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Research Review

Risk in Loss of Aquatic Diversity from Coal Based Thermal Power Plant Effluents: A Review

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A B S T R A C T

In India the increasing demand for electricity and combustion of fossil fuels are the major sources to fulfill our need of energy but combustion of coal produces fly ash and bottom ash. Which are the major environmental pollution issued when fossil fuels or coal are used as raw material for generating energy in thermal power plants that produces by-product as fly ash, some are contaminated with water through cooling system of machine and discharge of fly ash containing waste water into the aquatic water bodies from the different Coal based Thermal Power Plants causes changes in physico-chemical parameters of water, such as- pH, DO, BOD, COD, temperature, alkalinity, hardness, color, odor, conductivity, total solid and there also caused metal pollution in the aquatic environment such Silica, Iron, Aluminum, Manganese, Zinc, Copper and trace amount of heavy metals such Molybdenum, Mercury, Selenium, Cadmium, Chromium increased above the threshold limits. These are results in loss of aquatic biodiversity, extinction of some native fish species, natural fish food organism's phytoplankton or zooplankton and aquatic plants. Fishes are suffered from different types of diseases. Bioaccumulation of heavy metals occurs in the liver, gill, kidney, muscle and blood; resulting changes in fish physiology, behaviors, early reproduction, low life span and other problems. Histological analysis of liver, kidney, muscle shows severe damages due to toxic effects of trace elements. The main objective of this review work is to draw the attention on to set proper treatment plant before release of waste water into the aquatic ecosystem and to minimize the toxicity level on aquatic organisms to resist in the environment.

***Key words*:** Fly ash, Biodiversity, Heavy metal, Bioaccumulation

"Pollution is the introduction of substances or energy into the environment, resulting in deleterious effects on human health, living resources and ecosystems, and impair or interfere with amenities and other legitimate uses of the environment" Pollution Prevention Act of 1990 and the Agency's 1991 Pollution Prevention Strategy [Environmental Protection Agency] (EPA). There are different types of pollutants such as solid, liquid or gas and also in the form of energies such as sound, thermal or radiation by Environment (Protection Act), 1986 Section 2 (b). Environmental pollution occurs when addition of such pollutants into the environment is faster than its degradation, decomposition, and dilation and recycling; those results into accumulation of such pollutants in their respective niche and thus impressing their harmful effects. Pollution can be classified as Air Pollution, Land Pollution and Water Pollution. Beside these pollutants other types of pollutions made by Human civilization such as light pollution, noise pollution, automobile pollution, plastic pollution, agricultural pollution and industrial pollution (EPA). Now a day's different types of industry develop across the world for generating products. By this way they are releasing waste products such as chemicals, toxic elements etc. These waste products when released in the environment it cause pollution. About 17 industries are most causing pollution our environment. These are cements, dyes, fertilizers, soda, oil refineries, paper, pesticides, sugar, tanneries, thermal power plant etc. Coal based thermal power plant pollution is the major pollution sources, polluting air, soil and water. Thermal power plants have been used from decades for the generating of electricity; therefore, they are the key component in industrial development. As across the world the demands of electricity have been increasing; the introduction of high performance and low-price thermal power plants will be the future prospect for every country.

Water pollution is increasing day by day due to different types of pollutants like rapid industrial wastes,

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agro-chemicals and domestic sewage discharged into the rivers, lakes and wetlands. They disturb the aquatic ecosystem; pollution occurs both by physically and chemically. Change in the color, taste, odor, temperature are refers to as physical pollution of water. Chemical pollution in water bodies are the followings: pH, DO, BOD, COD, alkalinity and hardness etc.

Considering the overall impacts only focused on impacts of coal based Thermal Power Plant waste water containing effluents in aquatic system. Although thermal Power Plants play important role to fulfill our need of energy but waste products discharged from the power plants into the surrounding water bodies through surface run off disrupt the aquatic ecosystem and ecological balance of the water bodies and different types of metals and heavy metals pollution occurred in aquatic organisms. Thus, increased photosynthetic phytoplankton reduced in number by the metals and heavy metals pollution that serve loss of zooplankton population. Heavy metals toxicity on zooplankton species were reported highly sensitive by [1-2]. Cupper pollution killed the aquatic organism and decomposition of dead organism resulting increased the demand of oxygen [3] in water body. Metals pollution such as cupper, cadmium and zinc to *Cyprissubglobosa* and *Daphnia lumholtzi* drastically reduced pollution even at lower concentration reported by [4]. Metals and heavy metals pollution sensitivity to zooplankton much higher than fish and zooplankton are the natural aquatic feed for larval fishes and some other fishes so, metals and heavy metals bio-accumulate into the aquatic food chain [4].

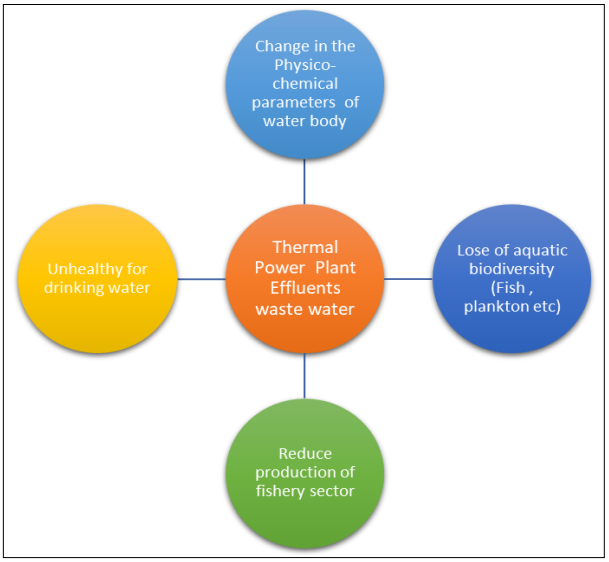

Fig 1 Effects of Thermal power plant effluents waste water

Aims

Determined the aquatic biodiversity lose due to different types of toxic elements present in coal based thermal power plant containing effluents and alternation of physic-chemical properties of the aquatic ecosystem.

Thermal power plants in India

The main source of power in India is Thermal Power. It is categorized into three types on the basis of fuel used such as Coal, Gas, and Diesel. In India about 71% energy is generated by Thermal Power Plants. About 62% electricity produced by coal based Thermal Power Plant as reported by (Central Electricity authority, Govt. of India) 2017. An India presently 117 Coal based Thermal Power Plants are enlisted of them 39 in Western, 35 in Eastern, 27 in Northern and 19 in Southern region. The net electricity generating capacity is about 169,387.88 Megawatts. Therefore, India is contributing in a large number of the thermal power plants so as to fulfill the electricity need in the country. Although thermal power plant required energy, but it's causing pollution in air, water and soil. The effluents of power plants when released into the water body alter the physic-chemical parameters of the aquatic ecosystem.

Effects on water quality

Accumulation of some heavy metals in each trophic levels of aquatic ecosystem was observed by [5]. They found Cu, Zn and Cd were more concentration in fly ash containing effluent waste water, Al and Fe high sedimentation in soil. Whereas Cu and Zn more concentration in invertebrate followed by Cd and Hg. Selenium toxicity occurs in some bacteria, crayfish and mosquito fish. Effluent form the coal based Thermal Power Plant which alter the pH of water body and metals pollution shows toxic to aquatic life mainly on microhabitat, mosquito fish, dipterans and some odonates examined by [6]. According to [7] metals concentration increased in the river part of Beresh closed to Thermal power plant than the upper and lower part of the river, lower part shows slightly lower concentration and higher in the upper part and moderate in the middle of the river Beresh. Seasonal variations of metals concentration also showed all three parts of the river. Observation made for 8 years and found high concentration of Ca, Na and Mg; low concentration of Si, K, Sr, Fe and Al. Waste water leaches from the dumped of fly ash of the Yatagan Thermal power plant severally changing the ground and surface water quality and different ions such as Ca^{++}, Pb^{++}, Cd^{++}, Sb^{++} and SO_4^{2-} were above the exceed limits according to WHO and EPA examined by [8]. Surface water and soil sedimentation of heavy metals accumulation in aquatic food chain of the lake Beysehir, Turkey [9] was reported by. For drinking water Cd and Pb were found above the permissible limits. According to [10] concentration of selenium and other trace metals exceed the threshold limits in the total fish body tissues and ovary. Long term effect of coal combustion residues caused changes in the water quality and aquatic organism studied by [11]. Laboratory test specimens were more sensitive than native one with coal combustion ash case studied by [12]. Groundwater was not safe for drinking, because contamination of heavy metals due to disposal of fly ash slurry through rain water from the Parichha Thermal power plant near Jhansi was reported by [13] lead, nickel, chromium, and iron were estimated high and magnesium low concentration. Concentrations of heavy metals were comparatively higher in rainy season than other season. Leaching of metals from the ash pond not only depends on acidic pH but also in concentration present metals present in fly ash and coal. Mixing of dissolved atmospheric SO_2 with acidic rain water creates more acidic conditions of ash pond that resulting release of heavy metals from the ash slurry into the groundwater increasing metal toxicity. By-products from the coal based Thermal Power plant has low effect on skin of the adult Spring Peepers (*Pseudacris crucifer*) [14].

Effect on zooplankton

Various metals toxicity to *Daphnia magna* in 48 hours shows 50% mortality and 16% population decreased

in 3 weeks, in laboratory condition LC50 performed with different types of metals and shows marked variation [15]. Acute bioassay and statistical analysis of Cu, Zn and Cd on *Cypris subglobosa* and *Daphnia lumholtzi* were evaluated by [16]; they found *Daphnia lumholtzi* was more sensitive than *Cypris subglobosa* had good resistance power against the metals toxicity. Even at low concentration of metals and heavy metal pollution sufficiently eliminated some zooplankton community which not directly affected the fish fauna but water body not fit for aquaculture. Heavy metals accumulation shows seasonal variation in plankton and water of Saryyar Dam Lake studied from April, 2000 to December 2004. Plankton shows the highest sensitivity to all kind of heavy metals concentration. Where mercury was highest and leads the lowest concentration in plankton body observed by [17]. According to [18] altered the physico-Chemical features of water affected the zooplankton density of river Kapila in Karnataka in 2012. Zooplankton diversity ware drastically reduced from the water body because of industrial effluents released into water and leading to eutrophication. Abundant of zooplankton community were closely related with physic-chemical parameters of Niger Delta observed by [19]. Environmental factors which affects the zooplankton diversity analysis by Canonical Cluster Analysis (CCA). Sample collected from three stations, station 3 shows the highest diversity and lowest diversity in station 2 and station 1 had moderate diversity of zooplankton community. That indicated station 2 was polluted by different types of pollutants where low DO, high TDS and BOD affects other water quality parameters which required for normal growth and development of zooplankton.

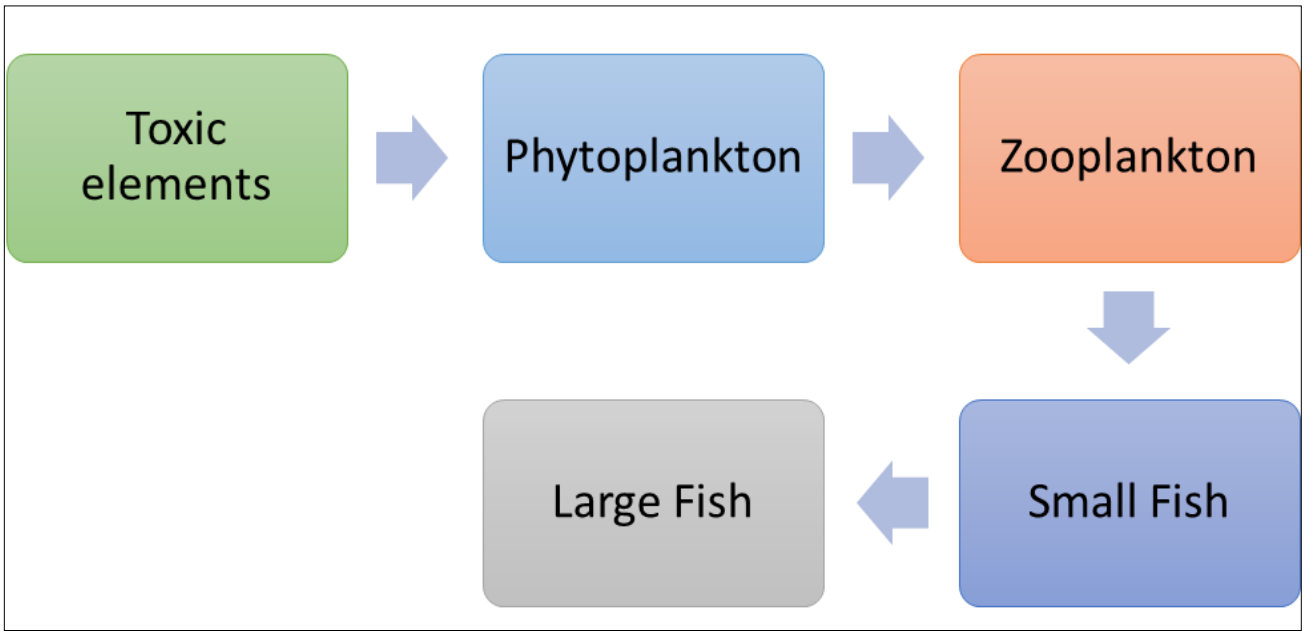

Fig 2 Bioaccumulation of heavy metals in each tropic level

Effects on fish

Accumulation of metals in some fish species such as *Cyprinus carpio, Trachelipus* sp, *Lumbricus terrestris, Melanoplus* sp, *Gryllus* sp were found different concentration in various organ [20]. In which Zn was the highest bioaccumulation than other metals. It was also reported in mole cricket that highest level of Se, Cr and Zn bio-concentration occurs. Oxidative stress in freshwater fish, *Channa punctata* to fly ash leachate for 24 hours was studied by [21], found that glutathione activity was reduced but catalase (CAT), glutathione *S*-transferase (GST) were showed high activity. Fly ash leachate stimulated lipid peroxidation in different organ and maximum prominent response occurred in gill. Enzyme activity in the liver showed high for detoxification activity. Fly ash leachate induced oxidative stress but when tested with lipid peroxidation antioxidant, it showed defensive mechanism by interacted with reactive oxygen species at initial stage. Coal combustion residues from coal based thermal power plant induced sub-lethal effects, oxidative stress, change in antioxidant function and breakage of single strand DNA in Grass shrimp (*Palaemonetes pugio*). Change in the larval metamorphosis of Grass shrimp occurs in experimental condition with coal combustion residues (CCR). COMET assay and sensitive assay used to determine genotoxicity in adults grass shrimp. Selenium and Cadmium accumulation found high in tissue of shrimp rather than mercury. Chronic exposure of CCR caused single strand breakage to DNA in hepatopancreas cells. Total antioxidant potential not significantly change [22]. Serum toxicity of heavy metals in *Labeo rohita* was studied by [23] Pb, Cd and Cr and some metals such as As, Zn, Ni, Mn, Fe, Al and Cu different concentration. These toxic elements caused damaged liver, kidney and tissues. Long term exposures of coal ash to three species of fish such as redear sunfish (*Lepomis microlophus*), bluegill (*Lepomis macrochirus*) and largemouth bass (*Micropterus salmoides*) showed change in blood chemistry and reproductive stress examined by [24]. Concentrations of iron was estimated high in the water and different organs of *Mastacembelus armatus* highest level of iron accumulation occurs in liver and lowest in muscle [25]. Toleration from iron toxicity leading to activation of iron-containing enzyme resulting 75% of heamoglobin binding occurs within the body [26].

Turbidity of the fly ash discharged in the pond and river increasing suddenly when its inlet gate was open due to discharged of fly ash particles with the flow, thus fluctuating unevenly. Physico- chemical properties of fly ash discharged pond are influenced by the constituent of fly ash and water quality used for making difficult for introduced life forms to

survive. pH is also fluctuating and non-constant our studies area. The bed of the pond is totally made of fly ash particles. This is constant in normal ponds, which have a very productive pond bed, where many producers inhabited. But here the pond bed is made up of seeped fly ash from the ash dyke, where amount of ash is increasing continuously, making it least productive.

The presence of heavy metals in any water body is important for carrying out various metabolic activities of living organism but once they reach their maximum level, they serve as environmental pollutants produce hazardous effects on the aquatic organisms. Heavy metals are known to as hazardous effects on cell structure, especially on cell membrane. Therefore, increasing in cholesterol may be a better indication of environmental stress. The kidney is one of the major target organs for environmental contaminants such as heavy metals, and they are important organs for metabolic waste excretion and heavy metal elimination in fish [27]. Kidney function tests such as serum creatinine, uric acid and urea can be used as a rough index of the glomerular filtration rate where low values of creatinine, uric acid and urea have no significance but increasing values indicate the presence of disturbance in the kidney [28].

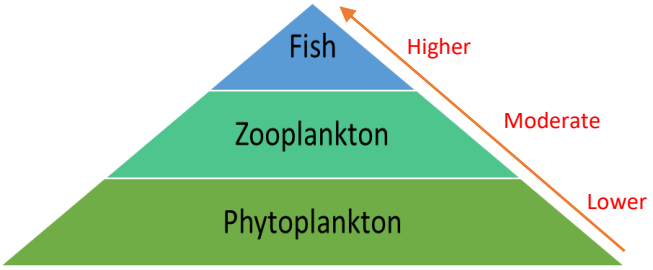

Fig 3 Biomagnifications of heavy metals in each tropic level

Labeo rohita collected from thermal power station showed an increase in serum creatinine indicate that action of heavy metals and other pollutants on glomerular filtration rate which causes pathological change the kidney. Toxicity of heavy metals can cause dermatological disease, skin cancer and internal cancer (liver, kidney, lung and bladder). Cardiovascular disease, diabetes and anaemia as well as reproductive, developmental, immunological and neurological affects in the human body. Prolong exposure of these heavy metals change in morphological histological and biochemical alternation in the tissues which may critically influence fish quality.

CONCLUSION

Waste water of thermal Power Plants contain some metals such as Al, Si, Fe, Mn, Zn, Ni, As and heavy metals such as Cd, Pb, Cr, Hg and Mo sometime it exceeds above the permissible limits for aquatic ecosystem and deposited into the bed of water bodies. As a results bioaccumulation into the aquatic food chain and that alter in the physico-chemical parameters of the water bodies, such as pH, temperature, total alkalinity, dissolved oxygen, chloride, total hardness and total dissolved solids. Phytoplankton and zooplankton productivity also reduced due to toxic environment. Diversity of plankton drastically decline. In fishes changes occurs in different enzymatic activity, protein synthesis and genetoxicity. Histological alteration markedly variation from the controlled one necrosis occurs in the different organs of fishes such as liver, kidney, gill, muscles and tissue flesh. Pollution not only affects the fishes but also human health too through drinking water and intake of aquatic organisms as food. Over view of this report we can say that if not proper treatment plants set before waste water discharged into the water body in short coming future some native or sensitive aquatic organisms will be extinct from the natural environment.

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LITERATURE CITED

1. Biesinger KE, Christensen GM, Fiandt JT. 1986. Effects of metal salt mixtures on *Daphnia magna* reproduction. *Ecotoxicology and Environmental Safety* 11(1): 9-14.
2. Baudouin MF, Scoppa P. 1974. Acute toxicity of various metals to freshwater zooplankton. *Bulletin of Environmental Contamination and Toxicology* 12(6): 745-751.
3. Spear PA, Pierce RC. 1979. *Copper in the Aquatic Environment: Chemistry, Distribution, and Toxicology* (Vol. 16454). NRCC Associate Committee on Scientific Criteria for Environmental Quality.
4. Vardia HK, Rao PS, Durve VS. 1988. Effect of copper, cadmium and zinc on fish-food organisms, Daphnia lumholtziand Cyprissubglobosa. *Proceedings: Animal Sciences* 97(2): 175-180.
5. Guthrie RK, Cherry DS. 1979. Trophic level accumulation of heavy metals in a coal ash basin drainage system. *JAWRA Journal of the American Water Resources Association* 15(1): 244-248.
6. Mandal A, Sengupta D. 2003. Radioelemental study of Kolaghat, thermal power plant, West Bengal, India: possible environmental hazards. *Environmental Geology* 44(2): 180-186.
7. Golovina VV, Eremina AO, Shchipko ML, Kuznetsov BN, Bakach VG. 2002. The effect of a thermal power station on the concentrations of metals and silicon in the water of a small Siberian river. *Water Resources* 29(4): 404-411.
8. Baba A, Kaya A, Birsoy YK. 2003. The effect of Yatagan thermal power plant (Mugla, Turkey) on the quality of surface and ground waters. *Water, Air and Soil Pollution* 149(1): 93-111.
9. Altındağ A, Yiğit S. 2005. Assessment of heavy metal concentrations in the food web of lake Beyşehir, Turkey. *Chemosphere* 60(4): 552-556.
10. Reash RJ, Lohner TW, Wood KV. 2006. Selenium and other trace metals in fish inhabiting a fly ash stream: implications for regulatory tissue thresholds. *Environmental Pollution* 142(3): 397-408.
11. Ruhl L, Vengosh A, Dwyer GS, Hsu-Kim H, Schwartz G, Romanski A, Smith SD. 2012. The impact of coal combustion residue effluent on water resources: A North Carolina. *Environmental Science and Technology* 46(21): 12226-12233.

12. Sherrard RM, Carriker NE, Greeley MS. 2015. How toxic is coal ash? A laboratory toxicity case study. *Integrated Environmental Assessment and Management* 11(1): 5-9.
13. Verma C, Madan S, Hussain A. 2016. Heavy metal contamination of groundwater due to fly ash disposal of coal-fired thermal power plant, Parichha, Jhansi, India. *Cogent Engineering* 3(1): 1179243.
14. Brieger G, Wells JR, Hunter RD. 1992. Plant and animal species composition and heavy metal content in fly ash ecosystems. *Water, Air and Soil Pollution* 63(1): 87-103.
15. Biesinger KE, Christensen GM. 1972. Effects of various metals on survival, growth, reproduction, and metabolism of Daphnia magna. *Journal of the Fisheries Board of Canada* 29(12): 1691-1700.
16. Cherry DS, Guthrie RK, Davis EM, Harvey RS. 1984. Coal ash basin effects (particulates, metals, acidic pH) upon aquatic biota: an eight-year evaluation. *JAWRA Journal of the American Water Resources Association* 20(4): 535-544.
17. Atici T, Ahiska S, Altindag A, Aydin D. 2008. Ecological effects of some heavy metals (Cd, Pb, Hg, Cr) pollution of phytoplanktonic algae and zooplanktonic organisms in Saryyar Dam Reservoir in Turkey. *African Journal of Biotechnology* 7(12): 1972-1977.
18. Hughey MC, Walke JB, Becker MH, Umile TP, Burzynski EA, Minbiole KP, Iannetta AA, Santiago CN, Hopkins WA, Belden LK. 2016. Short-term exposure to coal combustion waste has little impact on the skin microbiome of adult spring peepers (*Pseudacris crucifer*). *Applied and Environmental Microbiology* 82(12): 3493-3502.
19. Ekpo I. 2013. Effect of physico-chemical parameters on zooplankton species and density of a tropical rainforest river in Niger Delta, Nigeria using Canonical Cluster Analysis. *International Journal of Engineering and Science (IJES)* 2(4): 13-21.
20. Masindi V, Muedi KL. 2018. Environmental contamination by heavy metals, heavy metals, Hosam El-Din M. Saleh and Refaat F. Aglan, Intech Open, DOI: 10.5772/intechopen.76082. Available from: https://www.intechopen.com/chapters/60680
21. Ali M, Parvez S, Pandey S, Atif F, Kaur M, Rehman H, Raisuddin S. 2004. Fly ash leachate induces oxidative stress in freshwater fish Channapunctata (Bloch). *Environment International* 30(7): 933-938.
22. Kuzmick DM, Mitchelmore CL, Hopkins WA, Rowe CL. 2007. Effects of coal combustion residues on survival, antioxidant potential, and genotoxicity resulting from full-lifecycle exposure of grass shrimp (Palaemonetespugio Holthius). *Science of the Total Environment* 373(1): 420-430.
23. Anant D, Suresh Z. 2015. Thermal power station effluent induced biochemical changes in the blood of freshwater fish, Labeorohita. *International Jr. of Life Sciences* 3(4): 341-350.
24. Pracheil BM, Adams SM, Bevelhimer MS, Fortner AM, Greeley MS, Murphy CA, Mathews TJ, Peterson MJ. 2016. Relating fish health and reproductive metrics to contaminant bioaccumulation at the Tennessee Valley Authority Kingston coal ash spill site. *Ecotoxicology* 25(6): 1136-1149.
25. Javed M, Usmani N. 2013. Assessment of heavy metal (Cu, Ni, Fe, Co, Mn, Cr, Zn) pollution in effluent dominated rivulet water and their effect on glycogen metabolism and histology of Mastacembelusarmatus. *Springer Plus* 2(1): 390.
26. Voynar SA. 1960. The biological role of microelements in animal and human bodies. *High School, Moscow*. pp 544.
27. Yang F, Chen L, Hu Q, Pan G. 2003. Effect of the application of selenium on selenium content of soybean and its products. *Biol. Trace Elem. Research* 93(1/3): 249-256.
28. Elghobashy HA, Zaghloul K, Metwally MAA. 2001. Effect of some water pollutants on the Nile tilapia, *Oreochromis niloticus* collected from the River Nile and some Egyptian lakes. *Egyptian Journal of Aquatic Biology and Fisheries* 5: 251-279.