3 meters or longer, and rooting at the nodes. The big funnel shaped flowers, 2-5cm are purple or white. It is a plant trailing or floating, herbaceous, sometimes annual or perennial. Propagation is either by planting cuttings of stem shoots that will root along the nodes or planting seeds from flowers that produce seed pods. It is found throughout the tropical and subtropical regions of the world. It is known by many names, which includes water spinach, river spinach etc.²¹



Figure 1 Photograph of *Ipomoea aquatica*.

Samples collection, preparation and analysis

Water samples: Samples of water were collected using 250ml clean plastic containers from three sampling locations comprising the inlet (F) centre (G) and outlet (H) parts of Agodi Reservoir. The samples were clearly labeled and taken to the laboratory for their chemical and heavy metal analysis. The procedure employed demand immediate acidification with 5ml cone HNO_3 and transport to the laboratory for digestion, which was carried out within 24 hours of collection. All the samples, both for metals and anions analysis were kept in the refrigerator set at 4°C to inactivate any bacteria and prevent change in volume due to evaporation.

Plant samples

The *Ipomoea aquatic* plant samples were collected from three stratified locations F, G and H in the Agodi Reservoir (Figure 2). The plant samples were thoroughly cleaned with fresh water followed by distilled water, for the quantitative removal of soil and other foreign particles. The plant samples were kept separately in polythene bags and taken to the laboratory. The samples were dried separately to a constant weight in an oven at 105°C . The dry plant components were grounded into powder, sieved and made ready for digestion.

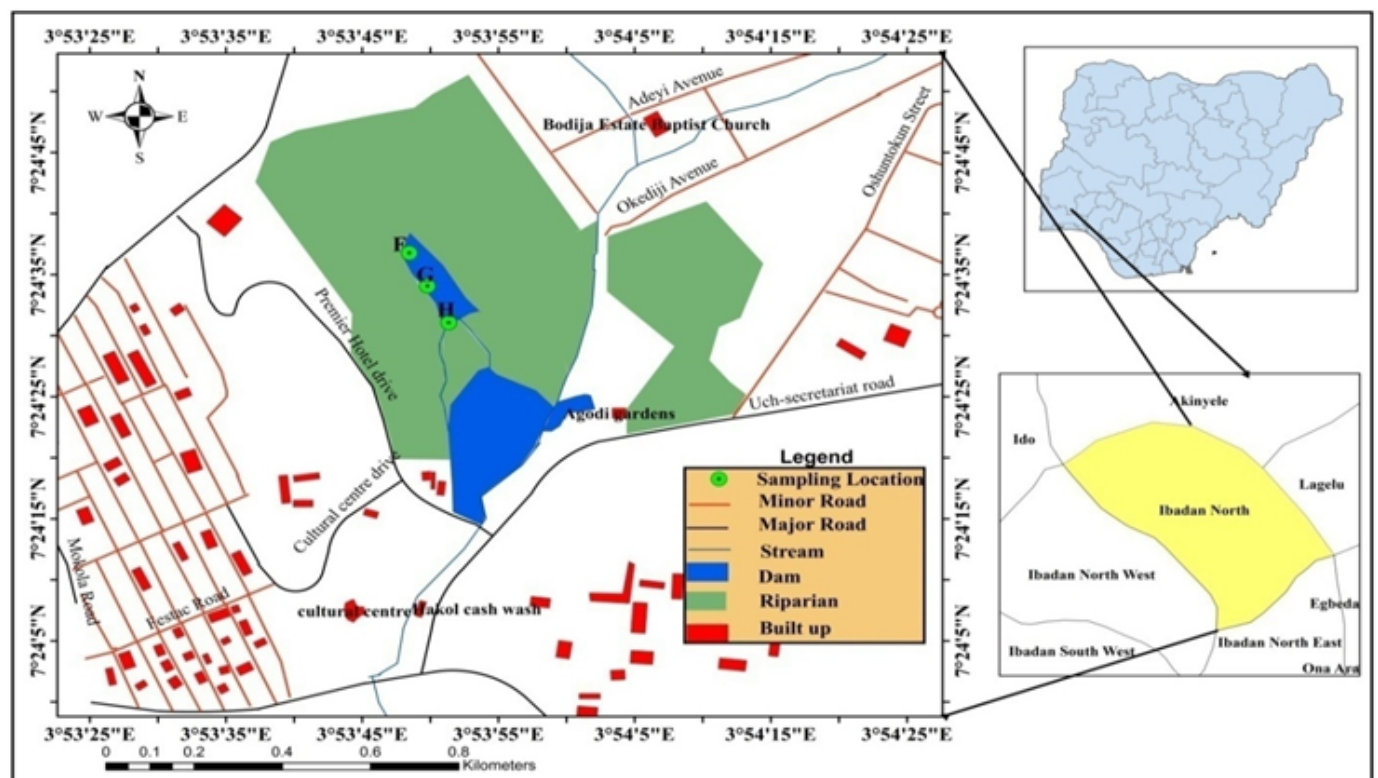


Figure 2 Map of Ibadan showing sampling locations F, G and H on Agodi Reservoir.

Analyses of samples

Chemical and heavy metal contents of the water and plant from Agodi Reservoir were studied for a period of twelve (12) months covering wet and dry seasons. The heavy metals investigated were Cd, Co, Cu, Fe, Mn, Ni, Pb and Zn, while the chemical indices included pH, Sulphate (SO_4^{2-}), Phosphate (PO_4^{3-}), Nitrate (NO_3^-), Chloride (Cl), Total Hardness (TH), Alkalinity (Alk). The chemical analyses of the water samples were carried out in accordance with the standard analytical method (APHA 1995) while heavy metals in the water and plant samples were digested and later analyzed using Atomic Absorption Spectrophotometer (AAS).

Statistics

Test location differences were examined using one-way Analysis of Variance (ANOVA) at $P < 0.05$ to determine if any gradient effect

is associated with pollution dynamics while seasonal variations were examined using T-test statistic at 95% C.I. to determine if there was significance difference or not between the dry and wet seasons. Linear regression curves were plotted to determine slopes, gradients and correlation coefficients. Results from each parameter were compared with the WHO (World Health Organization) permissible thresholds.

Results

Results of the chemical parameters, heavy metals in water and in plant samples from Agodi Reservoir are presented in Tables 1–4. The mean values of the chemical parameters are shown for both the dry and wet season (Table 1) compared with the WHO standard values. Table 2 provides the mean values of heavy metals in the sampled water and plants while Table 3 and Table 4 were attempts to interpret the curves obtained relative to location gradient and seasonal variation for the chemical and heavy metal contents respectively.

Table 1 Year-round chemical assessment with seasons in the Agodi Reservoir

Chemical parameters(mg/L)	Dry season	Wet season	Mean values (SD)	WHO standards
SO ₄ ²⁻	0.03	0.04	0.035 (0.05)	200
PO ₄ ³⁻	0.04	0.04	0.040 (0.02)	250
NO ₃ ⁻	0.03	0.02	0.025 (0.01)	10
Cl ⁻	0.03	0.03	0.030 (0.03)	250
TH	190.07	160.83	175.45 (84.16)	100
Alk	183.44	203.48	193.46 (82.68)	400

SD, standard deviation

Table 2 Heavy metals (mg/L) in sampled waters and (mg/kg) in plants during wet and dry seasons compared with the WHO standard

Heavy metals	Water			WHO standard	<i>Ipomoea aquatica</i>			WHO standard
	Wet season	Dry season	Mean value (SD)		Wet season	Dry season	Mean value (SD)	
Cd	0.17	0.06	0.12 (0.245)	0.005	0.37	0.11	0.24(0.615)	0.2
Co	BDL	0.37	0.19 (0.435)	5	0.12	0.25	0.19 (0.426)	5
Cu	9.61	15.18	12.40 (21.435)	1	5.8	6.81	0.31 (5.067)	73.5
Fe	58.26	29.23	43.75 (122.828)	0.1	256.41	49.72	153.07 (541.475)	20
Mn	25.95	103.67	64.810 (223.934)	0.5	15.64	40.88	28.26 (78.486)	20
Ni	0.16	0.18	0.17 (0.516)	0.02	0.05	BDL	0.03 (0.188)	67.9
Pb	0.01	BDL	0.005 (10.009)	0.05	11.64	BDL	5.82 (46.550)	0.3
Zn	10.66	35.59	23.13 (49.049)	5	16.15	55.64	35.895 (56.491)	99.4

All values in mg/L; BDL, below detectable level; SD, standard deviation

Table 3 Chemical concentration gradient along test locations and seasonal variations

Chemical parameters (mg/L)	*Slope of concentration against location	r ²	Established gradient	Seasonal variation
SO ₄ ²⁻	+ve	0.003	0	0
PO ₄ ³⁻	-ve	0.71	0	0
NO ₃ ⁻	-ve	0.99	0	0
Cl ⁻	+ve	0.8	0	0
TH	+ve	0.37	0	1
Alk	-ve	0.87	0	0

Notes: Test locations are F, G, H (Figure 2); * is slanting course from horizontal; for gradient effect and seasonal variation (1) means significant while (0) means not significant at P<0.05

Table 4 Statistical variation of heavy metals in water and plant with seasons

Heavy Metals	Waters			Plant (<i>Ipomoea aquatica</i>)				
	*Slope of concentration against location	r ²	Established gradient	Seasonal variation	*Slope of concentration against location	r ²	Established gradient	Seasonal variation
Cd	-ve	0.02	0	0	+ve	0.26	0	0
Co	-ve	0.05	0	0	+ve	0.84	0	0
Cu	+ve	0.1	0	0	+ve	0.95	0	0
Fe	+ve	0.06	0	0	+ve	0.25	0	0
Mn	+ve	1	0	0	+ve	0.62	0	0
Ni	-ve	0.77	0	0	-ve	0	0	0
Pb	-ve	0	0	0	-ve	0.75	0	0
Zn	+ve	0.73	0	0	+ve	0.75	0	0

Notes: Test locations are F, G, H (Figure 2); * is slanting course from horizontal; for gradient effect and seasonal variation (1) means significant while (0) means not significant at P<0.05

Sulphate (SO₄²⁻)

The mean value of sulphate in Agodi Reservoir was 0.035±0.05mg/L (Table 1). The mean values of SO₄²⁻ in both the dry and wet seasons were 0.03mg/L and 0.04mg/L respectively (Table 1). T-test statistic at 95% C.I. showed no significant difference between the two seasons (Table 3). One-way analysis of variance (F-statistic) showed no significant difference in all the locations which imply no gradient effect. A linear regression of SO₄²⁻ along sample locations showed weak negative correlation (Eqn. 1).

$$\text{SO}_4^{2-}: Y=0.005x+0.0379 \quad (1)$$

$$r^2=28\%$$

Phosphate (PO₄³⁻)

The mean value for phosphate was 0.04±0.02mg/L (Table 1). The mean values of phosphate in both dry and wet seasons were the same 0.04mg/L (Table 1). One-way analysis of variance (F-statistic) showed that phosphate values were not significantly different between the locations at P<0.05 which implies no gradient effect. A linear regression of PO₄³⁻ along sample locations a positive correlation (Eqn. 2). T-test statistic at 95% C.I. showed no significant difference between the two seasons (Table 3).

$$\text{PO}_4^{3-}: Y=-0.001x+0.0387 \quad (2)$$

$$r^2=72.26\%$$

Nitrate (NO₃⁻)

The mean value of Nitrate was 0.025±0.01mg/L (Table 1) for the experimental year. One-way analysis of variance (F-statistic) results showed no significant difference at (P<0.05) in Nitrate at the various locations which implies no gradient effect. Mean value of Nitrates in dry season was 0.03mg/L and in wet season Nitrate concentration was 0.2mg/L (Table 1). A linear regression along the sample locations showed negative correlation (Eqn. 3). T-test statistic at 95% C.I. showed no significant difference between the two seasons (Table 3).

$$\text{NO}_3^-: Y=-0.0021x+0.0265 \quad (3)$$

$$r^2=0.8\%$$

Chloride (Cl⁻)

The mean concentration of chloride in the water samples was 0.03±0.03mg/L (Table 1). Chloride concentration during the dry season and wet seasons were the same 0.03mg/L (Table 1). At p<0.05, one-way analyses of variance (F-statistics) showed no significant difference in Cl⁻ at the various locations which implies no gradient effect (Table 3). A linear regression of Cl⁻ along the sample locations showed a resultant positive correlation (Eqn. 4). T-test statistic at 95% C.I. showed no significant seasonal variation (Table 3).

$$\text{Cl}^-: Y=0.024x+0.0258 \quad (4)$$

$$r^2=80\%$$

Total hardness (TH)

Mean Total Hardness value in the water was 175.45±84.16mg/L (Table 1). TH during the dry season was 190.07mg/L, while mean value of TH during the wet season was 160.83mg/L (Table 1). One-way analysis of variance (F-statistic) at p<0.05 showed that there was no significant difference in TH in all the locations, which implies no gradient effect. A linear regression of TH along the sample locations

showed weak positive correlation (Eqn. 5). T-test statistic at 95% C.I. showed significant seasonal variation traceable to higher carbonate and bicarbonate concentrations in the waters during the dry season (Table 3).

$$\text{TH}: Y=3.7205x+163.14 \quad (6)$$

$$r^2=37\%$$

Alkalinity (Alk)

Mean Alkalinity value was 193.46±82.69mg/L (Table 1). Mean Alk value during the dry season was 183.44mg/L, while mean value of alkalinity in the water samples in wet season was 203.48mg/L (Table 1). At p<0.05, one-way analysis of variance (F-statistic) showed no significant differences in Alk at the various locations which implies no gradient effect. A linear regression of Alk along the sample locations showed a negative correlation (Eqn. 6). T-test statistic at 95% C.I. showed no significant seasonal variation (Table 3).

$$\text{Alk}: Y=-8.677x+214.15 \quad (6)$$

$$r^2=87\%$$

Heavy metals in water samples

Cadmium (Cd in water samples): Cadmium in Agodi Reservoir was 0.12±0.245mg/L (Table 2). The mean Cd in both the dry and wet seasons was 0.06mg/L and 0.17mg/L respectively (Table 3). The T-test statistic at 95% C.I. showed there was no significant difference in the two seasons (Table 4). One-way analysis of variance means (F-statistic) at p<0.05 showed no significant difference at the various test locations implying no gradient effect. A linear regression of Cd in Agodi Reservoir along the sample locations gave a weak negative correlation (Eqn. 7).

$$\text{Cd}: Y=-0.0145X+0.1593 \quad (8)$$

$$r^2=2\%$$

Cobalt (Co in water samples): Cobalt concentration in the water body was 0.19±0.435mg/L (Table 2). The mean Co during dry season was 0.37mg/L while in the wet season it was below detectable level (Table 2). T-test statistic at 95% C.I. showed that Co was significantly different between dry and wet seasons (Table 4). Analysis of variance (ANOVA) of Co showed no significant difference at (p< 0.05) at all the locations which imply no gradient effect. A linear regression of Co in the water body along the sample locations gave a weak negative correlation (Eqn. 9).

$$\text{Co}: Y=0.0345X+0.1953 \quad (8)$$

$$r^2=5\%$$

Copper (Cu) in water samples: The concentration of Cu in the water body was 12.40±21.435mg/L (Table 2). The mean concentration of Cu during the dry season was 15.18mg/L while in wet seasons the mean Cu concentration was 9.61mg/L (Table 2). Analysis of variance (ANOVA) of Cu data showed no significant difference (p<0.05) at all test locations which imply no gradient effect (Table 4). A linear regression of Cu in the water body along sample locations gave positive correlation (Eqn. 10). The T-test statistic at 95% C.I. shows no significant seasonal variation.

$$\text{Cu}: Y=0.752X+9.9607 \quad (9)$$

$$r^2=10\%$$

Iron (Fe) in water samples: Mean concentration of Fe in the water body was 43.75 ± 122.828 mg/L (Table 2). The mean value of Fe in dry season was 29.23 mg/L and wet season was 58.26 mg/L (Table 2). A linear regression of Fe in the water body along the sample locations showed a weak positive correlation (Eqn. 10). T-test statistic at 95% C.I. showed no significant seasonal differences (Table 4). One way analysis of variance at ($p < 0.05$) also showed no significant difference in Fe at the various locations.

$$\text{Fe: } Y = 7.1505X + 34.279 \quad (10)$$

$$r^2 = 7\%$$

Manganese (Mn) in water samples: Mean concentration of Mn in the water body was 64.8 ± 223.934 mg/L (Table 2). The mean value of Mn in both dry and wet seasons was 103.67 mg/L and 25.95 mg/L respectively (Table 3). A linear regression of Mn in the water body along the sample locations showed a strong positive correlation (Eqn. 11). T-test at 95% C.I. showed no significant seasonal differences (Table 4). One-way analysis of variance (F-statistic) at $p < 0.05$ also showed no significant difference in Manganese at the various locations.

$$\text{Mn: } Y = 51.447X - 51.039 \quad (11)$$

$$r^2 = 100\%$$

Nickel (Ni) in water samples: The mean concentration of Nickel in the water averaged 0.17 ± 0.516 mg/L (Table 2). The mean Nickel value during dry season was 0.18 mg/L while the mean value during the wet season was 0.16 mg/L (Table 2). One-way analysis of variance (F-statistic) at $p < 0.05$ showed no significant difference in values between the test locations (Table 4). A linear regression of Ni in the water bodies along the sample locations showed a negative correlation (Eqn. 12). T-test statistic at 95% C.I. showed no significant difference in the two seasons.

$$\text{Ni: } Y = 0.122X + 0.4107 \quad (12)$$

$$r^2 = 77\%$$

Lead (Pb) in water samples: Mean concentration of Pb in the water for the experimental period was 0.005 ± 0.009 mg/L (Table 3). The mean value of Pb during the dry season was below detectable level while during the wet season the mean value of lead was 0.01 mg/L (Table 2). One-way analysis of variance (F-statistic) at $p < 0.05$ showed no significant difference at the test locations. (Table 4) A linear regression of Pb in the water body along the sample locations showed a very weak positive correlation (Eqn. 13). T-test statistic at 95% C.I. showed no significant variation.

$$\text{Pb: } Y = 0.004 \quad (13)$$

$$r^2 = 0\%$$

Zinc (Zn) in water samples: The mean concentration of Zinc in the water body was 23.13 ± 49.09 mg/L (Table 2). The mean values of Zinc for dry and wet seasons were 35.59 mg/L and 10.66 mg/L respectively (Table 2). T-test statistic at 95% C.I. showed no significant variation with the seasons. One-way analysis of variance (F-statistic) at $p < 0.05$ in all the three locations showed no significant difference (Table 4). A linear regression of Zn in the water body along the sample location showed a positive correlation (eqn. 14).

$$\text{Zn: } Y = 5.4425X + 8.0807 \quad (14)$$

$$r^2 = 72\%$$

Heavy metal in plants samples (*Ipomoea aquatica*)

Cadmium (Cd in plant): The mean concentration of cadmium in *I. aquatica* during the experimental year was 0.24 ± 0.615 mg/kg (Table 2). Mean concentration of Cd in the dry season was 0.11 mg/kg while the Cd concentration during the wet season was 0.37 mg/kg (Table 2). T-test statistic at 95% C.I. showed no seasonal variation. Analysis of variance at $p < 0.05$ showed no significant between the sampling locations which signify no gradient effect (Table 4). A linear regression of Cd in the plant along sample locations showed a weak positive correlation (Eqn. 15).

$$\text{Cd: } Y = 0.045X + 0.1913 \quad (15)$$

$$r^2 = 24\%$$

Cobalt (Co in plant): Mean concentration of Cobalt in *I. aquatica* was 0.19 ± 0.426 mg/kg (Table 2). The mean concentration of Cobalt in both dry and wet seasons were 0.25 mg/kg and 0.12 mg/kg (Table 3). T-test statistic at 95% C.I. showed no significant seasonal variation (Table 4). Analysis of variance showed no significant difference at the sample locations, thus no gradient effect. A linear regression of Co in the plant along the sample locations showed positive correlation (eqn. 16).

$$\text{Co: } Y = 0.172X + 0.1823 \quad (16)$$

$$r^2 = 84\%$$

Copper (Cu in plant): Mean concentration of Cu in *I. aquatica* during the test period was 0.31 ± 5.067 mg/kg (Table 2). Cu concentration during the dry season was 6.81 mg/kg and in the wet season was 5.80 mg/kg (Table 2). Analysis of variance at $p < 0.05$ showed no significant difference along the sample locations which implies no gradient effect. A linear regression of Cu in the plant along the sample locations a strong positive correlation (Eqn. 17). T-test statistic at 05% C.I. showed no significant seasonal variation (Table 4).

$$\text{Cu: } Y = 0.5865X + 4.9667 \quad (17)$$

$$r^2 = 95\%$$

Iron (Fe in plant): The mean concentration of iron in *I. aquatic* was 153.07 ± 541.475 mg/kg (Table 2). Analysis of variance of the Fe concentrations at different locations showed no significant difference at $p < 0.05$ which implies no gradient effect. (Table 4) Mean values of Fe in *I. aquatica* during the dry season were 49.72 mg/kg, while in the wet season it was 256.41 mg/kg (Table 2). T-test statistic at 95% C.I. showed no significant difference in the two seasons (Table 4). A linear regression of Fe in plant along the sample location showed a weak positive correlation (Eqn. 18).

$$\text{Fe: } Y = 15.592X + 156.33 \quad (18)$$

$$r^2 = 25\%$$

Manganese (Mn in plant): The concentration of Mn in *I. aquatica* during the experimental year was 28.26 ± 78.48 mg/kg (Table 2). Manganese concentrations in both dry and wet seasons were 40.88 mg/kg and 15.64 mg/kg respectively (Table 2). T-test statistic at 95% C.I. showed no significant seasonal variation (Table 4). A linear regression of Mn in plant along the sample locations showed a positive correlation (Eqn. 19).

$$\text{Mn: } Y = 9.7X + 4.6507 \quad (19)$$

$$r^2 = 62\%$$

Nickel (Ni in plant): Concentration of Nickel in *I. aquatica* averaged $0.03 \pm 0.188 \text{ mg/kg}$ (Table 2). Analysis of variance at $P < 0.05$ showed no significant difference in Ni concentrations at the various test locations and therefore no gradient effect (Table 4). Mean concentration of Nickel in *I. aquatica* during the wet season was 0.05 mg/kg while Nickel was below detectable level in the dry season (Table 2). A linear regression of Ni in plant along locations showed a weak negative correlation (Eqn. 20).

$$\text{Ni: } Y = -0.001X + 0.038 \quad (20)$$

$$r^2 = 0.03\%$$

Lead (Pb in plant): For the test period mean concentration of Pb in *I. aquatica* was $5.82 \pm 46.550 \text{ mg/kg}$ (Table 2). The mean value of Pb in plant during the wet season was 11.64 mg/kg in the dry season Pb was below detectable level (Table 2). T-test statistic at 95% C.I. showed no significant seasonal variation (Table 4). Analysis of variance at $p < 0.05$ showed no significant difference at the various test locations that means no gradient effect (Table 4). A linear regression of Pb in the plant along sample locations showed negative correlation (Eqn. 21).

$$\text{Pb: } Y = -11.638X + 31.033 \quad (21)$$

$$r^2 = 75\%$$

Zinc (Zn in plant): For the test period, mean concentration of Zn on *I. aquatica* was $35.90 \pm 56.491 \text{ mg/kg}$ (Table 2). The mean value of Zn in *I. aquatica* for both dry and wet seasons was 55.64 mg/kg and 16.15 mg/kg respectively (Table 3). Analysis of variance at $p < 0.05$ showed no significant difference at the various test locations which connotes no gradient effect (Table 4). A linear regression of Zn in plants along sample locations a strong positive correlation (Eqn. 22).

$$\text{Zn: } Y = 11.5X + 6.3107 \quad (22)$$

$$r^2 = 77$$

Discussion

Results of the physicochemical parameters tested are presented in Table 1. At $P < 0.05$ one-way analysis of variance (F-statistic) showed no significant differences in all the chemical parameters at the various locations on Agodi Reservoir. T-test statistics at 95% C.I. showed no significant difference in all the physicochemical parameters which implies no seasonal variation except TH which showed significant difference in the two seasons (Table 2).

In this present study, the mean pH value is satisfactory. The pH of water body is very important because it has effect on the organisms living in the aquatic ecosystem. pH controls vital metabolic process like respiration. Respiration is the process by which living organisms produce energy for their various activities. Meybeck M²² recommended a pH of 6.5-7.5 while Huet²³ suggested 7.0-8.0 for the survival of fish in Tropical waters. These recommendations suggest that tropical fishes may prefer slightly alkaline environment, which is in agreement with this study.

The mean concentration of NO_3^- in the water samples of Agodi Reservoir 0.025 mg/L was below the WHO maximum concentration (Table 1). Surface water can be contaminated by sewage and other wastes rich in nitrates. This may be due to denitrification, since a high load of organic substances which consume oxygen through denitrification is transported into the reservoir.

Phosphate concentration in unpolluted waters ranges from 0.01-0.1 mg/L.¹² The mean concentration of PO_4^{3-} in Agodi Reservoir was below the WHO recommended maximum concentration for polluted water bodies, this implies that Agodi Reservoir is not polluted with PO_4^{3-} .

Sulphate occurs naturally in water as a result of leaching from minerals. Discharge of industrial wastes and domestic sewage tends to be the source of sulphate in the water body.

The sulphate was below 200 mg/L recommended for drinking water and aquatic life by WHO²⁴ (Table 1). This observation is similar to that obtained for Epe creek by Izonfuo and Barriweni.²⁵

Total Hardness mean value of Agodi Reservoir was higher than the 100 mg/L recommended for drinking and domestic use by WHO.²⁴ Levine et al.²⁶ reported that adequate hardness is desirable because environmental calcium deficiency in water may cause poor survival, decreased growth or poor disease resistance in fry. Increased environmental calcium concentrations decrease the toxicity of Ammonia (Hoffmann and Jackson, 2000.²⁷

The Alkalinity mean value of 193.46 mg/L was recorded in the reservoir (Table 1). A 50 mg/L had been reported for natural waters of Hatey region in Pakistan by Tepe et al.²⁸ According to Boyd²⁹ water with high alkalinity tends to be more buffered than that of low alkalinity.

Heavy metals in small amounts play great significance in the biochemical life process of organisms. Hawke,³⁰ some act as enzyme co-factor. However the trace amounts of the heavy metals may become lethal to fish and other aquatic organism when exposed to long duration.³¹ The heavy metal content in water showed that there was no seasonal variations in all the heavy metals (Table 4). There was no significant variation in heavy metal concentration between the locations. The overall mean concentration of heavy metals in the water column of Agodi Reservoir can be summarized as follows: $\text{Mn} > \text{Fe} > \text{Zn} > \text{Cu} > \text{Co} > \text{Ni} > \text{Cd} > \text{Pb}$ (Table 2). Co and Pb were below the recommended limits set by WHO for drinking and domestic waters while Cd, Cu, Fe, Mn, Ni and Zn showed concentration higher than WHO limits. This is indicative of potential environmental as to the use of water high in heavy metals could cause adverse health effects. It is therefore recommended that waters from Agodi Reservoir be subjected to treatment before use.

The concentrations of heavy metals in *Ipomoea aquatica* from Agodi Reservoir exhibited no significant difference between the test locations. There were no seasonal variations in all the heavy metals (Table 4). The overall mean concentration of heavy metals in *I. aquatica* can be summarized as follows: $\text{Fe} > \text{Zn} > \text{Mn} > \text{Cu} > \text{Pb} > \text{Cd} > \text{Co} > \text{Ni}$. Cd, Fe, Mn and Pb have concentrations higher than permissible level in *Ipomoea aquatica* which implies that the plant high tolerance for these metals which could gradually build up to chronic toxicity levels. The low concentrations of Co, Cu, Ni and Zn below standard threshold in the tested plant are a pointer that these metals are still at tolerable levels (Table 2).³²⁻³⁴

Conclusion

The chemical parameters of the water samples analyzed were below the WHO recommended allowable limit for water except for TH that was high and above the permissible standard limits. The

order of overall mean concentrations of heavy metals in the water samples of Agodi Reservoir is Mn>Fe>Zn>Cu>Co>Ni>Cd>Pb. The overall order of abundance of heavy metals in the plant sampled Fe>Zn>Mn>Cu>Pb>Cd>Co>Ni. The study have revealed that the water quality was polluted with heavy metals which include Cd, Cu, Fe, Mn, Ni and Zn, having concentrations high and above the WHO recommended limits for drinking water. The heavy metal pollution of the water body give cause for concern, hence it is recommended that water from Agodi Reservoir be treated before consumption or use for other domestic purposes. Sampled plant selected for this study is highly contaminated with Pb and Cd and poses a major health risk.

One way analysis of variance (F-statistic) for all the chemical parameters of water analyzed showed no significant differences between the sampled locations thus no gradient effect. T-test statistic for all the chemical parameters showed no significant difference in the two seasons except for the TH. One-way analysis F-statistic at P<0.05 for all the heavy metals on both water and plant samples analyzed showed no significant difference at the various test locations implying no gradient effect. Seasonally there were no significant differences in the heavy metals of water and plants analyzed which signifies no differences in the dry and wet seasons.

Potential health hazard in the use of water from Agodi Reservoir could be avoided if the water discharged into the water body is sufficiently treated.

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Conflicts of interest

The authors declare there are no conflicts of interest.

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