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# Animal and Plant Responses to Water Pollution: An Overview

**Bhattacharyya Phalguni[1*], Acharya Ritwik[2], Kar Sayanti[3], Ghosh Indrajit[3] and Ghosh Amitava[4]**

[1]Department of Botany, Shibpur Dinabundhoo Institution (College), West Bengal, India
[2]Department of Botany, Hiralal Mazumdar Memorial College for Women, Dakhineswar, West Bengal, India
[3]Department of Environmental Science, Asutosh College, West Bengal, India
[4]Department of Botany, Asutosh College, West Bengal, India

**Corresponding Author*

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**Abstract:** Fresh water is available only 0.5% on this planet for mankind. The ground water (percolated and closed in aquifers), river water, lake, pond and well are the main sources for water. Population density, heavy metals, toxic waste disposal, pesticides, herbicides, fertilizer, eutrophication, house hold chemicals, dish washing, laundry waste etc. increases the amount of water pollutants at the outfall of the main rivers which shows proportionate rise in content on a seasonal basis. These pollutants primarily disturb the metabolic systems of economically important plants and then the dependant animals and human beings. Different physical factors responsible to sustain the aquatic life are temperature, BOD, COD, pH and turbidity. The ecological sustenance of plant species is very much dependable on the quality of water. The poor quality of water causes health hazard and death of human being, aquatic life and also disturbs the production of different crops. Heavy metals from the water directly percolate into food crops with stress indicator, the antioxidants or free radical scavenging enzymes. Waste water induced synthesis of low molecular weight peptides in certain irrigated crop plants are extremely inhibitory in nature for biological systems.

**Keywords:** Water, Pollutant, Metals, Aquatic life, Peptides, Antioxidant

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## Introduction

Water, the wonder indispensable molecular form is the most important pillar for the survival and sustenance of life on this planet. The quality of water suffers mostly due to human advancing towards so called civilization. Indiscriminate but destined industrialization and urbanization is the fate of capitalist society. Around 2030 the scarcity of fresh drinking water will appear as a disastrous problem. Natural vegetation depends on the clean water for their normal healthy growth and development and natural genetic inheritance. The percentage of available fresh water on earth is very little; no addition to that amount but careless degree of increase of the human population and

their unending demand with sense of imperialism destroys the plant kingdom. Eighty per cent of the fresh water is polluted which have devastating effects on plant metabolic system limiting their existence with speciation. Accumulation of such pollutants in plants and herbivores, which then become prey to higher predator in the food chain results in the accumulation of the pollutants in the tissues of those predators. This review discusses the types of water pollution and pollutants, their impact on the animal and plant morphology, physiology, molecular biology and reproductive system; ultimately to genetic configuration which also leads to serious impact on the trophic level.

*Water Pollution: Definition, Types and Extent of the Problem*:

The chemical formula of water is $H_2O$. Water is an inorganic chemical substance which is transparent in appearance, and also without any taste and odour. One oxygen and two hydrogen atoms are connected by covalent bonds forming the most important fluid for cells of the living organisms. It is the main component of the hydrosphere of Earth, and as a universal solvent it is the main driving force for the existence of life on this planet. The different natural states of water like precipitation, fog, clouds, snow and water vapour maintain the water cycle through evaporation, transpiration, condensation, precipitation and runoff. Maximum percentage of water forms seas and oceans whereas freshwater is very small in availability. On this planet water is the natural source of dissolved oxygen. It may be SOD (Sediment oxygen demand) which is the decomposed form of organic material and sediment at the bottom; BOD (Biological oxygen demand); microbial cellular respiration by oxygen and COD (Chemical oxygen demand).

The quality of water is vital for the sustenance of human health as well as for the protection of environment surrounding us. For its universal solubility the water is the source of 80% of the human diseases and most alarmingly many countries do not provide safe drinking water to their citizen causing around 3.1% mortality (WHO). Around the year 2030, arid areas will increase on this planet which may affect 3.9 billion people approximately. Increasing urbanization due to overgrowth of the population will use maximum land mass which means simultaneous decrease in the source of the fresh water. Marine pollution and nutrient pollution are the two types of surface water pollution. Former involves the introduction of toxic substances (such as toxic metals, pharmaceuticals, pesticides, dyes, and surfactants) whereas the later refers to contamination by excessive inputs of nutrients, which is primarily responsible for eutrophication of the surface water. While discussing about Indian perspective the condition is more serious. According to an estimation 40 million litres of waste water, not treated, daily contaminate rivers and other water bodies. Estimation from another study reveals that in India downstream of polluted stretches is associated with a 9% reduction in agricultural revenues and a 16% drop in downstream agricultural yields. The effect of severe water pollution is also noticed multiple times which have caused the death of fish and also other animals which have consumed that polluted water. During the second wave of corona pandemic floating dead bodies were found on the rivers which may have also caused severe water contamination. Antibiotics and different disposed drugs along with medical wastes are a real threat to the water ecosystem as these substances have detrimental effect on soil microorganisms. These soil microbes help plants in their growth and development. Tetracyclines have been found effective in increasing radish yields, but simultaneously found to affect negatively into bean yields (Batchelder, 1982). A significant increase in the activities of the plant stress proteins glutathione S-transferases and peroxidases was observed in maize plants when grown in chlortetracycline-treated soil. Emerging contaminants (ECs) with a list of variety of chemicals related to human pharmaceuticals, veterinary medicines, nanomaterials, personal care products, paints and coatings etc. are recent area of concern for water pollution. A plethora of

product types are there causing ECs rise and thus cover a wide range of chemical classes. In case of agricultural productivity, there are a number of EC types of concern such as-- Fungi, bacteria and plant produced natural toxins, Bio-terrorism/sabotage agents, Human personal care products such as essential oils, herbal medicines, anti-bacterial products and fragrances, Organic pollutants which are gradually emerging and also persistent such as flame retardants and dioxin-like compounds, antibiotics and anti-parasitic agents used as veterinary medicines, hormones like estrogens and androgens which can be natural or synthetic, nanomaterials, medicines and Metabolites and transformation products of man-made chemicals that are produced from biological, chemical and physical breakdown reactions.

These chemicals have potential hazardous effects on plant system; though areas of research of the effect of these chemicals on plant system are not so wide and elaborately informative. The examples of this sort of artificial pollution is getting worsen day by day. Pollution of water is the results of various causes (Fig. 1). There are three major sources of pollutants of water- Home, Agriculture and Industry. They do manifest these reasons-- high population density, pollution of ground water through drilling activities, industrial waste dumped into water (industrial waste is extremely harmful to both people and environment), sewage leakage, flooding during rainy season which carries waste deposits into water (it happen mainly river Ganges in India), heavy metals, toxic waste disposal, Soil digging inside river area, eroded sediments, deforestation, littering, pesticides, herbicides and fertilizer, using HYV seed and eutrophication (eutrophication is an increased level of nutrients in water bodies). This results in bloom of algae in water. It also depletes the oxygen in water, which negatively affects fish and other aquatic animal population, failing septic system, household chemicals (dishwashing waste, laundry waste), animal waste, heat (industrial areas hot water mixed into cold water and polluted: Farakka thermal power project area: hot water mixed with Feeder canal water).

Proper waste disposal system and timely treatment of waste before entering into river is highly recommended. Organization of educational awareness programs should be done to control the pollution. Human settlements, industries and agriculture are the major sources of water pollution. Around 80 per cent of municipal wastewater throughout the world is discharged into water bodies untreated, and industry is responsible for dumping millions of tonnes of solvents, heavy metals, toxic sludge and other wastes into water bodies each year (WWAP, 2017). Agriculture plays a major role in water pollution, by accounting about 70 per cent of water abstractions worldwide (Fig. 2). Farm discharges a huge quantity of agrochemicals, organic matter, drug residues, sediments and saline drainage into water bodies. The resultant water pollution poses risks to aquatic ecosystems, human health and productive activities (UNEP, 2016).

The water pollution problem is spreading worldwide. The Nation with lesser population and high economic growth has the potentiality to overcome the hazards of water pollution. The Government of these countries with high education rate and positive concern for environmental sustainability by their citizens reduces the risk of water pollution and simultaneous effect of different pollutants on living systems. We can present a map of the countries (Fig. 3) with degree of water pollution compared with education rate and disciplined society with greater information for water pollution effect on plant and animal system.

*Plant and Water Pollution*:

Plants suffer from the different contaminants of water, especially the water source used for irrigation. The main rivers flowing down the main cities are pollutant contaminated. The industrial pollutants, dyes, inorganic wastes, domestic effluents and heavy metals cause heavy damage to the plant morphology as well as metabolic system. Mahmoud and Ghoneim (2016) showed different grades of heavy metal pollution like, Cd, Zn, Pb,

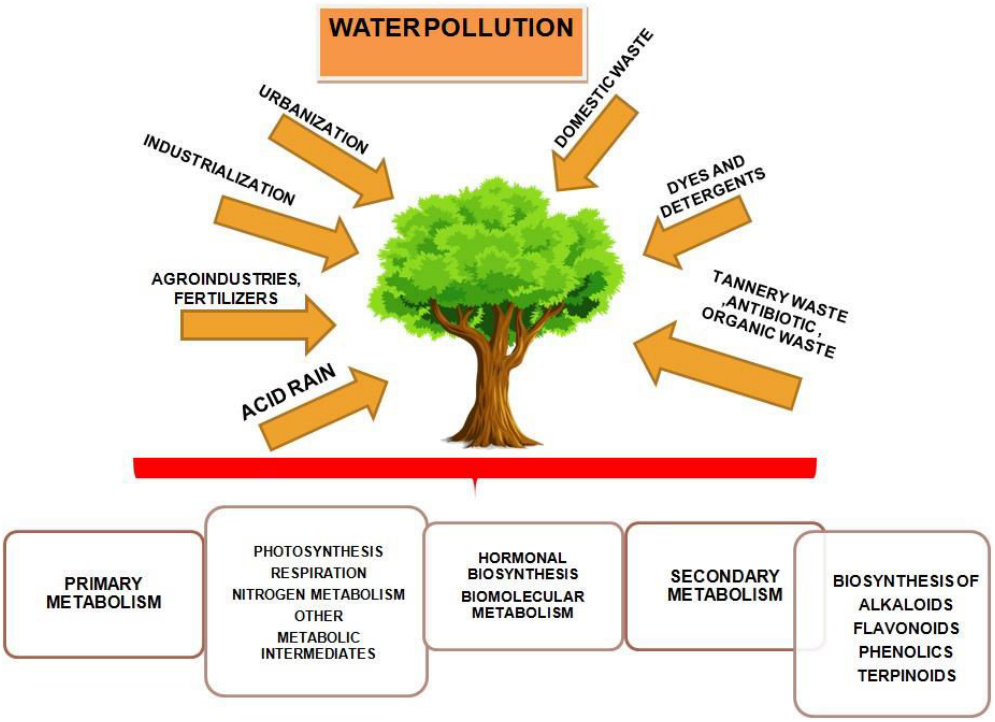


Fig. 1: Water Pollution, its type and impact.

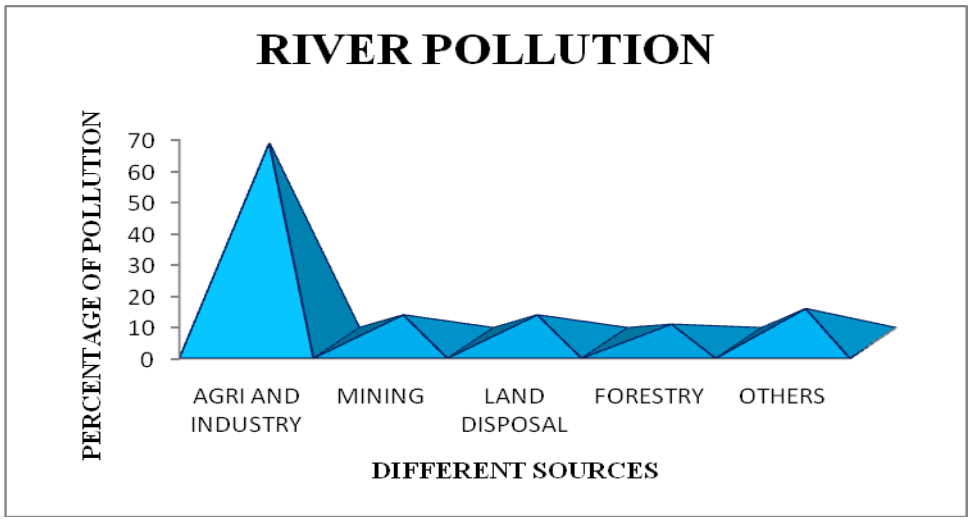


Fig. 2: Extent of different sources of pollution in river water-- the main source of fresh water.

Ni and Cr on carrots and other economically important plants. Bhattacharyya *et al.* (2012) and Kar *et al.* (2018) worked on vegetables and economically important plants where they showed the presence of high concentrations of pollutants. Bonanno (2013) showed that *Phragmites australis* and *Typha domingensis* species may be used as biomonitors of trace element contamination in sediment. Singh and Gupta (2016) have listed a number of causes of water pollution and their effect on different sections of the plant kingdom. These are acid deposition, nutrient deficiency, organic matter deposition, detergent deposition, agricultural chemicals, industrial wastes, silt deposition, oil spillage, thermal pollution, nutrient enrichment, phytotoxicity etc. which ultimately disrupts the plant system. Macrophytes, algae and submerged aquatic plants suffer most due to the

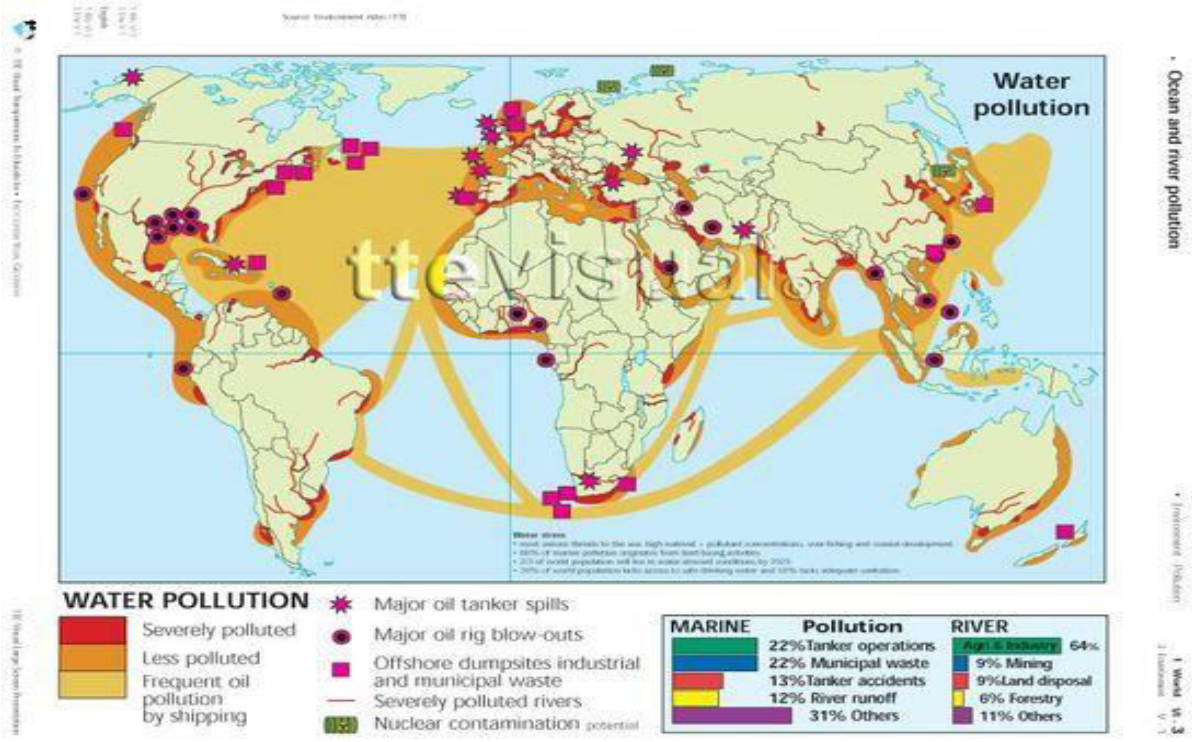


Fig. 3: From the map it is clear that the delta region of the river or thickly polluted adjoining cities is the main root of water pollution taking concern of the tidal movement of water. The scope of agriculture, horticulture and silviculture are very much in need to meet up the increasing food and economic demand per capita (Kar *et al.*, 2018).

water pollution. Antibiotic contaminants from waste expired drugs in water are a recent problem to the irrigated food plants. Zang *et al*. (2017) have observed serious damage to the plant system by antibiotic, especially the known antibiotics like tetracycline, cephalexin, and sulfamethoxazole at 50 per cent lethal dose. The *Brassica chinensis* L., Water spinach, *Ipomoea, Azolla, Salvinia, Hydrilla, Tradescantia,* and different other water plants along with algal species like *Oedogonium*, *Cladophora*, *Chara, Nitella* are some of the common victims of the water pollution (Table 1).

The effect of different types of water pollutants on plant morphology is mostly concentration dependent. The leaf size and shape, phyllotaxy, stem diameter, node and internodal length, root length, inflorescence appearance or flower bud appearance time, pollen tube extension, choice on stigmatic surface, fruiting delay, abscission zone development and stomatal closure are some of the parameters which indicate the direct effect of water pollution on plants (Fig. 4). The biochemical aspects or metabolic events like photosynthesis, respiration, nitrogen metabolism, transpiration, water conductance those are related to plant productivity, growth and development have suffered most due to water pollution (Osakabe *et al*., 2014; Al-Zurfi *et al*., 2018). Freshwater pollution including wastewater, metals and metalloids, industrial effluents, sediments, nutrients, pharmaceuticals, polycyclic aromatic hydrocarbons, flame retardants, persistent organic pollutants, pharmaceuticals and illicit drugs, emerging contaminants, pesticides, herbicides, and endocrine disruptors are important stress initiators in plant. Griboff *et al*. (2018) also showed significant effect of water pollution with heavy metals in plants. Due to water pollution conductivity in leaves, free proline content in leaves, Chlorophyll a/b ratio in leaves are also affected (Feng *et al*., 2019). In most of the cases

Table 1: Name of some plants which suffer and show tolerance against water pollution

| BOTANICAL NAME/ ( FAMILY ) | LOCAL NAME | HABIT |
|---|---|---|
| *Oxalis corniculata* (Oxalidaceae) | Amrul, Tinpatta | Marginal |
| *Oldenlandia corymbosa* (Rubiaceae) | Khetpapra | Marginal |
| *Hygrophila auriculata* (Acanthaceae) | Kullikhara | Marginal |
| *Alternanthera sessilis* (Amaranthaceae) | Gurundi | Marginal |
| *Ranunculus scleratus* (Ranunculaceae) | Jaldhania | Marginal |
| *Ammannia baccifera* (Lythraceae) | Dadmari | Marginal |
| *Spillanthes acmella* ( Asteraceae ) | Akarkara | Marginal |
| *Eclipta prostrate* ( Asteraceae) | Bhingraj | Marginal |
| *Rumex dentatus* ( polygonaceae) | Jangli palak | Marginal |
| *Ipomea aquatica* (Convolvulaceae) | Kalmisag | Immersed |
| *Nymphoides indicum* (Menyanthaceae) | Kumudni | Immersed |
| *Centella asiatica* ( Apiaceae) | Thankuni Gotakola | Immersed |
| *Ludwigia adscendens* (Onagraceae) | Labangi | Immersed |
| *Utricularia aurea* ( Lentibulariaceae) | Jhangi | Submerged |
| *Eichhornia crassipes* (Pontederiaceae) | Jalkumbhi | Floating |
| *Marselia quadrifolia* (Marseliaceae) | Susni saag | Marginal |

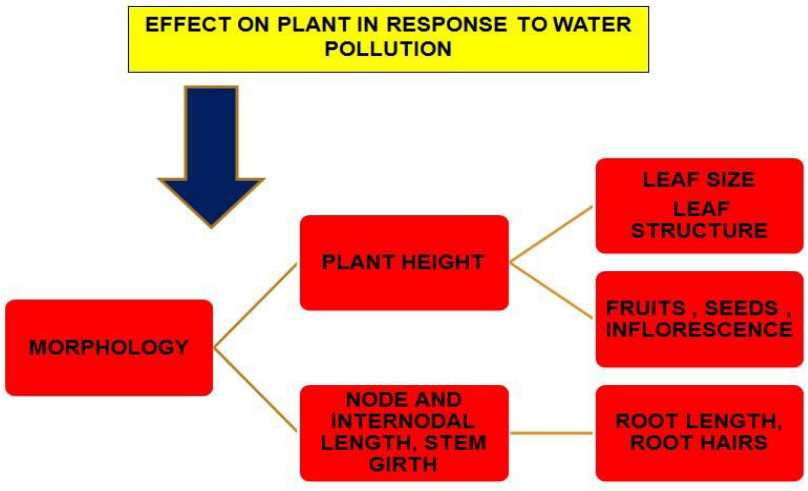


Fig. 4: Effects of the water pollution on plants.

water contamination mainly caused due to agricultural fertilizers, industrial and household waste waters, heavy metals (HMs), acid rains, pesticides, oil and many other organic and inorganic chemical compounds (Verla *et al*., 2018 ). Heavy metals like cadmium (Cd), lead (Pb), chromium (Cr), copper (Cu), zinc (Zn), nickel (Ni), vanadium (V) and selenium (Se) contaminate water for human use which can be controlled with distinct awareness (Eid *et al*., 2020). These heavy metals by synthesizing ROS disturb metabolic processes like photosynthesis and respiration thus initiating premature death of the plant (Zhang *et al*., 2017). Many plants can tolerate heavy metal stress by anthocyanin, thiol and antioxidants (Leão *et al*., 2014). Organic pollutants are also reported to create hazards on plant system (Liu and Wu, 2018). Zhou *et al*. (2018) have recognized approximately 400 metal hyper-accumulating plant species. In this context, various species of aquatic plants such as *Lemna, Wolfia, Azolla, Spirodela, Wolfialla, Hydrilla, Eichhornia, Typha, Pistia, Crinum, Alternanthera, Phragmites and Crysopogon* have been tested to phytoremediate and hyper-accumulate metals, metalloids and other contaminants (Upadhyay and Tripathi, 2007). The water gets polluted by acid rain where normally dissolved $CO_2$ make it acidic. But atmospheric pollutants like sulphur dioxide ($SO_2$) and Nitrous oxides ( $NO_X$) formed due to the result of burning fossil fuel create acid rain. The acid rain caused extensive damage to aquatic life with plants, forest trees, vegetation of forest beds, and soil (Brezonik, 1994).

In response to different grades of water pollution plants exhibit antioxidant defence mechanism. They may be enzymatic and non-enzymatic processes. To protect from oxidative damage plants possess antioxidant enzymes such as superoxide dismutase (SOD, EC 1.15.1.9), catalase (CAT, EC 1.11.1.6), ascorbate peroxidase (APX, EC 1.11.1.11), and guaiacol peroxidase (GPX, EC 1.11.1.9). During $O_2$ radical generation (Gill and Tuteja, 2010), the SOD enzyme is the first line of defence as it converts and eliminate radical $O_2$ to $H_2O_2$ (Muradoglu *et al*., 2015). However, $H_2O_2$ is also toxic to cells, so it is necessary to remove it from cells. The enzymes involved in this process (CAT, APX and GPX) convert $H_2O_2$ into water and oxygen. The balance is required between the antioxidant systems and ROS content. This will help cellular metabolic process to remain in steady state (Halliwell, 2006). In arsenic contaminated water the role of *Azolla* plant and the antioxidant metabolism process is a very interesting chapter. It was observed that antioxidant enzymes Superoxide dismutase, peroxidases, catalases and glutathione reductase activities are correlated with As concentrations, the inactivity persist at higher concentrations of heavy metals. So, water contaminants directly affect the tolerance of plants by altering antioxidant mechanism. On the other hand metabolic pathways are also subjective to stress concentrations of the pollutants.

The response to different pollutants initiates systemic signalling pathways, such as the ROS in biologic system (Mittler *et al*., 2011) along with calcium waves (Toyota *et al*., 2018), electric signals (Nguyen *et al*. 2018), or hydraulic waves (Christmann *et al*., 2013).

ABA and ROS wave co-regulate the rapid response process. Stomatal movement is another assay to get early response of the metabolic disorder initiated by pollutants (Kangasjarvi *et al*., 2009) Abiotic stress induced early rise in $Ca^{2+}$ wave via the Glutamate Receptor-Like (GLR) proteins (Toyota *et al*., 2018; Nguyen *et al*., 2018). The metal pollution induces micro-RNAs and gene expression for membrane transporter, such as members of ZIPs, HMAs, MATE, YSL, and MTPs families (Memon, 2016). Accumulation of metals also increases shoot biomass, at least in Indian mustard, *Brassica juncea* L. (Dalyan *et al*., 2017; Cevher-Keskin *et al*., 2019). Till date, 155 proteins have been identified in plants, and they fulfil many important functions ranging from metal absorption, transport, sequestration, and storage in specific organelles. They also play an important role in metal homeostasis in plant cell (Memon, 2016). Metal transporters are classified into six main groups, which include natural resistant-

associated macrophage protein (NRAMP), ZRT/ RT-like protein (ZIP), cation diffusion facilitator (CDF) transporters, yellow stripe-like (YSL) proteins, and P1B-type heavy metal ATPases (HMAs) (Memon, 2016; Bestow *et al*., 2018). Genome of *Brassica napus* having 22 NRAMP transporter genes, and based on sequence identity. These transporters can be classified into six subfamilies. RNA-sequencing analysis has revealed 19 NRAMP transporters, and 10 NRAMP genes were differentially expressed under Cd exposure (Meng *et al*., 2017). Most of the ABC genes were validated by RNA sequencing. Among 132 genes which were differentially expressed, 84 genes were significantly expressed by Cd stress (Gong *et al*., 2017). Excess nitrate as fertilizer cannot be taken by the plant and poor growth will result. Natural water with a minute concentration elevation of phosphate increases the algal density and also boost the growth of different aquatic plant. This event causes eutrophication of the aquatic ecosystem. On the other hand common occurrence of chloride, bromide and fluoride in water results salinity which limits the uptake of water by the plant. In maize the height of the seedling, the size of the leaf, root/shoot height, chlorophyll synthesis and photosynthetic rate are 5decreased by their presence which is indicated by the increased concentration of peroxidise, super oxide dismutase and catalase. Organic pollutants like oxygen demanding and synthetic salts in domestic outlets, municipal sewage, canning industries, food processing units, butcheries, paper and pulp industries, tanneries, breweries, distilleries, synthetic pesticides, food additives, synthetic detergents, pharmaceuticals, insecticides, fibres, plastics, synthetic solvents, paints and volatile organic compounds (VOCs) dyes, cosmetics, petroleum organic pollutants. Persistent organic pollutants (POPs) containing polychlorinated biphenyls (PCBs), polychlorinated dibenzo-pdioxins, organochlorine pesticides (OCPs), perfluorooctanoate (PFOA), polybrominateddiphenyl ethers (PBDEs) and perfluorooctanesulfonate (PFOS) or Dichlorodiphenyltrichloroethanes (DDTs) and hexachlorocyclohexanes (HCHs) lindane, dicofol, and DDT-containing anti-fouling paints industry are water soluble toxic chemicals which inhibit the quality of the agricultural product like fruit, grains, vegetables and primary metabolic process of aquatic plants. Coloured papers and towels used in body wiping have found to damage the domestic garden plants (Madhav *et al*., 2020). Prosposito *et al.* (2020) invented a nano-particle based chemosensor for colorimetric estimation of water pollutants specially Hg(II), Ni(II), Cu(II), Fe(III), Mn(II), Cr(III/V) Co(II) Cd(II), Pb(II) and other trace elements. Heavy metal contamination incites the synthesis of secondary metabolites, and detoxification pathways (Lajayer *et al*., 2017).

In response to waste water, both domestic and industrial low molecular weight peptide(s) ( 0.5 – 3.0 kDa) are synthesized in plant. These plant peptides are characterized through MASS spectrometry and HPLC. Those peptides are expressed within the range of 1000 to 3000 Da and bear secondary structure, so is bioactive (Bhattacharya *et al*., 2014; Kar *et al*., 2017).

*Effect water pollution on animals*:

The water pollution affects multiply as they move up the food chain (Winemiller and Jepsen, 1998). As, we are at the top of the food chain, this gives us no choice but to be concerned about them. Water pollution effect is severe on aquatic fauna, because their existence is dependable on water and if there is any sort of disturbance in their ecosystem, the impacts are maximum on them (Agrawal *et al*., 2010). Inside the polluted water, due to excessive growth of algae, the oxygen content becomes lesser, causing the death of fishes and other organisms. It is observed that during the last twenty years, there is a decrease of about 40 per cent in aquatic life. Further it can also affect those 70 per cent terrestrial animal which are dependent upon water (Mateo *et al*., 2017).

Algae are the responsible organism for imparting taste and odour to many of the water supplies and can also cause gastrointestinal

disorders. This algal growth gets further growth support in polluted water body. Algal toxins usually affect the central nervous system and skin and are reported as a causal agent of fatal cirrhosis of the liver (Palmer, 1959). Plenty of cases are on record regarding the destruction of marine life by polluted water. Massive killing of fish was among the earliest and most common result of indiscriminate pollution of water. Pollution from municipal sewage is another type of fish killer. Along with that industrial, thermal, radioactive pollution etc. are also severe threats to marine life (Agrawal *et al*., 2010).

Over 70 per cent of terrestrial animal species are dependent upon water, at some point in their life cycle (Schoeninger, 1984). Despite of the warnings, water pollution continues. Coastal environments continue to be affected by oil spills, killing wildlife and causing millions of dollars in property damage. One of the most noticeable results of the water pollution is massive death of ducks (Shumway *et al*., 2003). For example, 1,40,000 ducks died due to botulism in California in the year 1970 (Friend, 2002). Frequent deaths of animals have also been reported by drinking of polluted water (Pandey and Madhuri, 2014).

## Conclusion

It is a very concerning area of knowledge about water pollution and its effect on plants and animals. Water contaminants with natural inorganic and organic pollutants enhance metabolic disorder with simultaneous changes in morphology and anatomy of the plants. The impact of waste water and its bringing on changes on secondary metabolites are very interesting. Different aquatic plants are sensitive to water pollutants either as accumulator or subjective to extinction. But tolerance to water pollutants initiates the synthesis of several transporter molecules and genes are expressed. Low molecular weight peptides (0.5-3.0 kDa) are expressed in response to waste water which inhibit seed germination. Even, we can easily see that most animals get hit harder when water is contaminated in terms of their sustainability. Although huge steps need to be taken on national and industrial levels to arrest this situation before it goes totally out of our control, we, humans can play our small part by refraining from littering beaches and lakes with paper, plastic and other garbage, for the sake of the healthy life of ours and our next generation.

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