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Some Studies on Heavy Metal Concentration in Aquaculture Ponds of Bhimavaram Mandal, Andhra Pradesh, India

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Abstract

Heavy metal pollution in aquaculture farms through the food chain has a significant impact on the ecosystem and human health, which may be dangerous as a result of improper management, improper waste management, and excessive use of artificial feed to increase performance and increase profits. Optimum fish production strongly depends on the physical, chemical and biological properties of water. Therefore, successful fishpond management requires a deep understanding of water quality. This study was conducted to assess heavy metal contamination in water samples of five selected aquaculture ponds located in and around Upputeru Reserve Forest in Bhimavaram mandal of West Godavari District. The ten heavy metals analyzed are cadmium (Cd), mercury (Hg), lead (Pb), arsenic (As), manganese (Mn), chromium (Cr), nickel (Ni), copper (Cu), zinc (Zn) and iron (iron). Atomic absorption spectroscopy (AAS) was adopted for the analysis of heavy metals. Most of these values were well below the standards given for drinking (BIS, WHO, EU, US EPA) and pond aquaculture purposes. Although metal levels did not exceed the threshold limit, appropriate measures and continuous monitoring are recommended to reduce heavy metal contamination in farms and prevent deterioration of water quality.

Keywords: upputeru reserve forest, heavy metals, fish pond, AAS, water quality.

Introduction

Most aquatic organisms, including fish, require water as their sole environment (1). Water provides services for fish respiration, nutrition, growth, waste removal, salt balance and reproduction (2). For this reason, the quality of water used in fish farming is as important as the quality of water used by humans, and unfortunately this is not taken seriously (1). Fish forming is guided by water quality standards, so success is a direct result of water chemistry (3, 1). Fish ponds around the world provide habitat for many fish species and can be easily managed by controlling water quality, which affects fish production. The decrease in water in the fish pond can be caused by the use of fertilizers and additives added to fish feed [4] to improve the fertilization of the pond while increasing fish production [5]. The presence of environmental stressors such as poor water quality, elevated nutrients, insects, and low oxygen levels affects the ability of aquatic organisms, including fish, to control their internal environment (e.g., catabolism, metabolism, and reproduction) [6].

Several studies have reported the presence of lead, cadmium, and mercury in fish ponds, which are considered to be highly toxic [7, 8, 9]. In many developing countries, there is increasing concern about bio concentrations of heavy metals in fish ponds. A study in Zimbabwe [10] and Malawi [11] showed that heavy metal pollution in farmed fish is a serious problem. In general, heavy metals occur in low concentrations in fresh water.

MATERIALS AND METHODS

Study area

The study area of Bhimavaram Mandal in West Godavari district of Andhra Pradesh is shown in Figure 1. A large number of fish pond water samples were collected from five different ponds of Upputeru Reserved Forest, Bhimavaram mandal.

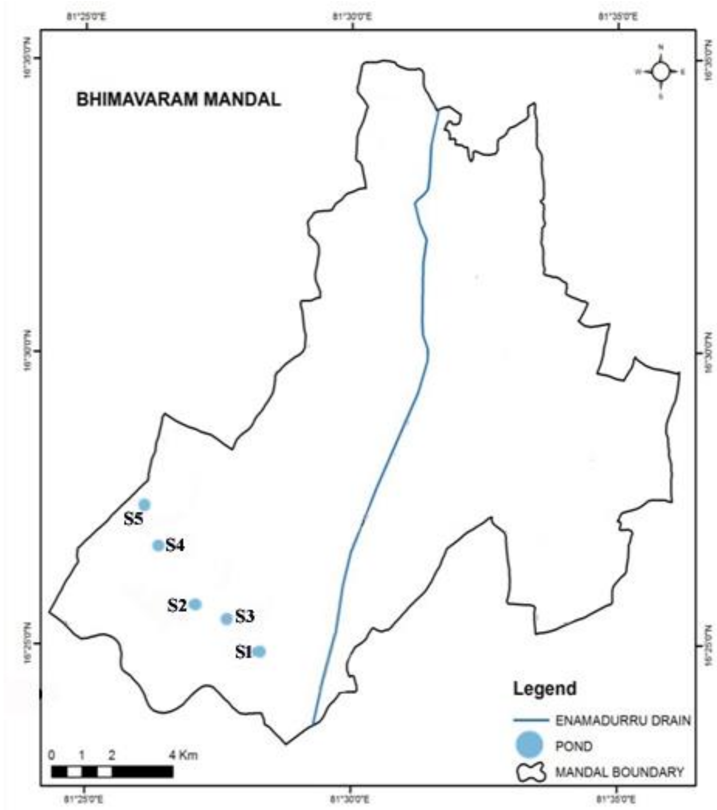


Fig 1: Study area of Bhimavaram Mandal

Collection of Samples:

From July 2014 to June 2015, aquaculture water samples were collected from five ponds in Upputeru Reserved Forest twice a month in the morning hours from 7:00 a.m. to 9:00 a.m. Water was collected in polyethylene bottles labelled with the sample code and transported to the laboratory in containers. The icebox kept them cold, preferably between 4 and 10°C, but did not freeze. The concentration of heavy metals is being investigated at the Environmental Laboratory of Andhra University, Visakhapatnam. The samples were processed and studied according to the appropriate methods listed in Table 1.

Table 1: Analytical Methods

S. No.	Heavy Metals	Method
1	Cadmium	Atomic absorption spectrometer method
2	Mercury	Cold vapour flame less atomic absorption
3	Lead	Atomic absorption spectrometer method
4	Arsenic	Atomic absorption spectrometer method
5	Manganese	Atomic absorption spectrometer method
6	Chromium	Colorimetric method
7	Nickel	Atomic absorption spectrometer method
8	Copper	Atomic absorption spectrometer method
9	Zinc	Atomic absorption spectrometer method
10	Iron	Colorometric – Phenanthroline method

RESULTS AND DISCUSSION

Effect of heavy metals on fish

Heavy metals such as cadmium, lead, arsenic, chromium, mercury and copper are among the most dangerous and widespread inorganic environmental pollutants originating from industrial wastes and mining practices [12].

When fish are exposed to elevated levels of metals in a polluted aquatic ecosystem, they tend to take up these metals from their immediate environment. Heavy metal contamination can have devastating effects on the ecological balance of the receiving environment and the diversity of aquatic organisms [13]. Transport of metals in fish takes place through the blood, where the ions are usually bound to proteins. Metals come into contact with fish organs and tissues and subsequently accumulate to varying degrees in different fish organs and tissues [14]. Heavy metals are non-biodegradable and once they enter the environment, in the case of aquatic environments, they bio-concentrate in fish tissue through metabolic and biosorption processes [15]. The presence of heavy metals is associated with reduced fertility and other reproductive abnormalities in birds, fish, molluscs and mammals, as well as altered immune function [16]. Heavy metals such as mercury and cadmium are known to accumulate in marine organisms and cause rapid genetic changes [17, 18]. It is also possible that it may increase the susceptibility of aquatic animals to various diseases by disrupting the normal functioning of their immune, reproductive and developmental processes [19]. Long-term exposure to water pollutants even at very low concentrations has been reported to induce morphological, histological, and biochemical changes in tissues that can critically affect fish quality [20, 21]. It was reported that aquatic organisms showed a high capacity to accumulate heavy metals.

Analysis of the water quality of fish ponds at five different locations in Bhimavaram mandal was carried out and the concentrations of various heavy metals were estimated. The results are shown in Tables 2-6 and Figures 2-11.

Discussion on Each Metal:

Cadmium (Cd):

Cadmium and its compounds are highly toxic and soluble in water, when compared to other heavy metals and thus have higher chances of bioavailability and bioaccumulation. Cadmium is not biodegradable and will remain in nature for a long time. In this study, the concentration of cadmium ranges from 0.0001 mg/L to 0.001 mg/L (Fig 1). The highest value of cadmium was observed in all the three seasons for sample S2 and the lowest concentration of cadmium metal was observed in all the three seasons for S5 sample. The main sources of cadmium pollution were domestic wastewater discharge, smelting and refining of non-ferrous metals, and chemical and metal production [22, 23].

Mercury (Hg):

It is a highly volatile element with a long half-life in the atmosphere. As a result of these physical properties, it is ubiquitous in the environment and exposure is not an isolated problem but rather a global threat to human health [24]. In recent years, research has revealed that even chronic exposure to very low exposure concentrations has the ability to cause long-term neurological and renal damage [25]. Mercury is one of the most toxic heavy metals in our environment including the lithosphere, hydrosphere, atmosphere and biosphere. In this study, the concentration of mercury ranges from 0.0001 mg/L to 0.0009 mg/L (Fig 2). The highest value of mercury was observed in summer season for sample S3 and the lowest concentration was observed in all the three seasons for S2 sample. Mercury's volatile nature and long atmospheric residence time (approximately one year) have led to global cycling of Hg and its deposition in terrestrial, marine, freshwater and wetland ecosystems in regions of the world remote from the source [26,27].

Lead (Pb):

Plating, battery cells, dyes and pigments, chemical fertilizers, gasoline additives are the main sources of lead pollution in the aquatic ecosystem [28, 29]. In this study, the values of lead concentration range between 0.001 mg/L to 0.002 mg/L (Fig 4). From the values, it is clear that the highest values were obtained during summer and winter period for samples S1 &S4 and lower values were obtained during all the three seasons for samples S2, S3 and S5. Lead toxicity in humans can cause kidney dysfunction, damage to the central nervous system and cardiovascular system, as well as cause infertility. Haemoglobin synthesis can be affected by lead toxicity [30].

Arsenic (As):

More recently, anthropogenic activities such as the treatment of agricultural land with arsenic pesticides, the treatment of wood with copper chromate arsenate, the burning of coal in thermal power plants, and gold mining operations have increased the permeability of arsenic to the environment and its release rate into a freshwater biotope [31]. In addition, arsenic is widely used as sodium arsenite to control submerged aquatic vegetation in freshwater ponds and lakes [32]. In this study, the values of arsenic concentration range between 0.001 mg/L to 0.003 mg/L (Fig 5). From the values, it is clear that the highest values were obtained during winter period for samples S3 &S4 and lower values were obtained during rainy season for all five samples. According to [33], 1.5-3.8 mg/L arsenite is effective and considered safe for fish. Many species of fish that live in arsenic-contaminated water contain arsenic between 1-10 g/g. In gout, arsenic levels in fish are reported to be higher than100μg/g [34].

Manganese (Mn):

In aquatic ecosystems, manganese compounds are attached to circulating particles or deposited in sediments [35]. A significant difference in manganese concentration was observed during the study. The concentration of manganese varied between 0.01 mg/L to 0.06 mg/L in different water samples (Fig 6). The decrease in manganese concentration is observed for sample S3 in summer season. The very high concentration of manganese observed at S4 & S5 Sampling stations during the winter. Manganese is an essential micronutrient, but excessive accumulation in the human body causes neurological diseases, neonatal bone diseases, rheumatoid arthritis, and diabetes [36, 37].

Chromium (Cr):

Chromium compounds are usually insoluble in water and occur in various oxidation states such as the trivalent and hexavalent states. Chromium(III) oxide and chromium(III) hydroxide are the water-soluble forms of chromium compounds identified in nature so far [38]. In this study, the value of chromium ranged between 0.001 mg/L to 0.03 mg/L (Fig 7). Higher concentrations of chromium were observed at all stations except sample S2 in summer season. The lowest values were reported from rainy and winter seasons' for S3, S4 and S5 Sampling stations. The main sources of chromium pollution are electroplating, metal surface treatment, laundry chemicals, leather, runoff water, etc. In humans, long-term exposure to hexavalent chromium causes lung cancer, severe respiratory problems [39].

Nickel (Ni):

Nickel is a naturally occurring trace metal, soluble in water without odor or taste. Common sources of nickel pollution include industrial waste from nickel alloy or nickel compound plants, oil-burning power plants, non-ferrous ceramics plants, batteries, etc. [40]. Nickel toxicity in humans causes nausea, vomiting, abdominal pain, diarrhea, breathing problems, etc. [41]. The nickel concentration was ranged from 0.002 mg/L to 0.01 mg/L (Fig 8). The highest nickel concentration was reported from all the three seasons for all the sampling stations. The lowest value of nickel concentration was observed in the rainy season at S2 & S4 sampling stations.

Copper (Cu):

Common sources of copper pollution in aquatic ecosystems were mainly from industrial sources, domestic wastes, plating or leaching of minerals [42]. The concentration of copper varied between 0.001 mg/l to 0.005 mg/l in different water samples. Seasonal data for copper at different stations are shown in Fig 9. Seasonal data showed that high concentration of copper was observed in summer period for sampling station S5. The lowest copper concentration was observed in both rainy and winter seasons for sample S3, which may be due to the dilution of rainwater. Excessive accumulation of copper results in various bodily disorders such as hypertension, kidney dysfunction, and various neurological disorders [43].

Zinc (Zn):

Zinc is an important trace metal, it has a major role in maintaining proper physiological and metabolic processes in most living organisms. Zinc plays an important role in protein synthesis. However, its high concentration leads to toxicity. Industrial wastewater, slurry, fertilizers and pesticides are the main sources of zinc pollution in the aquatic ecosystem. [44].The concentration of zinc in the water samples varied between 0.002 mg/L and 0.006 mg/L (Fig 10). The high concentration of Zinc was observed at S5 Sampling station during the summer while the decrease in zinc concentration is observed for samples S2, S3 and S4 in rainy season. Since zinc has limited mobility, its concentration in natural surface waters is low [45]. Zinc is difficult to break down, so it will remain in the ecosystem for a long time and therefore it becomes toxic to all aquatic organisms in its sub lethal concentration [46, 47].

Iron (Fe):

Industrial by-products and household wastes are the main sources of iron pollution in water bodies. When present in high concentration, it results in color changes in this water system. In this study, concentration of iron in the water samples varied between 0.02 mg/L to 0.2 mg/L (Fig 11). The highest value was recorded in the summer period and lowest value was recorded in rainy and winter period. The buffering effects of organic compounds or calcium salts make the water less toxic, even if the water contains iron in the above desirable limit [49, 50]. But, if it is present in excessive amounts, it leads to high blood pressure, drowsiness, rapid blood clotting and increased heart rate [48].

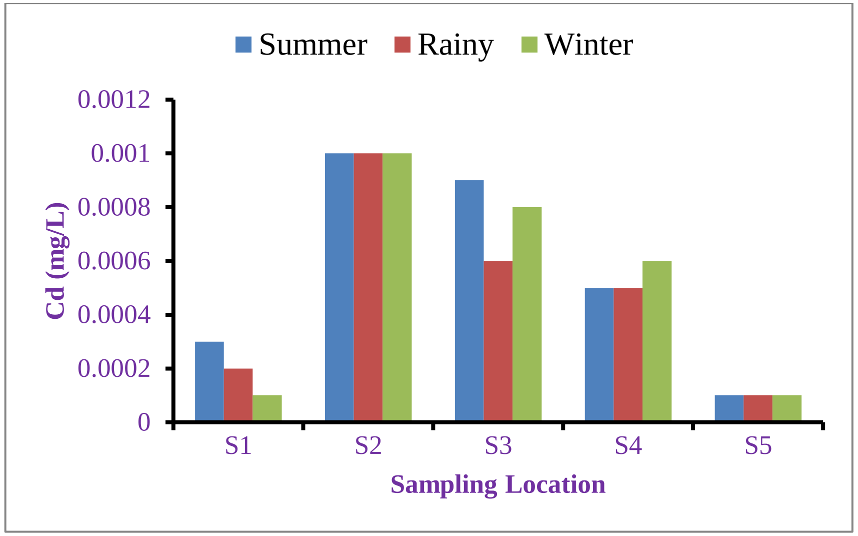


Fig 2: Graph showing Cadmium (Cd) metal readings

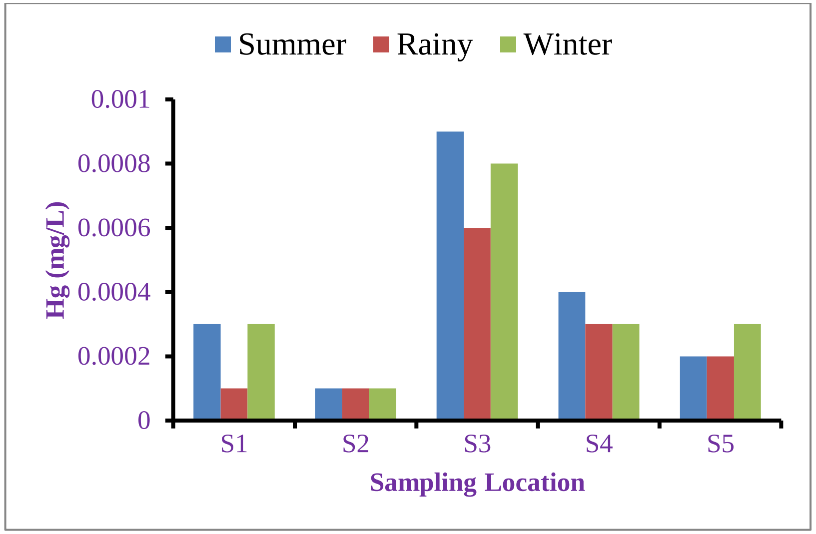


Fig 3: Graph showing Mercury (Hg) metal readings

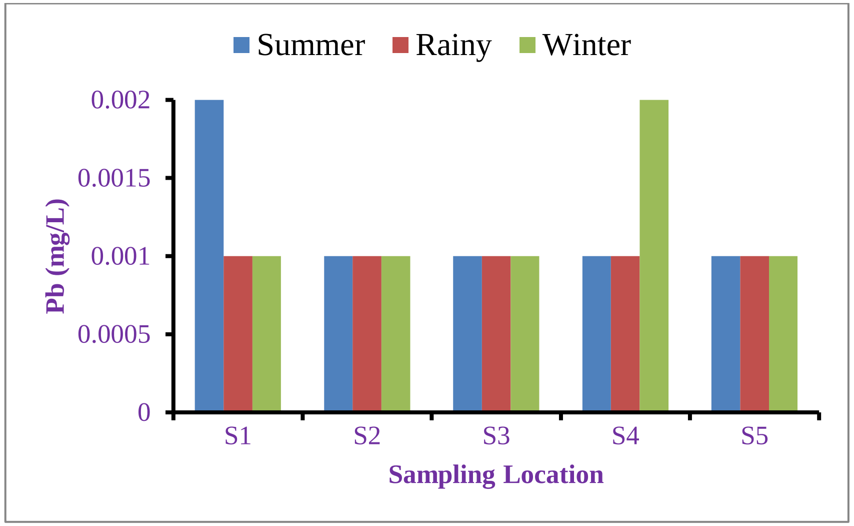


Fig 4: Graph showing Lead (Pb) metal readings

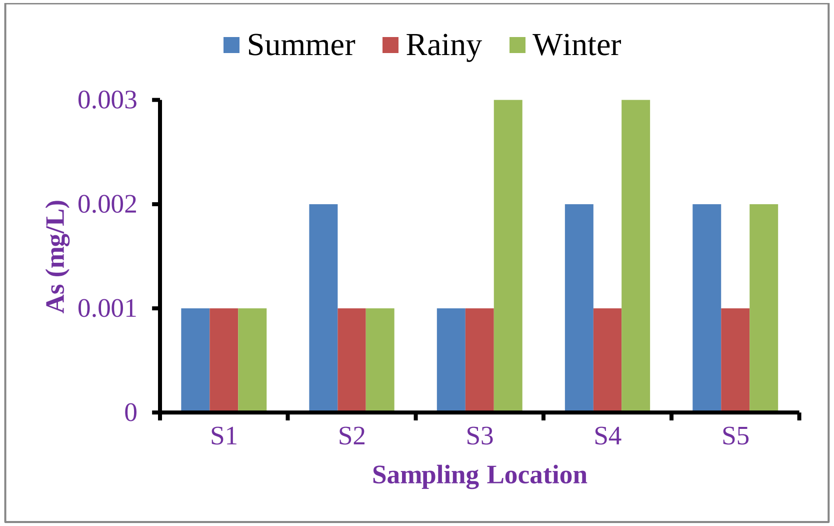


Fig 5: Graph showing Arsenic(As) metal readings

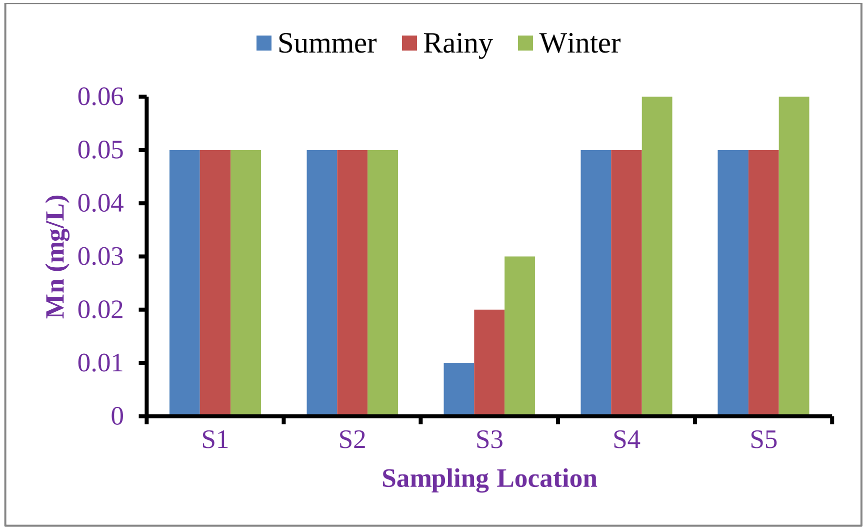


Fig 6: Graph showing Manganese (Mn) metal readings

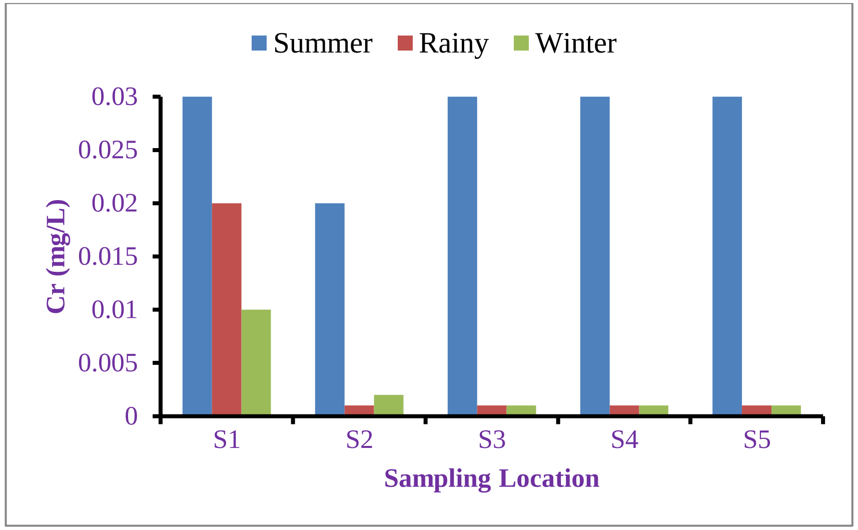


Fig 7: Graph showing Chromium(Cr) metal readings

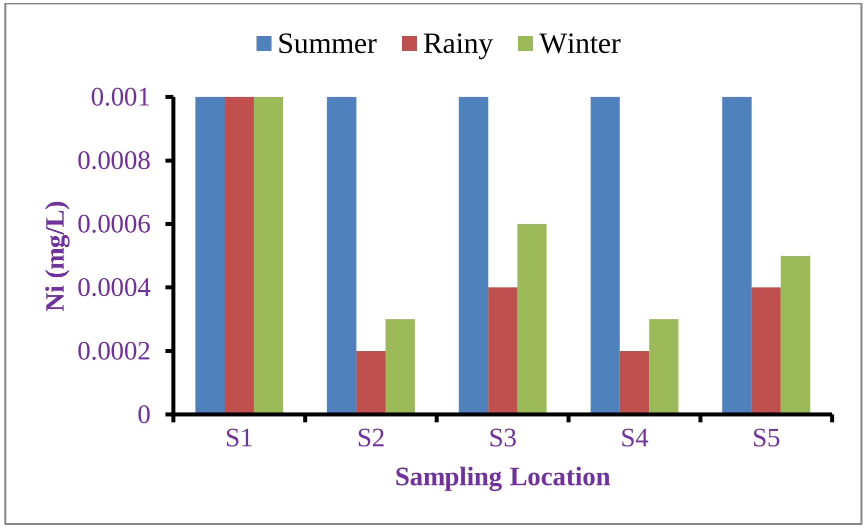


Fig 8: Graph showing Nickel(Ni) metal readings

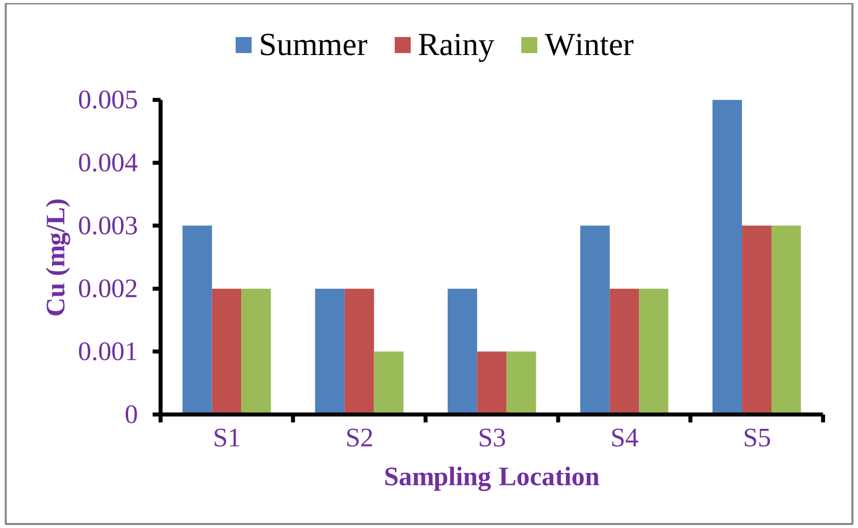


Fig 9: Graph showing Copper(Cu) metal readings

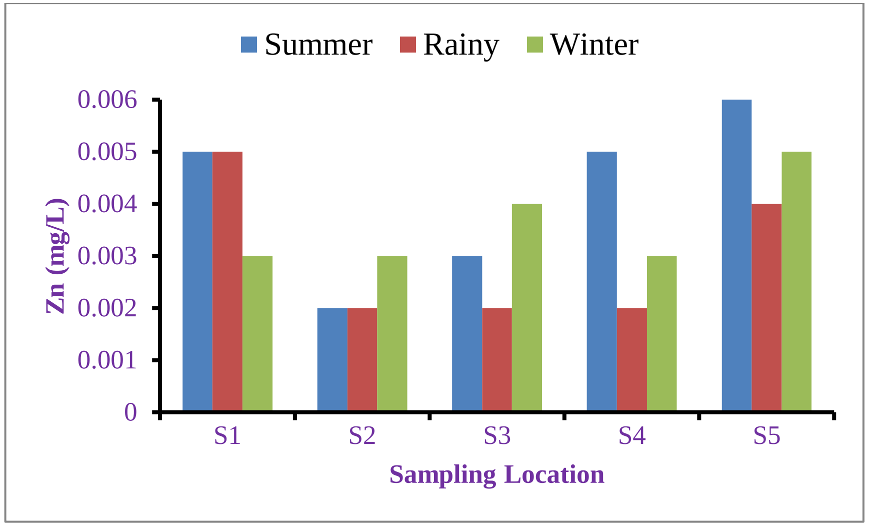


Fig 10: Graph showing Zinc(Zn) metal readings

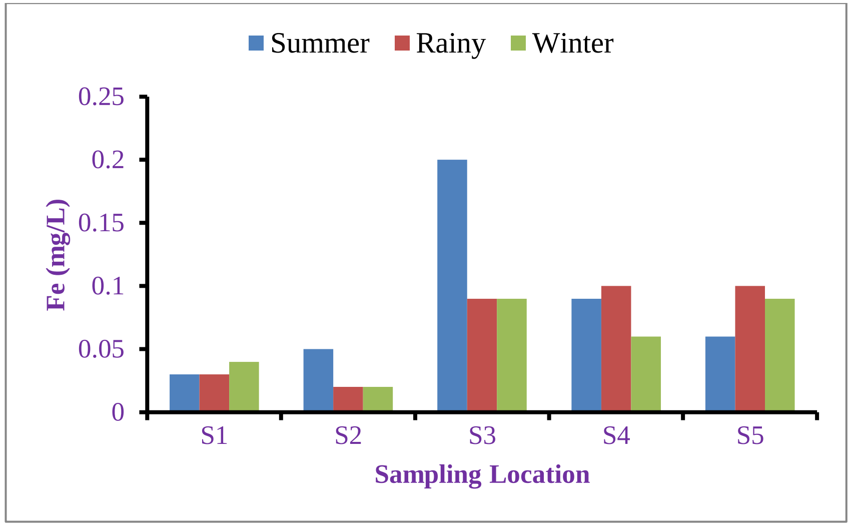


Fig 11: Graph showing Iron(Fe) metal readings

Sampling location: S1 Garimilladibba	Results of water quality parameters tested in 3 different seasons					Water quality standards					
Latitude: 16° 24' 52.130" N Longitude: 81° 28' 11.395" E Located nearby aquaculture ponds Area (Hectare):1.54	**Heavy Metals**		**Summer**	**Rainy**	**Winter**	**BIS 10500 : 2012**		**WHO**	**EU**	**US EPA**	**Boyd (1998) Water Quality for Pond Aquaculture**
						Acceptable limit	**Permissible limit**				
	Cadmium (Cd)	mg/L	0.0003	0.0002	0.0001	0.003	-	0.003	0.005	0.005	0.001
	Mercury (Hg)	mg/L	0.0003	0.0001	0.0003	0.001	-	0.006	0.002	0.001	0.001
	Lead (Pb)	mg/L	0.002	0.001	0.001	0.01	-	0.01	0.015	0.01	0.003
	Arsenic (As)	mg/L	0.001	0.001	0.001	0.01	0.05	0.01	0.05	0.01	-
	Manganese (Mn)	mg/L	0.05	0.05	0.05	0.1	0.3	0.1	0.05	0.05	0.05 -0.2
	Chromium (Cr)	mg/L	0.03	0.02	0.01	0.05	-	0.05	0.1	0.05	-
	Nickel (Ni)	mg/L	0.001	0.001	0.001	0.02	-	0.07	0.1	0.02	0.001
	Copper (Cu)	mg/L	0.003	0.002	0.002	0.05	1.5	2	1.3	2.0	< 0.005
	Zinc (Zn)	mg/L	0.005	0.005	0.003	5	15	4	5	5.0	< 0.01
	Iron (Fe)	mg/L	0.03	0.03	0.04	0.3	-	0.3	0.3	0.2	0.01 -0.3
Bureau of Indian Standards IS 10500 : 2012; WHO Guidelines for Drinking-Water Quality (2011);US EPA Primary Drinking Water Standards; E.U: European Union /European Communities (Drinking Water) (No. 2) Regulations 2007 (S.I. 278 of 2007); Water Quality for Pond Aquaculture-Acceptable Concentration Ranges in Aquaculture Pond Waters" Boyd (1998).											
Remarks: Heavy metal concentrations are well below the standards given for drinking (BIS, WHO, EU, US EPA) and pond aquaculture purposes (Boyd, 1998).											
Note: Season wise data primarily compared with Boyd (1998) water quality standards for pond aquaculture.											

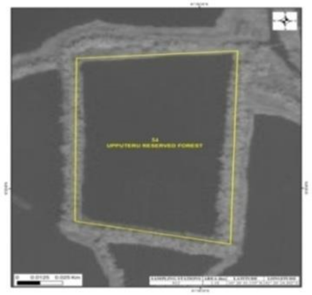
Sampling location: S2 Kotta Pusalamuru	Results of water quality parameters tested in 3 different seasons					Water quality standards					
Latitude: 16° 25' 40.019" N Longitude: 81° 26' 59.982" E Located adjacent Kottachedunala Area (Hectare):0.99	**Heavy Metals**		**Summer**	**Rainy**	**Winter**	**BIS 10500 : 2012**		**WHO**	**EU**	**US EPA**	**Boyd (1998) Water Quality for Pond Aquaculture**
						Acceptable limit	**Permissible limit**				
	Cadmium (Cd)	mg/L	0.001	0.001	0.001	0.003	-	0.003	0.005	0.005	0.001
	Mercury (Hg)	mg/L	0.0001	0.0001	0.0001	0.001	-	0.006	0.002	0.001	0.001
	Lead (Pb)	mg/L	0.001	0.001	0.001	0.01	-	0.01	0.015	0.01	0.003
	Arsenic (As)	mg/L	0.002	0.001	0.001	0.01	0.05	0.01	0.05	0.01	-
	Manganese (Mn)	mg/L	0.05	0.05	0.05	0.1	0.3	0.1	0.05	0.05	0.05 -0.2
	Chromium (Cr)	mg/L	0.02	0.001	0.002	0.05	-	0.05	0.1	0.05	-
	Nickel (Ni)	mg/L	0.001	0.0002	0.0003	0.02	-	0.07	0.1	0.02	0.001
	Copper (Cu)	mg/L	0.002	0.002	0.001	0.05	1.5	2	1.3	2.0	< 0.005
	Zinc (Zn)	mg/L	0.002	0.002	0.003	5	15	4	5	5.0	< 0.01
	Iron (Fe)	mg/L	0.05	0.02	0.02	0.3	-	0.3	0.3	0.2	0.01 -0.3
Bureau of Indian Standards IS 10500 : 2012; WHO Guidelines for Drinking-Water Quality (2011);US EPA Primary Drinking Water Standards; E.U: European Union /European Communities (Drinking Water) (No. 2) Regulations 2007 (S.I. 278 of 2007); Water Quality for Pond Aquaculture-Acceptable Concentration Ranges in Aquaculture Pond Waters" Boyd (1998).											
Remarks: Heavy metal concentrations are well below the standards given for drinking (BIS, WHO, EU, US EPA) and pond aquaculture purposes (Boyd, 1998).											
Note: Season wise data primarily compared with Boyd (1998) water quality standards for pond aquaculture.											

Sampling location: S3 **Kotta Pusalamuru**	**Results of water quality parameters tested in 3 different seasons**					**Water quality standards**					
Latitude: 16° 25' 27.894" N Longitude: 81° 27' 41.323" E Located beside Lossari main channel extension Area (Hectare): 1.81	**Heavy Metals**		**Summer**	**Rainy**	**Winter**	**BIS 10500 : 2012** **Acceptable limit**	**BIS 10500 : 2012** **Permissible limit**	**WHO**	**EU**	**US EPA**	**Boyd (1998) Water Quality for Pond Aquaculture**
	Cadmium (Cd)	mg/L	0.0009	0.0006	0.0008	0.003	-	0.003	0.005	0.005	0.001
	Mercury (Hg)	mg/L	0.0003	0.0002	0.0003	0.001	-	0.006	0.002	0.001	0.001
	Lead (Pb)	mg/L	0.001	0.001	0.001	0.01	-	0.01	0.015	0.01	0.003
	Arsenic (As)	mg/L	0.001	0.001	0.003	0.01	0.05	0.01	0.05	0.01	-
	Manganese (Mn)	mg/L	0.01	0.02	0.03	0.1	0.3	0.1	0.05	0.05	0.05 -0.2
	Chromium (Cr)	mg/L	0.03	0.001	0.001	0.05	-	0.05	0.1	0.05	-
	Nickel (Ni)	mg/L	0.001	0.0004	0.0006	0.02	-	0.07	0.1	0.02	0.001
	Copper (Cu)	mg/L	0.002	0.001	0.001	0.05	1.5	2	1.3	2.0	< 0.005
	Zinc (Zn)	mg/L	0.003	0.002	0.004	5	15	4	5	5.0	< 0.01
	Iron (Fe)	mg/L	0.2	0.09	0.09	0.3	-	0.3	0.3	0.2	0.01 -0.3

Bureau of Indian Standards IS 10500 : 2012; WHO Guidelines for Drinking-Water Quality (2011);US EPA Primary Drinking Water Standards; E.U: European Union /European Communities (Drinking Water) (No. 2) Regulations 2007 (S.I. 278 of 2007);
Water Quality for Pond Aquaculture-Acceptable Concentration Ranges in Aquaculture Pond Waters" Boyd (1998).

Remarks: Heavy metal concentrations are well below the standards given for drinking (BIS, WHO, EU, US EPA) and pond aquaculture purposes (Boyd, 1998).

Note: Season wise data primarily compared with Boyd (1998) water quality standards for pond aquaculture.

Sampling location: S4 **Upputeru Reserved Forest**	**Results of water quality parameters tested in 3 different seasons**					**Water quality standards**					
Latitude: 16° 26' 41.119" N Longitude: 81° 26' 24.202" E Located nearby Ennamadurdrain Area (Hectare): 1.18	**Heavy Metals**		**Summer**	**Rainy**	**Winter**	**BIS 10500 : 2012** **Acceptable limit**	**BIS 10500 : 2012** **Permissible limit**	**WHO**	**EU**	**US EPA**	**Boyd (1998) Water Quality for Pond Aquaculture**
	Cadmium (Cd)	mg/L	0.0005	0.0005	0.0006	0.003	-	0.003	0.005	0.005	0.001
	Mercury (Hg)	mg/L	0.0004	0.0003	0.0003	0.001	-	0.006	0.002	0.001	0.001
	Lead (Pb)	mg/L	0.001	0.001	0.002	0.01	-	0.01	0.015	0.01	0.003
	Arsenic (As)	mg/L	0.002	0.001	0.003	0.01	0.05	0.01	0.05	0.01	-
	Manganese (Mn)	mg/L	0.05	0.05	0.06	0.1	0.3	0.1	0.05	0.05	0.05 -0.2
	Chromium (Cr)	mg/L	0.03	0.001	0.001	0.05	-	0.05	0.1	0.05	-
	Nickel (Ni)	mg/L	0.001	0.0002	0.0003	0.02	-	0.07	0.1	0.02	0.001
	Copper (Cu)	mg/L	0.003	0.002	0.002	0.04	1.5	2	1.3	2.0	< 0.005
	Zinc (Zn)	mg/L	0.005	0.002	0.003	5	15	4	5	5.0	< 0.01
	Iron (Fe)	mg/L	0.09	0.1	0.06	0.3	-	0.3	0.3	0.2	0.01 -0.3

Bureau of Indian Standards IS 10500 : 2012; WHO Guidelines for Drinking-Water Quality (2011);US EPA Primary Drinking Water Standards; E.U: European Union /European Communities (Drinking Water)(No. 2) Regulations 2007 (S.I. 278 of 2007);
Water Quality for Pond Aquaculture-Acceptable Concentration Ranges in Aquaculture Pond Waters" Boyd (1998).

Remarks: Heavy metal concentrations are well below the standards given for drinking (BIS, WHO, EU, US EPA) and pond aquaculture purposes (Boyd, 1998).

Note: Season wise data primarily compared with Boyd (1998) water quality standards for pond aquaculture.

Sampling location: 5 **Upputeru Reserved Forest**	**Results of water quality parameters tested in 3 different seasons**					**Water quality standards**					
Latitude: 16° 27' 20.374" N Longitude: 81° 26' 5.736" E Located nearby an aquaculture ponds, Area (Hectare): 1.30	**Heavy Metals**		**Summer**	**Rainy**	**Winter**	**BIS 10500 : 2012**		**WHO**	**EU**	**US EPA**	**Boyd (1998) Water Quality for Pond Aquaculture**
						Acceptable limit	**Permissible limit**				
	Cadmium (Cd)	mg/L	0.0001	0.0001	0.0001	0.003	-	0.003	0.005	0.005	0.001
	Mercury (Hg)	mg/L	0.0002	0.0002	0.0003	0.001	-	0.006	0.002	0.001	0.001
	Lead (Pb)	mg/L	0.001	0.001	0.001	0.01	-	0.01	0.015	0.01	0.003
	Arsenic (As)	mg/L	0.002	0.001	0.002	0.01	0.05	0.01	0.05	0.01	-
	Manganese (Mn)	mg/L	0.05	0.05	0.06	0.1	0.3	0.1	0.05	0.05	0.05 -0.2
	Chromium (Cr)	mg/L	0.03	0.001	0.001	0.05	-	0.05	0.1	0.05	-
	Nickel (Ni)	mg/L	0.001	0.0004	0.0005	0.02	-	0.07	0.1	0.02	0.001
	Copper (Cu)	mg/L	0.005	0.003	0.003	0.05	1.5	2	1.3	2.0	< 0.005
	Zinc (Zn)	mg/L	0.006	0.004	0.005	5	15	4	5	5.0	< 0.01
	Iron (Fe)	mg/L	0.06	0.1	0.09	0.3	-	0.3	0.3	0.2	0.01 -0.3

Bureau of Indian Standards IS 10500 : 2012; WHO Guidelines for Drinking-Water Quality (2011);US EPA Primary Drinking Water Standards; E.U: European Union /European Communities (Drinking Water)(No. 2) Regulations 2007 (S.I. 278 of 2007);
Water Quality for Pond Aquaculture-Acceptable Concentration Ranges in Aquaculture Pond Waters" Boyd (1998).

Remarks: Heavy metal concentrations are well below the standards given for drinking (BIS, WHO, EU, US EPA) and pond aquaculture purposes (Boyd, 1998).

Note: Season wise data primarily compared with Boyd (1998) water quality standards for pond aquaculture.

CONCLUSIONS

The minimum and maximum heavy metal concentrations in different parts of the Upputeru Reserved Forest, Bhimavaram Mandal are reported. Heavy metal concentrations are well below the standards given for drinking (51, 52, 53) and pond aquaculture purposes (54, 55).

SUGGESTIONS

Based on the results obtained in the present study, conditions governing cultural practices, and critical analysis of data on fishpond water in and around Upputeru Reserved Forest, Bhimavaram Mandal, we make the following recommendations.
Proper implementation of the following precautions and guidelines will not only increase productivity and economic returns, but also help fish farmers maintain eco-friendly fish ponds and the environment necessary for sustainable aquaculture.

1. Green technologies such as planting shade trees on the sides of fish pond aquariums and creating artificial shade during summer temperature stratification can protect fish in fish ponds. It should be implemented immediately.
2. Mechanical aeration can prevent the accumulation of ice in large areas of the fish pond. Mechanical aeration is also the most common and effective ways to increase DO.
3. For rectangular ponds, it is recommended to adjust the length to width ratio to increase low velocity and reduce bio-solids accumulation.
4. Adopting environmentally friendly techniques in fish farming ponds (when using harmful feed, antibiotics, wastewater treatment facilities, etc.).
5. If you use organic fertilizers instead of organic fertilizers to reduce pollution, the fish will grow well there.

REFERENCES

[1] H.Westers. (1991). Operational Waste Management in Aquaculture effluents. In Nutritional Strategies and Aquaculture Waste. C. B. Cowey and C. Y. Cho, eds. University of Guelph,Ontario, Canada 231-238.
[2] M.A.Munni, Z.Fardus,M.Y.Mia, R. Afrin. (2013). Assessment of pond water quality for fish culture: A case study of Santosh region in Tangail, Bangladesh. Journal of Environmental Science and Natural Resources, 6(2) 157-162.
[3] L.D. Swann. (1993), Water Sources used in aquaculture. Illinois-Indiana Sea Grant Program AS-486.Purdue University, West Lafayette.
[4] A.G.J. Tacon. Fishmeal replacers: Review of antinutrients within oilseeds and pulses - A limiting factor for the aquafeed Green Revolution?In: Tacon A.G.J (ed).Basurco B.(ed).Feeding tomorrow's fish. Zaragoza: CIHEAM (1997), p.153-182 (Cahiers Options Mediterraneenes,n.22)
[5] A. Dhawan, S Kaur. (2002). Pig dung as pond manure: Effect on water quality, pond productivity and growth of carps in polyculture system. NAGA, the ICLARM quarterly, 25(1), 11-14.
[6] F. Henry, R. Amara, L. Courcot, D. Lacouture, M.L. Bertho. (2004). Heavy metals in four fish species from the French coast of the Eastern English Channel and Southern Bight of the North Sea. Environment international, 30(5), 675-683.
[7] S. Zaza, K. de Balogh, M. Palmery, A.A. Pastorelli, P. Stacchini, P. (2015). Human exposure in Italy to lead, cadmium and merury through fish and seafood product consumption from Eastern Central Atlantic Fishing Area. Journal of Food Composition and Analysis: 40, 148-153.
[8] M. Stancheva, A. Merdzhanova, E.T. Petrova-Pavlova, D. Petrova. (2013). Heavy metals and proximate composition of Black Sea sprat (Sprattus sprattus) and goby (Neogobiusmelanostomus). Bulgarian Journal of Agricultural Science 19(1), 35-41.
[9] P. Kumar, Y. Prasad,A.K. Patra, D. Swarup. (2007). Levels of cadmium and lead in tissues of freshwater fish (Clarias batrachus L.) and chicken in Western UP (India). Bulletin of Environmental Contamination and Toxicology, 79(4), 396-400.
[10] C. Teta,M. Ncube, Y.S. Naik. (2017), Heavy metal contamination of water and fish in peri-urban dams around Bulawayo, Zimbabwe, African Journal of Aquatic Science, 42(4), 351-358,
[11] T.Puchase, D. Jamu. (2009). Determination of lead levels in farm-raised fish (oreochromisshiranus) in Zomba district, Malawi.Malawi Fisheries repository.

[12] Nriagu, J.O. and Pacyna, J.M. (1988).Quantitative assessment of worldwide contamination of air, water and soils by trace metals. Nature, 333; 134–139.

[13] Farombi, E.O., Adelowo, O.A. , R.Ajimoko, A. (2007).Biomarkers of oxidative stress and heavy metal levels as indicators of environmental pollution in African Cat fish (Clarias gariepinus) from Nigerian Ogun River. Int J Environ Res Public Health 4(2);158 – 165.

[14] Kalay, M. and Canli, M. (2000). Elimination of essential (Cu and Zn) and non essential (Cd and Pb) metals from tissues of a fresh water fish, *Tilapia zillii*",Tropical Journal of Zoology. 24;429-436.

[15] Wicklund-Glynn, A . and Olsson, P.E. (1991).Cadmium turnover in minnows *(Phoxinus phoxinus*) exposed to water borne cadmium",Environmental Toxicology and Chemistry ,10;383-94.

[16] Colborn, T., vom Saal, F.S. and Soto, A.M. (1993).Developmental effects of endocrine-disrupting chemicals in wildlife and humans. Environ. Health Perspect., 101;378-384.

[17] Nimmo, D.R,.Rigby, R.A., Bahner, L.H. and Sheppard, J.M. (1978).The acute and chronic effects of cadmium on the estuarine mysid *Mysidopsisbahia*", Bulletin of Environmental Contamination and Toxicology,19;80–85.

[18] Nevo, E., Noy RLavie, B., Beiles, A. and Muchtar, S. (1986). Genetic diversity and resistance to marine pollution . Biological Journal of the Linnean Society ,29;139-144.

[19] Couch, J.A. (1987). Diseases, parasites and toxic responses of commercial penaeid shrimps of the Gulf of Mexico and Atlantic coast of North America , Bull Fish , 76;1-44.

[20] Burger, J. and Gochfeld, M. (2005). Heavy metals in commercial fish in New Jersey.Environ Res., 99;403-12.

[21] Kaoud, H.A., Khaled, M.A., Rezk and A., Khalf, M.A. (2012).Bioremediation the toxic effect of mercury on liver histopathology, some hematological parameters and enzymatic activity in Nile tilapia, *Oreochromis niloticus*. Researcher, 4(1); 60-69.

[22] Cadmium in Drinking-water Background document for development of WHO Guidelines for Drinking-water Quality, (2011).

[23]Nordic Council of Ministers Cadmium Review, (2003). http://www.who.int/ifcs/documents/forums/forum5/nmr_cadmium.

[24] Schroeder ,W.H. and Munthe, J.(1998).Atmospheric mercury - an overview.Atmos Environ., 32;809-822

[25] Murata, K., Sakamoto, M., Nakai, K., Weihe, W., Dakeishi, M. , Iwata, T., Liu ,X.J., Ohno, T., Kamiya, K . and Satoh, H.(2004).Effects of methylmercury on neurodevelopment in Japanese children in relation to Madeiran study.Int Arch Occup Environ Health, 77;571-579.

[26] Parson, M.B. and Percival, J.B.(2005).Mercury:Sources,measurements,cycles and Effects.34 ,Mineralogical Association of Canada.

[27] Clarkson, W.T. (2002). The three modern faces of mercury. Environ Health Perspect., 110 (Suppl. 1);11–23.

[28] S. A. Abbasi, Naseema Abbasi, Soni Rajendra. (1998). "Heavy metals in the environment," Mittal publications, 1, pp. 314.

[29] Aboud S. Jumbe , N. Nandini. (2009). "Impact assessment of heavy metals pollution of Vartur lake, Bangalore," *Journal of Applied and Natural Science* 1(1) pp. 53-61.

[30] Rashmi Verma, Pratima Dwivedi. (2013). "Heavy metal water pollution- A case study," Recent Research in Science and Technology, 5(5), pp. 98-99.

[31] Pacyna, J.M., Scholtz, M.T. and Li, Y.F. (1995).Global budgets of trace metal sources*",* Environ Rev., 3;145-159.

[32] Roy,S. and Bhattacharya, S.(2006). Arsenic-induced histopathology and synthesis of stress proteins in liver of *Channa punctatus* .Ecotoxicol Environ Saf ., 65; 218-229.

[33] NAS. (1977). Arsenic. Natl Acad Sci , Washington, D.C.,pp.332 .

[34] Oladimeji ,A.A., Qadri, S.U. and de Freitas, A.S. (1984).Measuring the elimination of arsenic by the gills of rainbow trout (*Salmo gairdneri*) by using a two compartment respirometer**",** Bull. Environ ContamToxicol ., 32 (6); 661-668.

[35] Annalisa Pinsino, Valeria Matranga, Maria Carmela Roccheri, (2012). "Manganese: A New Emerging Contaminant in the Environment," – 18-36.

[36] S. A. Abbasi, Naseema Abbasi, Soni Rajendra. (1998). "Heavy metals in the environment," Mittal publications, 1, pp. 314.

[37] Aboud S. Jumbe , N. Nandini. (2009). "Impact assessment of heavy metals pollution of Vartur lake, Bangalore," *Journal of Applied and Natural Science* 1(1) pp. 53-61.

[38] M. Pavan, G.Benarjee. (2015). "Studies on physico-chemical parameters and occurrence of heavy metals in an urban lake of Warangal district during different seasons," International journal of plant, animal, and environmental science, 5(3).
[39] L. E. Towill, Carole R. Shriner, John S. Drury, Anna S.Hammons, Jamesw, Holleman. (1978). Reviews of the environmental effects of pollutants: III, chromium, pp. 12-17.
[40] U.S. department of health and human services, Public Health Service Agency for Toxic Substances and Disease Registry. http://www.atsdr.cdc.gov/toxfaqs/tfacts15.pdf
[41] F William Sunderman, Brian Dingel, Sidney M. Hopfer, Thomas swift. (1988). "Acute Nickel Toxicity in Electroplating Workers who accidentally ingested a solution of nickel sulphate and nickel chloride," American journal of industrial medicine, 14, pp. 257-266.
[42] T. Byragi Reddy, Ch. Venkata Ramana, Ch. Bhaskar & P. Jagadeesh chandrababu. (2012). Assessment of heavy metal study on ground water in and around Kapuluppada MSW site, Visakhapatnam, AP., International Journal of Science and Nature, 3(2), pp. 468-471.
[43] A. K. Krishna, P. K. Govil, (2004). "Heavy metal contamination of Soil around Pali Industrial Area,Rajasthan, India," Environmental Geology, 47(1), pp. 38–44.
[44] S. Srinivasa Gowd, Pradip K. Govil, (2008). "Distribution of heavy metals in surface water of Ranipet industrial area in Tamil Nadu, India," *Environ Monit Assess*, 136, pp. 197–207.
[45] Ruqia Nazir, Muslim Khan, Muhammad Masab, Hameed ur Rehman, Naveed ur Rauf, Surrya Shahab, Nosheen Ameer, Muhammad Sajed, Mohib Ullah, Muhammad Rafeeq, Zeenat Shaheen, (2015). " Accumulation of Heavy Metals (Ni, Cu, Cd, Cr, Pb, Zn, Fe) in the soil, water and plants and analysis of physico-chemical parameters of soil and water Collected from Tanda Dam Kohat," *J. Pharm. Sci. & Res*., 7(3), pp. 89-97.
[46] Ibemenuga, Keziah Nwamaka, (2013). 'Bioaccumulation and toxic effects of some heavy metals in freshwater fishes," Animal Research International, 10(3), pp. 1792 – 1798.
[47] C. I. Nsofor, E. B. C.Ufodike, S. O. ONUOHA, (2007). "The bioaccumulation of some heavy metals in some organs of two commercial fish; Clarias gariepinus (Burchell) and Chrysicthysnigrodigitatus (Lacepede) from River Niger, Onitsha shelf, Anambra State, Nigeria. Journal Of Aquatic Sciences," 22(1), pp. 33 – 38.
[48] Gautam Patil, Irfan Ahmad,(2011). "Heavy metals contamination assesment of Kanhargaon dam water near Chhindwara city, *Acta Chim. Pharm. Indica*, 1(1), pp. 7-9.
[49] P. S. Welch, 1952. "Limnological Methods*,"* McGraw Hill Book Co., Inc. New York, pp. 538.
[50] Fawzia Adib Flowra , Jibon Kumar Ghosh, Md. Abu Sayed Jewel, Anannya Sen Tumpa, M. Afzal Hussain, (2012). "Analysis of heavy metal components in some urban ponds in Rajshahi, Bangladesh ," J. Life Earth Sci., 7 pp. 115-117.
[51] BIS. (2012): Indian Standards specifications for drinking water. IS: 10500:2012, Bureau of Indian Standards. New Delhi.
[52] WHO, Glass report. (2012): Un-Water Global analysis of Assessment of sanitation and drinking water – WHO April 2012. (WASH). Water Sanitation and Hygiene.
[53] USEPA.(United States Environmental Protection Agency). (1975) Quality Criteria for water (Ed. R.E. Train) caste house publication Ltd. Great Britain.
[54] Boyd, C.E. (1998). Pond aquaculture water quality management /Claude E. Boyd, Craig S. Tucker. ISBN 0-412-07181-9.Copyright © 1998 by Kluwer Academic Publishers.
[55] Boyd, C.E. and Lichtkoppler, F. (1979): Water Quality Management in Fish Ponds. Research and Development Series No. 22, International Centre for Aquaculture (J.C.A.A) Experimental Station Auburn University, Alabama, pp 45-47.