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Article *in* Water Environment Research · October 2018

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Effects of Pollution on Freshwater Organisms

B.S. Choudri[1*], Yassine Charabi[1], Mushtaque Ahmed[2]

ABSTRACT: The scientific literature review in this paper includes research papers published in 2017 on issues related to pollutants from human activity and its effects on organisms of freshwater reported from the different parts of the world. The fist part of the literature review highlights on two broad sections that are focused on research conducted at the field level as well as surveys based on field experiments. A number of sections categorized in order to reflect the different class of pollutants follows the first part of literature review. Sections in this part of review includes non-point source pollution, stormwater, wastewater, nutrients, sediment cap materials and suspended clays, botanical extracts, surfactants, metals, persistent organic pollutants, pharmaceuticals, endocrine disruptors, pesticides, petroleum hydrocarbons and polycyclic aromatic hydrocarbons, nanomaterials and ionic liquids. The final part of the literature review highlights the published research on recent innovations of recent in addressing problem of pollution in the freshwater and its management.

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KEYWORDS: aquatic toxicity, nutrients, freshwater pollution, metals, persistent organic pollutants, pharmaceuticals, wastewater, stormwater, endocrine disruptors, pesticides, petroleum hydrocarbons, nanomaterials.

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Research Reviews

Haynes et al. (2017) provided a summarized review on the latest knowledge available on the effects of photocatalytic involving nanoparticles of TiO_2 on organisms in the aquatic environment and discusses shortcomes of some of those studies in order to provide an outline with relevant environmental factors that could be considered in view of conducting experiments in the future. Further, this review suggests that protocols and approaches for ecotoxicological studies be requirements in addressing predicatable effects of photoactive nanomaterials.

A study reviewed the application of 8 different assays of genotoxicity in which the comet assay was mostly preferred in view of its greater ability to estimate DNA damage at lower levels (Mahaye et al., 2017). The review considered important activities of metal-based ENP induced genotoxicity, role of nanoparticle as well as environmental

factors. These factors would influence the observed genotoxic effects and challenges involved in interpreting reported data. Finally, authors provided recommendations on how these challenges might be addressed.

Duan et al. (2017) provided a review focused on the hazards of ecotoxicology of p-xylene as well as a xylene mixture on organisms present in the aquatic body. The purpose of the review was to pinpoint understanding the diffusion and transfer of toxicity on marine and freshwater organisms of xylene in the aquatic environment.

A review was presented based on data collected and analyzed on the possible incidence and presence of personal care products (PCPs) as pollutants of emergence in different water compartments of effluents and influents of wastewater by Montes-Grajales et al. (2017). The review showed that a number of PCPs recognized as emerging pollutants were found in the effluents of wastewater treatment plants. Analysis indicated that the presence of PCPs in the bodies of water were due to activity of human.

Broad Field Studies and Surveys

De Castro-Catala et al. (2017) conducted an experiment to detect indirect and direct effects of two pollutants with relevant concentrations on the shredder *Gammarus pulex.* The pollutants considered were antidepressant fluoxetine and fungicide prochloraz in the experiment. This study demonstrated that the fungicide and antidepressant might cause sublethal effects at low concentrations

A study synthesized zinc oxide nanoparticles (ZnO-NPs) using the aqueous leaf extracts from Musa *paradisiaca* (Vijayakumar et al., 2017). The authors characterized the extracts physico-chemically with the help of Ultraviolet-Visible spectroscopy, x-ray diffraction, fourier transform infrared, scanning electron microscopy and atomic force microscopy. In general, this study highlights the possible impacts of the biologically synthesized ZnO-NPS in comparison to zinc acetate in the crustacean *C. cornuta* of freshwater.

Investigations were conducted at reference sites contaminated by metals in northwestern Portugal by Pedrosa et al. (2017). The aim was to determine the variation in genetics in populations of the model species having ecotoxicological importance such as c*hironomus riparius* and its cryptic sister species c*hironomus piger*. Results indicated there was an observed presence of flow in genes and dynamic processes of population contributed on pollutant effects. Some of these results suggest pollution by chemicals can lower the levels of genomes in genetic variability among population of species considered in the study.

Wastewater. Plahuta et al. (2017) studied biological in vivo assay with the freshwater isopod *Asellus aquaticus* to define as well as to address the effects of produced wastewater from the treatment plant on local wildlife. This study used untreated, mechanically and biologically treated wastewater samples in the experiment. Results indicated that chronic exposure caused reduced locomotion and body pigmentation of the studied species. Further, the effects noticed were of toxicity and endocrine disruption from the samples of wastewater.

Kalcikova et al. (2017) undertook an experiment to determine the quantity of microbeads that are released through pathways into surface waters. Authors have conducted this study on the Jubljana as a case study in Slovenia. Experiments were considered at the scale of lab considering sequencing batch biological wastewarer treatment plant. Results confirmed that capture of microbeads in sludge were about 52 percent on average. It was also estimated that 112,500,000 particles might be released into waters of rivers every day. Such releases would result in a concentration of microbeads of 21 particles per cubic meter and shows the concern for possible effects in the in aquatic ecosystem.

Aquaculture effluents. Davidson et al. (2017) conducted a study over a period of eight months to compare the effects high and low nitrate-nitrogen on the health of post-smolt Atlantic salmon. Authors considered culture and replicate of freshwater recirculation in aquaculture systems. Results of the study observed no differences in the treatments for gas in the blood, chemistry of plasma as well as histopathology of tissue. These parameters suggested that the health of fish was not affected by the presence of nitrate.

Pulp and paper effluents. For bioremediation of the paper and pulp industry efflents lignin peroxidases, Haq et al. (2017) used producing *Serratia liquefaciens*. The treatment used in the experiment showed the reduction of chemical oxygen demand, colour, lignin and phenolic content by different pecentages (in each case more than 50%). Results of this study suggested that the *S. liquefaciens* culture could be useful for bioremediation of paper and pulp industry efflents. The treatment was effective and helped in lowering the loads of pollutants as well as reduced the effects of cytotoxic and genotoxic effects of effluent.

Fonseca et al. (2017) examined the effects that relate to histopathology in the gills of fish as well as changes in concentrations of metal. Freshwater samples were collected for study to understand the relationships among early indications of fauna populations present in the aquatic environment. Results indicated that the key biomarker was filament epithelium proliferation (FEP), which was the main contributor to the toxicity of sub lethal concentrations of metals and was attributed to FEP as it was correlated with most of the metals analyzed.

Industrial effluents. Seralathan et al. (2017) used textile effluent in the raw form in order to estimate toxicity reduction by employing different treatment protocols in the laboratory such as physical, chemical bacterial, phycoremediation and their combination on the species *Lyisinibacillus sphaericus.* The study results showed that chemical and phycoremediation-combined activity had helped the population of fish survive chronic toxicity in the short term with less damage to the organs and slightly improve the response of their immunology.

Bielen et al. (2017), conducted a study to analyse chemical, ecotoxicological and microbiological parameters on the effluents of two pharmaceutical industries in Croatia over a period of four seasons. Pollutants from pharmaceutical industries are known to have greater impacts in generating aquatic pollution with high concentrations of antibiotics. Based on results obtained, this study showed that using a wide array of analyses on discharges can pose an effect to the ecological and public health and there is a

possibility of toxicity to aquatic organisms with the prevelance of spreading antibiotic resistance.

Municipal wastewater effluents. Gillis et al. (2017) analysed the effect of effluents produced from wastewater treatment plants (WWTP) on invertebrates of freshwater mussels in the River of Grand, Ontario. The studied populations were related to wastewater treatment plant outfall. Analysis was considered to determine the richness and presence of species of freshwater mussels.

An evaluation of four aerated submerged and attached growth bioreactors was undertaken in order to estimate the removal of three micro pollutants having pharmaceutical origin in the municipal wastewater by Flores Velázquez and Mijaylova Nacheva (2017). Results showed that low organic loading, high solid retention times as well as the implementation of effluent recirculation improved the removal in the compounds of pharmaceutical origin. Further, reactors having cubes of polyurethane indicated improved rates in the removal in comparison with the ones packed with polyethylene tapes.

Hospital Wastewaters. Babic et al. (2017) conducted tests on toxic effects of a wastewater treatment plant located in Virovitica of Croatia by collecting downstream samples. The zebrafish *danio rerio* was used for testing with a set of biomarkers that enabled an insight in the wastewaters toxic potential on embryos. Results showed that embyos exposure to the wastewater increased the rates of mortality and abnormality. Further, effects on the rates of heartbeat, spontaneous movements and formation of pigmentation were observed.

Zhang, Dhi et al. (2017), studied the risks of pharmaceuticals and personal care products as well as endocrine disrupting chemicals in aquatic organisms in the Bohai coastal region of China. The study results showed that the highest risk from the pharmaceuticals was from antibiotics.

Stormwater and Non-Point Source Pollution.

Oliveira et al. (2017) conducted a study to determine the toxicity of biocides considering tralopyril, triphenylborane pyridine and capsaicin as antifouling representatives in the environment. These contaminants were used as non-target organisms in freshwater systems considering three trophic levels of algae namely crustacean d*aphnia magna*, c*hlamydomonas reinhardtii* and fish species d*anio rerio*. Analysis found that capsaicin was the compound most environment friendly but other elements such as tralopyril, triphenylborane pyridine have shown to have a greater effecs on ecosystems of freshwater.

A study compared concentrations of methylmercury and mercury in the inorganic form by Strickman and Mitchell (2017). The concentrations also included the percenatage of total as well as potential mercury methylation rate constants in the sediments of terrestrial aquatic transects that were having stormwater and wetlands habitat. Analysis showed that the association of aquatic vegetation to the accumulation of methylmercury was uncertain and very weak. This factor suggested that plants are weak drivers of carrying methylmercury biogeochemistry.

Dawoud et al. (2017) conducted a study to investigate possible effects of two pesticides on two groups of organisms. The focus of the study was on the functioning of a model stream detrital food web consisting of a detritivore and microbes consuming leaf litter. The study results indicated possible association of stress such as trophic and multiple, which can interact at the level of moderate ecosystem and are effected by the chemicals studied. This phenomenon highlights predicting and evaluating challenges on understanding the effects of multiple chemical stressors in the web chain of foods.

A study was conducted in Germany that used modelling of six macroinvertebrates based on metrics towards understanding the ecological quality of streams with the help of principal component analysis in the catchment land use and wastewater exposure indices by Berger et al. (2017). Results of this study showed wastewater impacts on the quality of ecology that was evident through caffeine. The study results suggested improvement of treatment plants towards controlling the release of poorly treated wastewater would help communities maintain freshwater.

Nutrients. Saad et al. (2017) studied sulfide effects on the activity of polyphosphate accumulating organisms (PAO). This study examined the anaerobic stage of the process used for enhanced biological phosphorus removal. Data obtained from the study showed that sulfide was most commonly found in a variety of wastewaters. It was found that sulfide affects the anaerobic metabolism of PAOs as well as it could be considered valuable in the improvement of treatment processes by which high concentrations of sulfide can be removed.

Yang et al. (2017) studied three ponds having intensive shrimp farming with zero water exchange rates to determine the cycling of nutrient in different stages of growth of shrimp. The aim was to determine concentations of inorganic nutrients dissolved in the water, sediment porewater and fluxes across the interface between the water and sediments. Results showed that the effluents of aquaculture ponds play one the main contributors to the pollution of water in the area of the coastal region in China and suggested treatment of these wastewater effluents.

Schaller and Planer-Friedrich (2017) studied the effect of filter feeders such as zebra mussels represented by d*reissena polymorpha*. This species is one of the important invasive organism in the ecosystems of freshwater in parts of Europe and North America. Experiments were conducted exposing *D. polymorpha* to organic sediment sites that were polluted by heavy metals namely arsenic, copper, lead, and uranium. Results showed that accumulation and the uptake of arsenic, copper, iron and particularly uranium into the soft body tissues as well as the seashells was predominent. These results were in agreement with biomonitoring studies undertaken in the past on accumulation of metals.

Sediment Cap. Zimmer-Faust et al. (2017) evaluated the capacities of culturable FIB and DNA for genetic markers in *Enterococcus* sp considering the ageing parameter. The study took into account the bacteroides of general interest and bacteroides (HF183) associated with human activity in the sediments collected from the freshwater. Models used in the study showed that low concentrations in the ambient enterococci of sediment of the up stream (90 MPN per gram) compared to the lower

watershed (530 MPN per gram) and low ambient levels of the HF183 marker were lowest in sediments of lower and upper watersheds.

Tuttle-Raycraft et al. (2017) studied the effect of total suspended solids pressence on the rates of newly transformed juvenile and adult l*ampsilis fasciola*, *L. siliquoidea*, *ligumia nasuta* and *villosa iris*. It was found that an increase in levels of total suspended solids could interfere with the processes of feeding. The results of the experiment showed total suspeneded solids presence reduces rates of feeding in suspension unionids of freshwater. Given this fact, authors suggest that total suspended solids are controlled in order to incrase survival rates.

A study compared the total uptake in embryos of zebrafish namely *Danio rerio* to about 17 hydrophobic pollutants occurring in the environment and its presence and absence of the model chemosensitiser verapamil (Kurth et al. 2017). Results showed that none of the pollutants from the group selected showed a capacity to increase in reproductivity on bioaccumulation with the application of chemosensitisation in verapamil. Further, observed data indicated there was a minimal effect of verapamil uptake of hydrophobic chemicals in embryos of fish.

Metals

Bioaccumulation of metals in mixture. Pressence of heavy metals in muscles, gills and liver tissue of croaker fish collected from rivers polluted by oil spills was studied by Abarshi et al. (2017) in the Delta of Niger. Data generated from this study showed that patterns in heavy metal concentrations as well as distribution varied greatly in parts of fish tissue and sites of samples collected. In addition, a sample of fish caught from the Finna creek had greater concentrations of copper and iron in the tissue of liver compared with liver of a fish that was caught from the river Bonny.

Liu et al. (2017) determined the pattern of distribution, bioaccumulation and occurrence of six endocrine disrupting compounds in various parts of a water body. Samples were mainly from water, sediment and biota of freshwater lakes in China. The assessment of ecological risk showed greater potential for NPs in surface water that can be dangerous to the aquatic life. Further, the concentration of estrogen equivalent was more in male as compared with female species. The observed concentration was in the order of city > rural-urban > countryside.

Behavioural as well as chemical responses of *Gammarus fossarum* to copper, cadmium, nickel, lead and and zinc were tested individually and in mixture at concentrations twice the levels of the European Water Framework Directive's water quality standards (Lebrun et al. 2017). This study concluded that effects at sub-lethal mixtures identified by the multi-biomarker approach could lead to disturbances in the dynamics of the population of gammarids.

Guo et al. (2017) exposed species of *scallop chlamys farreri* to concentrations of benzo, pyrene and chrysene for about 15 days to investigate the detoxification responses, damage effects as well as biotransformation. Results of this experiment showed that pyren and chrysene had similar effects. In addition, most of the biomarkers studied indicated more toxic effects for the mixture of

pyrence and chrysene. These results provide a highlight basis for the study of detoxification mechanism of poly aromatic hydrocarbons (PAHs) in bivalves and add value in monitoring the effects of pollution.

Arsenic. Usese et al. (2017) studied concentrations of arsenic from Lagos Lagoon in Nigeria in water samples. The study also examined arsenic concentations in muscle tissue of four fish species namely c*hrysichthys nigrodigitatus, mugil cephalus, liza falcipinnis and bathygobious soporator* along with tissues of *periwinkle*. Analysis of this study found higher values of target hazard quotient that were shown in t*ympanotonus fuscatus.* Observations suggested that arsenic concentations could have deadly effects for the non-carcinogenic outcome of health in adults if such species were consumed over a long period.

Cells of Nostoc sp. PCC 7120 were incubated with arsenite As (III) for two weeks and extracted by Xue et al. (2017). In this study, authors used dichloromethane and the methanol method for extaction and the extract was partitioned between water and dichloromethane. Results showed that total arsenic of methylated arsenic, arsenosugars and arsenosugar phospholipids in nostoc cells with increasing As (III) as per the level of exposure. Observed trends indicated that transformation to organo arsenic in nostoc did not show any association on the concentration of arsenite.

Mardirosian et al. (2017) studied the toxicodynamics of chemical arsemoc. The experiment was conducted in developing toad embryos of *rhinella arenarum* and larvae exposed from fertilization. Results showed active accumulation of arsemoc in toad embryos and larvae. The accummulations were reached in tissues with concentrations more than one-thousand times higher than control levels after exposure of twenty-three days, which was about 10 mg of arsemoc per liter. In addition, bioconcentration factors also increased up to 50 times more in toad and larvae considering the levels of media.

Cadmium. A study examined the hormonal systems of freshwater snail *physa acuta* to identify several genes, the response of stress and system of detoxification in order to evaluate cadmium effects (Martínez-Paz et al., 2017). This study results showed that there were effects of Cd noticed on the endocrine system of g*astropoda* similar to the size of molecular. These results provide new putative biomarker genes that could be useful in studying ecotoxicology, bioremediation and assessment of risk.

Huo, Dong et al. (2017) investigated the histopathology and ultrastructure lesions of liver in the freshwater turtle *Chinemys reevesii*. In the experiment, the turle was exposed to various concentrations of cadmium. Results indicated that tissues of liver from Cd treatment showed a range of histopathological lesions. Further, cells of liver were swollen and degeneration and necrosis were mostly dependent on the dose. The study concluded that Cd has toxic effects on the tissue of liver in the freshwater turtle.

Chandurvelan et al. (2017) studied the freshwater shrimp *paratya curvirostris* living near lowlands of coastal streams effected by cadmium to understand sensitivity to this metal. Data obtained were described by an increased dependence on the availability of carbohydrates. In addition, the lipid presence was available as a metabolic substrate,

which was supported by increased metabolic costs of exposure to toxicity. Results suggest cadmium cannot be a significant environmental stressor to frehwarer shrimp unless highly contaminated.

Chromium. With the help of a radioactive tracer, ^{51}Cr, the accumulation of two-chromium forms in green unicellular alga c*hlamydomonas reinhardii* was studied by Aharchaou et al. (2017). After exposure for about seventy-two hours, there was involvement of another biomolecule of lower molecular weight noticed in the binding of chromium. It was observed that there was a presence of higher intensities of signals in Cr (VI) than Cr (III). This study showed that Cr (III) and Cr (VI) had same fate within the cells of algae and faroured the principle of unique redox in the cells.

Copper. Lambert et al., (2017) conducted a study to understand the causal relationship between chronic copper exposure and measured tolerance levels of copper with the help of varied conditions of temperature during the phases of pollution induced in the tolerance of community. Results of this study showed the influence of temperature on the basal capacity of phototrophic periphyton, which can tolerate subsequent exposure to copper. Authors concluded that temperature must be considered when using phases of the pollution induced community tolerance in order to establish links between exposure of chronic copper as well as its effects on phototrophic periphyton.

Angel et al. (2017) studied two freshwater green alage species to determine effects of dissolved concentation of copper pulse and the level of toxicity during exposure. For the effects of single copper pulses, 1 to 48 hour and continuous exposures of 72 hours were considered on growth rate inhibition of *pseudokirchneriella subcapitata and chlorella sp*. Results of the experiment showed that water quality guideline values for copper may be relaxed in exposures of pulse by a factor less than the average concentration and time to achieve the protection for the studied species of algae.

Fitzgerald et al. (2017) investigated the widespread effects of presence of toxic metals in the aquatic environment with the focus on copper and hypoxia. This study used three species of spined stickleback namely *gasterosteus aculeatus* as one of most important species. This species has environmental relevance and flexibility in assessing studies of environmental toxicology. Results showed that interaction between multiple stressors was important in order to support the correct prediction on possible effects of exposure to multiple stressors with changing conditions of the environment.

Lead. Fan et al. (2017) investigated effects of titanium oxide nanoparticles on lead accumulation with the help of *corbicula fluminea* in sediments. The study also explored concentrations of lead on extracellular and intracellular soft tissues of the bivalve. Results of the study indicated that concentration of titanium oxide nanoparticles in *C. fluminea* tissues significantly increased with a rise in the concentrations of titanium oxide nanoparticles present in the sediments. The accumulation was in the order of gill > mantle > foot > visceral mass. This order of accummuation was completely different from the results that were found in the aqueous phase.

A study was done to investigate the effect of lead bioturbation on oligochaete worm namely *lumbriculus variegatus* using microcosms of freshwater (Blankson et al., 2017). The experiment used lead concentrations of 0, 140, 700 and 3500 microgram per gram in samples of sediment. In addition, two different populations of *L. variegatus* at the laboratory level were also studied. Results indicated that high concentrations of lead could affect the function of ecosystem activity by decreasing the level of bioturbation in benthic organisms considered in the study.

Li et al. (2017) investigated the effects of lead on calcium homeostasis and the calcium channel in the sperm of freshwater crab s*inopotamon henanense*, which were exposed to lead at different concentratin levels. The concentration of calmodulin was measured by enzyme-linked immunosorbent assay method. Lead enters the sperm of the crab *S.henanense* through the channels of calcium.

Nickel. To evaluate the interactive exposure effects of waterborne chronic copper and nickel on tissue specific metal accumulation as well as the capacity of reproduction in fathead minnows, p*imephales promelas* was studied by Driessnack et al. (2017). Experimental results of this study indicated that the waterborne exposure of chronic copper and the nickel in a binary mixture could possibly damage the capacity of fish reproduction. This could form as a part of histopathological damage in ovarian tissue, which would disrupt the energy of homeostasis in fish.

Topal et al. (2017) investigated exposure effects of nickel chloride in nuclear factor kappa B activity, antioxidant responses as well as histopathological effects on rainbow trout. The exposure was specifically focused on trouts liver and tissue. Results showed that effects of nickel toxicity may disturb the functions through biochemical and physiology in the health of the fish. Thereby, such activity would cause some changes in kappa B as well as oxidative damage in the rainbow trout tissues. It was concluded that results of this study could help in understanig toxicity of nickel in species.

Damasceno et al. (2017) individually as well as in combination under salinities of 10, 17 and 35 psu concentation studied zinc and nickel exposures acute toxicity in *artemia sp*. The conentrations of mixtures were considered based on the individual toxic units in order to follow a fixed ratio design in the experiment. Results showed that the concentation of zinc had a higher rate of toxicity as compared to the nickel. At individual toxicity levels, both metals were higher at low salinity concentations. The observed changes in the toxicity can be attributed to the biotic ligand model in comparison to the speciation of metals.

Mercury. Zhang, Yu et al. (2017) investigated the rate of survival, oxygen consumption, ammonia excretion and accumulation of metal in *E. carinicauda* juveniles. In order to address the acute toxic effects, species were exposed to zinc and mercury. Results of this study indicated accumulation was dependent on heavy metals concentration. It was observed that gills, hepatopancreas and muscles of the species used in the experiment had higher accumulation with 16.3 times for zinc and 72.8 times for mercury than in the gills of juveniles after exposure of about 24 hours.

Abu Bakar et al. (2017) studied effects of mercury chloride on zebra fish. In the experiment, embryonic

exposure of fish was studied to determine motor function and the behavior of anxiety. The embryo of fish were exposed to six different concentrations of mercury chloride at five HPF until hatching in a condtion of semi-static. It was observed that the mortality rate increased depending upon the dose, but chronic exposure of embryo to 100 nM showed the number of tail coiling and decrease in activities of heartbeat as well as swimming. It was concluded that effects of mercury chloride on locomotor and biochemical defects affects efficiency in the motor performance and responses associated with anxiety.

The western grebes, namely *aechmophorus occidentalis* and Clark's grebes namely *A. occidentalis* from various lakes and reservoirs of California was studied by Hartman et al. (2017). The study was focused on understading the seasonal and physiological influences of mercury on these species. Results of this study found that concentrations of seasonal trends in grebe for mercury were not consistent as per samples of lakes. Futher, this factor indicated variation in mercury concentrations that could be attributed to the dynamics of lakes for seasonal decline in grebe blood.

Selenium. Zheng et al. (2017) investigated the effects of selenium in unicellular green alga *Haematococcus pluvialis*. These species can accumulate as well as uptake selenium that can be sometimes essential and toxic depending upon the dosage on the growth of the algal species. Resutls of the study showed the EC_{50} for the algal growth rate was 24 mg per liter and the selenite low dosage indicated no effects on the growth of cell in *H. pluvialis*. It was found that concentration levels of selbut selenite of more than 13 mg per liter could affect the growth of cell.

Kumar et al. (2017) studied biologically synthesised selenium nanoparticles from the wastes samples of fisheries that were collected in the form of fish gills. These wastes were used to evaluate the efficiency tolerance in *pangasius hypophthalmus*, which was fed under concentrations of lead at higher temperatures for about 72 days. The results of the experiment showed that mixing of selenium nanoparticles in l mg per kg in diet could affect its protection against the stress of thermal coniditions as well as lead concentrations in *P. hypophthalmus.*

Lanctot et al. (2017) examined the influence of different feeding mechanisms as well complexity involved with exposure on kinetics of bioaccumulation and body distribution. For the assessment, the study considered common metal (loid) pollutants on specie *limnodynastes peronii* during early development post-embryonic activity. Results showed that exposure conditions can influence the bioaccumulation of metaloids and experimental factors can play important roles for toxicity experiments in the controlled system as well as for understanding the risks of exposure in amphibian populations.

Schiavon et al. (2017) provided an overview on the recent developments related to the current understanding of selenium uptake and its accumulation as well as the process of metabolism in species of algae. The review also discusses possible implications of ecotoxicology and various issues associated with nutrient cycling in algae. Finally, the review concludes by highlighting those algae of macro as well as micro species and how they play a valuable role in

selenium transfer in the food chain. In addition, it was concluded that toxicological and nutritional aspects derived from selenium can bioaccumulate and transform into organic forms.

Uranium. Annamalai and Arunachalam (2017) investigated the early biomarkers for the hematological, serological and histological alterations due to the effect of ^{238}U in different organs in the freshwater fish *Pangasius sutchi*. This study observed extensive histological lesions in tissues, which were affected by the oxidative stress due to the toxicity accumulation of ^{238}U. Toxicity was in the order of gills < liver < brain < muscle. These results could be used as indicators towards assessing the toxicity of ^{238}U with regard to health of fish as well as for biomonitoring of uranium.

The embryo of fish was used in order to address the potential of genotoxic and teratogenic acute toxixity associated with uranium effluents and sludge of a neutralized mine waste (Lourenço et al., 2017). This study showed that the acute toxicity test on the fish embryo was useful in determing both affects associated with eflluents and sludge. It was concluded that care should be given while using benchmark values calculated for specific stressors due to the chemical chemical complexities associated with uranium.

Zinc. Six species of the *glochidia* larvae from Australia belonging to freshwater mussels were studied for sensitivity to heavy metals such as cadmium, cobalt, copper, lead (Markich, 2017). Both nickel and zinc were studied to understand key metal cotaminants affecting urbanized coastal rivers. Results of this study showed there was no chronic effect by the concentrations of copper, zinc and nickel and concentrations of these elements were below the values of National Freshwater Standards. This factor indicated that mussels in freshwater may not required to be protected for studied metals in urbanized coastal rivers of southeastern part of Australia.

Falfushynska et al. (2017) studied the effects of pharmaceutical and personal care products and especially focused on nano zinc oxide and a Ca-channel blocker nifedipine (Nfd). These two pollutants are considered very common and have effects of endocrine and cellular stress markers. Experimental tests were conducted on using a sample of the marsh frog. The study found that nano zinc oxide exposures in the absence of Nfd had less impact related to trails of cellular stress in the species of frog. This factor indicated that low concentration levels of these elements in pharmaceuticals mainly Nfd and freely available metals associations can be highly effective towards the health of the frogs.

Sub-lethal effects in dietary exposure to zinc oxide nanoparticles on serum proteome profile of juvenile common carp *cyprinus carpio* was evaluated with the application of proteomics by Chupani et al. (2017). Results showed there was no observed significant difference for the accumulation of zinc in exposed fish in comparison with control experiments. It was concluded that in the absence of accumulation, exposure of common crab to zinc oxide nanoparticles might disturb homeostasis in fish by affecting its proteins in immune and haematological systems.

Persistent Organic Pollutants

Polychlorinated biphenyls (PCBs). From dated sediment core samples, Huo et al. (2017), measured concentrations of polychlorinated biphenyls (PCBs). Samples were collected from Chaohu freshwater lake in China. Authors particulary investigated temporal trends, accumulation as well as environmental fate of PCBs. Compositional and principal component analysis showed that PCBs originated from sources other than comercial activities located the vicinity of the lake. Further, the concentration of PCB209 indicated the source of origin from the city located upstream.

Champoux et al. (2017) conducted a study to monitor contaminants in eggs of Northern gannet *Morus bassanus* collected from the Bonaventure Island of Quebec. Authors measured polychlorinated dibenzo-p-dioxins, dibenzofurans and non-ortho polychlorinated biphenyls concentations from the years 2004 to 2009. Results showed that over different time intervals, the concentrations of studied contaminants reflected a decreased trend in levels of contamination.

Pharmaceuticals. From Taihu Lake in China, samples of water from the surface, sediments and aquatic species of fourteen varieties were colleted to investigate the bioaccumulation as well as to understand trophic transfer of twenty-three pharmaceuticals by Xie et al. (2017). Aquatic species included were plankton, invertebrates and fish along with water and sediment. The study observed higher pharmaceutical presence in zoobenthos in comparison to the levels of concentations in plankton, shrimp and fish muscle. In addition, concentations of pharmaceuticals in fish liver and brain tissues were higher than in the observed parts of muscles and gills.

Miller et al. (2017) investigated asseessment on the uptake and elimination techniques in *Gammarus pulex* for various concentrations of pharmaceuticals. Authors considered investigation for nine pharmceuticls such as sulfamethazine, carbamazepine, diazepam, temazepam, trimethoprim, warfarin, metoprolol, nifedipine and propranolol with the help of mass spectroscopy to determine factors of bioconcentration. Results showed that accumulation of pharmaceuticals was low in amphipods, which explains the rapid biotransformation and excretion.

Nieto et al. (2017) evaluated effects of two pharmaceuticals commonly occurring on the exposure of *Chironomus riparius* in sediments through spiked experiments. The pharmaceuticals used in this study were drugs of the non-steroidal anti-inflammatory, diclofenac and the anti depressant carbamazepine. Results of the study showed there are possible effects on aquatic invertebrates and these species can be considered for risk assessment of pharmaceuticals absorbed in sediments.

Endocrine Disruptors. Combined effects of temperature, synthetic progestin and levonorgestrel on the fitness as well as reproductive related endpoints of zebrafish *Danio rerio* was evaluated by Cardoso et al. (2017). This study data suggested that considering the scenarios of climate change of global warming, the exposure of synthetic hormones and the reproduction in zebrafish could be endangered. Further, such changes can consequently affect the functioning capacity and structure associated with aquatic ecosystems.

Cocci et al. (2017) presented a study on the use of primary cells cultures of erythrocyte in vitro models for evaluating the effects of different endocrine disrupting chemicals on the expression of estrogen receptors. In addition, this study also evaluated toxicity levels of erythrocyte caused by endocrine disrupting chemicals using Alamar Blue assay and the expression of heat shock proteins. Results indicated that loggerhead erythrocytes constitutively express estrogen receptor as well as heat shock proteins at the transcript level and respond to endocrine disrupting chemicals by their expression in known concentrations.

Correa de Andrade et al. (2017) conducted acute and chronic toxicity tests neonates on adults of *Pomacea lineata* to determine the effects of bisphenol A. In the experiment, adults and neonates were divided into groups and exposed to bisphenol A with concentrations ranging from 1 to 20 mg per liter along with control tests. Results showed that bisphenol A is toxic to species of *Pomacea lineata* based on biological parameters. Authors concluded that results of this experiment would contribute in understanding toxic effects of bisphenol A in aquatic invertebrates.

The terrestrial snail *Cantareus asperses* was exposed to an herbicide during embryogenesis to study its growth and reproduction phases Druart et al. (2017). In order to assess effects, authors used a glyphosate-based herbicide on endpoints having different ranges with parameters. Results of this study indicated that herbicides helped to enhance the growth but it reduced the capacity of reproduction. Both chemical mixtures acted on the fertility through a delay in the process of laying eggs by 20 days and reduced number of clutches.

Pesticide Regulation, Risk Assessment and Modeling Studies. Panizzi et al. (2017) provided a review on current methods as well as limitations associated with and assessment of mixtures of pesticides. The assessment reviewed through the data available related to analysis and the approaches adopted in order to investigate possible risks linked to different non-target organisms. This review provides some important considerations on the future possibilities to improve the procedures of risk assessment related to pollution effects on freshwater organisms. Such information has been identified in depth towards considerations of harmful effects with mixture of pesticides on non-target organisms.

Besseling et al. (2017) presented scenario based study examples with respect to the fate as well as movement of spherical particles of nano materials. These particles were like microbeads that were used in a state of the art hydrological model. The model used factors such as advective transport, combination of homo and hetero, resuspension of sedimentation, degradation of polymer and the presence of biofilm. Results indicated that hydrodynamics of rivers affects the distribution of size of microplastic, which has implications for emissions to aquatic systems.

In order to investigate the presence and occurrance of antibiotics, surface water samples were collected from Poyang Lake in different seasons spread over a period from 2014 and 2015. Ding et al. (2017) used a mass spectroscopy method for the investigation of antibiotics in the water

samples. The assessement of risk for main contaminants of antibiotic in the study showed that most of the quotient risk of the target antibiotics were low in concentration. Therefore, it was concluded that the risk by these antibiotics was minimal to organisms given three different trophic levels.

Cifoni et al. (2017) described procedures for testing sub chronic effects of chemicals measurement on the freshwater species *cyclopoid eucyclops serrulatus.* This study tested the possible effects of four type of diets considering temperatures of two different ranges as well as two rearing volumes. These conditions were applied on the survival, reproduction, population growth rates and development of *cyclopoid Eucyclops serrulatus.* Authors concluded that complete life cycle tests can be used in a glass of 2 ml vials that consists of a mixute of diet cells of c*hlorella sorokiniana* and *scenedesmus quadricauda* at various temperatures.

To assess the acute toxicity in sepcies of glochidia of wavy rayed lampmussels *Lampsilis fasciola* and newly released juvenile fatmucket mussels *Lampsilis siliquoidea* were collected from winter road runoff by Prosser et al. (2017). The effects were examined under different water hardness concentrations. The results of risk assessement indicated chronic exposure to higher concentations of chloride in mussels of freshewater. Authors suggested conducting futher studies to make sure to protect sensitive organisms.

Biomarkers of Pesticide Effects. Somparn et al. (2017) investigated the effects on the tropical chironomid namely *Chironomus javanus* which is a kiffer of sediment contaminated with an insecticide chlorpyrifos with the help of biomarker assessment. Results of this study found *C. javanus* was sensitive to chlorpyrifos and indicated that it can be a potential biomarker for pesticide assessement at low contamination levels. It was concluded that this method could be useful for ecological risk assessment on addressing the sensitivity of tropical biota to contaminants.

In *Daphnia magna* species, the level of toxicity by three diamides namely chlorantraniliprole, cyantraniliprole and flubendiamide was evaluated by Cui, Chai et al. (2017). Results of acute toxicity testing showed that chlorantraniliprole, cyantraniliprole and flubendiamide were at different levels. In addition, measurements on biochemical activity tended to increase oxygen in species *D. magna* after acute exposure to the three diamides. It ws concluded that even lower levels of diamides can pose ecological risks for aquatic ecosystems.

Altun et al. (2017) evaluated changes in histopathology of the fish brain, gills, liver, kidney, testis, and ovaries after exposing for about 21 days in the concentration to chlorpyrifos pesticide. With the help of an immunofluorescence assay, activation of 8-OHdG cleaved caspase-3 and iNOS were assesed in chlorpyrifos exposed brain and liver tissue. This study detected strong and diffuse signs of immunofluorescence reaction for various concentrations of 8-OHdG, iNOS and cleaved caspase-3 in tissues of liver and brain.

Yamamoto et al. (2017) evaluated five cascading reservoirs from the Iguaçu River to understand the impact of endocrine disrupting chemicals. This study focused on reproductive endpoints in three native fish species namely

Astyanax bifasciatus, Chrenicicla iguassuensis and *Geophagus brasiliensis*. Results of this study showed that reproductive responses were associated with the bioavailability of endocrine disrupting chemicals in the rivery system. Further, it was concluded that such impacts are evident in chemicals released by the anthropogenic activites as reported by previous studies.

Petroleum Hydrocarbons and Polycyclic Aromatic Hydrocarbons (PAHs).

Medeiros et al. (2017) assessed assays of genotoxicity and analysis of histopathology of fish gills under experiments having two different procedures. This experiment considered the *Juvenile Centropomus parallelus* for the first assessment, which was exposed to various concentrations of water-soluble fractions of petroleum (WFSP). The second fish group was exposed to 50 percent WFSP. Results of this study showed that short-term exposure to WSFP compounds caused alterations in cells of *C. parallelus,* however, the total recovery did not occur within the time considered under the experiment.

Gu et al. (2017) investigated PAHs in surface sediments from Fuxian Lake, the largest deep plateau lake in China. Results of correlation analysis showed that total organic carbon was positively correlated with total PAHs, while percentages of grain size fraction were poorly correlated with total PAHs. Authors concluded that surface sediments of Fuxian Lake had a 9% incidence of adverse biological effects based on the mean effects rangemedian quotient.

Mixed effects of temperature and PAHs namely fluorene, phenanthrene and pyrene were evaluated by Mansour et al. (2017). This study used two concentrations to assess the immune responses of the European clam *ruditapes decussatus* that were exposed for 24 hours in vitro. Results of the experiments indicated strong effects of PAHs and high temperature on immune functions and haemocyte viability on the species including activities of antibacterial and phosphatase alkaline.

Concentations in sediment core samples were measured and evaluated chronically for PAHs and organochlorine pesticides (OCP) that was collected from a deep lake (Yuan et al., 2017). Results in the sediment core showed gradual increases in the concentrations of PAH and OCP starting from the year 1950s to the 1990s and subsequently decreased in recent years. It was concluded by the authors that sudden decreases from the year 1980 onwards might be attriburted to the fact of banning of DDTs in China.

Zhao et al. (2017) investigated sediments collected from Lake Basin and body of Taihu Lake in China. In the sediments, residues of PAHs and OCPs were analysed. Results showed higher concentrations of both PAHs and OCPs in the lake basin and the lake body. In addition, spatial distribution of PAHs and OCPs indicated a higher pressece associated with the land use of Taihu lake basin, which is surrounded by human activity. These results showed that there was a transport of studied pollutants entering into the basin and the water body based on the flow direction of the water.

Mining Effluents. A study considered a mecosom approach to test the effects on algal and aquatic invertebrate communities at different concentrations on salt effluent coming from a potash mine (Canedo-Argüelles et al., 2017). Results of the treatment approach showed that effects were dependent on time, which was clearly demonstrated at the end of the study. In addition, the generated data also suggested that mining of potash effluent has the potential to to alter biological communities in streams and rivers. Therefore, authors concluded that specific biotic indices in order to assess level of salt pollution be developed.

Blanco et al. (2017) presented an advanced framework for assessing services of ecosystems in life cycle assessment that considers model integration from adjacent fields as well as partitions that are required in the modeling steps into the different phases of life cycle assessment. The study demonstrated that the framework focused on one case study in Chile on water extraction by the mining industry. The services of the ecosystem were compared on losses that result from the transformation of coastal ecosystems and wetland.

Effects of acid mine drainage from the coal mine on fish, namely *channa punctate*, was studied by Talukdar et al. (2017). This study examined the occurrence of haematological, morphological, histological changes and deoxyribonucleic acid fragmentation in tissues of *C. punctata* in laboratory conditions. Results showed high frequency in alterations of morphology and histology in the species. There was a clear evidence on haematological changes in association with deoxyribonucleic acid breakage in *C. punctate*. Such evidence is an indication of the potential for cytotoxic and genotoxic effects of acid mine drainage in view of coal mining.

Ionic Liquids. A study on the effects of hypoxia on the osmorespiratory functions of the posterior gills of the crab *Carcinus maenas*sed in seawater was conducted by Lucu and Ziegler (2017). Results of this study showed variations in the concentration level of oxygen as well as exposure time to hypoxia. These variations lead to an increase in the surface of mitochondria per epithelium area and that might have compensated for the decrease in the availability of oxygen under hypoxic conditions.

For exraction of metals from sediments, a new extraction method was developed and studied by Alvarez et al. (2017). In the experiment, the chelating agent ethylenediaminetetraacetic acid was mixed with a minimal amount of the ionic liquid 1-butyl-3-methylimidazolium tetrafluoroborate which was assisted with the help of ultrasound energy. Results of the experiment were in agreement with similar results obtained by the conventional method that used the student-paired t-test.

Nanomaterials. Cui, Chae et al. (2017) examined aquatic species, *daphnia magna* and *daphnia galeata*, as model species in order to assess and compare the effects of toxicity by silver ions and multi dimensional silver nanomaterials. Particulary, silver ions considered were silver nanoparticles, silver nanowires and silver nanoplates. Results of this study indicated more toxicity with the presence of silver in comparison with silver nano particles having different sizes and dimensions. However, particles of silver nanoplates indicated to be most toxic of the silver

nanoparticles. Authors suggested conducting more studies in order to explain the actual risk associated on the ecosystem with the presence of multi dimensional nanomaterials.

In vitro system fish cell lines were evaluated on the usefulness for ranking a set of engineered nanomaterials to study their cytotoxicity (Bermejo-Nogales et al., 2017). Authors used the topminnow namely *poeciliopsis lucida* liver cell line and the *oncorhynchus mykiss* of rainbow trout, which was a fibroblast-like gonadal cell line. Findings of this study showed that fish cell lines are suitable for establishment of hazard rankings of engineered nanomaterials in the framework of integrated approaches for possible testing as well as assessment.

Chatel and Mouneyrac (2017) provided an overview on the signaling molecules, which have an important role in addressing metal-based nanomaterials mediated cytotoxicity in freshwater and marine organisms. The review highlights studies that have shown a specific effect of nano materials. Authors found three mechanisms such as detoxification, immunomodulation and genotoxicity based on the available literature. These studies were selected to represent the mechanisms of cell defense and are the most studied in the assessment of engineered nano materials exposure.

Jahan et al. (2017) presented a summary of the review on pathways and factors that control the transport and toxicity of engineered nanomaterials in five extensively used elements. This review discusses potentially utilized five engineered nanomaterials and their risk of toxicology factors in aquatic plants, vertebrates models and microbes. The review found that the effect of engineered nanomaterials on surface transformations have greater reaction with objects having importance in the environment. In addition, dissolved natural organic matter issues and the effect of engineered nanomaterials used in surface coating was also discussed.

New Techniques in Freshwater PollutionResearch

New Toxicological Methods. Two analytical approaches such as screening of cynotoxins and target analysis in freshwater organisms was studied by Bogialli et al. (2017), which was based on a liquid chromatograph system. In this study, authors considered a database of 369 compounds contributing to the cyanobacterial metabolites. In addition, a retrospective analysis data has been used that was based on high-resolution mass spectrometry. This study highlighted that methods developed can be used by agencies concerned about environment and health towards improving the monitoring of cyanotoxins occurring in water systems.

In surface and drinking waters, a selective multi-residue method for analysis of twelve alternatives of microcystin was optimized and validated by Di Gregorio et al. (2017). This method was used considering the implementation of the European Union Directive on Drinking Water in Italy. The improved protocols of analytical procedures were applied for the analysis of water samples collected from the Occhito Lake since this lake water is one of the important source of drinking water that reported an unexpected boom in the population of of *Planktothrix rubescens*.

New Models for Estimating Toxic Effects. One study assessed the effects of toxicity originating from triclosan and triclocarban in *C. elegans* with the help of

endpoints from organismal to molecular levels by Lenz et al. (2017). This study found oxidative stress induced by both compounds in the worm. This factor indicated relocalization of green fluorescent protein from cytoplasm to the nucleus based on exposure. Further, there was also indicaton of germline toxicity of the two compounds in the transgenic strain. These results suggested systemic toxic effects in *C. elegans* by both compounds.

Sierra et al. (2017) conducted a study to forecast the bioavailability of the potentially toxic elements such as cadmium, lead, mercury, nickel, copper, zinc, arsenic, chromium and selenium in six locations along the river basin of Ebro. The possible bioavailable fractions of each potential toxic elements was determined with the help of modelling tools for their chemical speciation by three programs namely WHAM 7.0, Visual MINTEQ 3.1 and Bio-met. These progrms are proposed in the regulations of the European Union. Results showed potential toxic elements, and the bioavailability estimated by deploying DGTs in river waters was slightly lower than the data estimated by the models of speciation.

New Cellular and Molecular Methods. A full-length cDNA encoding a novel alpha-2 macroglobulin gene in giant freshwater prawn was cloned and sequenced (Likittrakulwong et al., 2017). This study showed that immune response analysis in prawns stimulated with *Aeromonas hydrophila* clearly indicated that Mr-2α2M was quickly converted to high levels in hemocytes and hepatopancreas. The authors concluded that the use of the novel α2M gene technique might play an important role in giant freshwater prawn immune systems.

In zebra mussels, a study compared Gadolinium ($GdCl_3$) and a gadolinium based magnetic resonance imaging contrast agent effects after 28 days exposure through the approach of multibiomarkers (Hanna et al., 2017). Data analysis of this study showed that exposure to $GdCl_3$, the mRNA level of metallothionein was modulated and there was an increase in observed cytochrome c oxidase and superoxide dismutase. In addition, there was downregulation in the gene expressions of catalase and Glutathione-S-transferase.

Future of the Topic

Ecosystems of freshwater play a valuable part and are important for human kind existence, which provide great supply of water for most of the population living on this earth. Other than their valuable role and being important to human kind, over the recent years, around the world large number of rivers, lakes and ecosystems of wetlands have been affected to a great extent by human induced activities including number of inhabited species present in the bodies of freshwater. Given such importance, ecosystems of freshwater are under continuous threat and declining in quality at faster rate than expected. Therefore, in view of such effects, changes occur and the system largely affected. The review work in the future should involve addressing the effects of various human induced pollutants on these bodies. Many topics topics could be considered towards addressing the issues related to wastewater management entering in to freshwater systesm. Many other issues such as management of stormwater and non-point source pollution, nutrients, sediment cap materials, suspended clays, botanical extracts,

surfactants, metals should also be considered. In addition, the research should also focus on persistent organic pollutants, pharmaceuticals, endocrine disruptors, pesticides, petroleum hydrocarbons, polycyclic aromatic hydrocarbons, ionic liquids as well as nanomaterials.

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