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Review Article

IMPACT OF POLLUTION ON AQUATIC FAUNA OF RIVER ECOSYSTEM: A REVIEW

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A B S T R A C T

Fresh water is a natural element which is limited in quantity and it is being polluted at a very fast pace. Whole world is facing the water scarcity problems and along with humans, each and every living being needs water to survive.The influence of the pollutants are complex in mechanism and diverse in its direction and degree. It consists of hydro-chemical, hydro-biological, bio-chemical processes, and different ecological zones.The river biocoenosisis an open system with high intensity of the substantive and energy interaction between land and water, with heterotrophic type of metabolism. Polluting organic substances, heavy metals and other inorganic substances, changing the pH of the environment, have acute or chronic toxic influence on the different components of the water biocoenosis. The influence of the pollutant is a change of effects in different trophic levels of the bio-accumulation of the pollutant, which are part of the fundamental ecological processes.The anthropogenic activities are influencing through hydro-technical constructions, irrigation, and through dumping of polluting substances in aquatic system. The hydro-ecological state of rivers are changing under anthropogenic activities, due to changes in abiotic and biotic conditions. The abiotic factors - temperature, light, river flow, velocity, depth and configuration of the riverbed - change significantly after hydro-technical implements. The biotic conditions - food substances, substances cycle, bioaccumulation etc also change significantly under anthropogenic influence.

INTRODUCTION

Our World is made up of five basic elements i.e. air, water, soil, space and fire. With the continuous process of evolution, living being started to exploit these basic natural resources. With ever growing process of human being, they discovered many things and also from inventing the wheel to farming revolution, the human civilization explored industrial revolution. With industrial revolution the process of consumption of the natural resources accelerated. This also resulted into increase in pollution especially of aquatic resources which needs utmost attention in order to make avail these resources to the future generation (1,12). Pollution can be categorized mainly into air pollution, water pollution and land pollution. Recently noise pollution, thermal pollution and light pollution has attracted the attention of researchers across the world. The prime focus has remained around water pollution. Fresh water is a natural element which is limited in quantity and it is being polluted at a very fast pace. Whole world is facing the water scarcity problems and along with humans, each and every living being needs water to survive(14). The sources of water pollution can be depicted in figure-1

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Anthropogenic Impacts on River Bionetworks

The hydro-ecological state of rivers is changing under anthropogenic activities, due to changes in abiotic and biotic conditions. The anthropogenic activities are influencing through hydro-technical constructions and irrigation, and through dumping of polluting substances in water streams. The first group includes water reservoirs, water supply and irrigation supply systems, transferring of water from one watershed to another (2). This type of anthropogenic load changes the alluvial conditions and the flow regime, the morphometric (brightness and deepness of the river bed etc) and hydrodynamics (flow velocity) characteristics. All these activities directly influence the abiotic conditions namely the hydro-physical, hydro-chemical, hydro-biological processes. The second group includes waste disposal, disposal of organic and inorganic substances of diverse concentration. These activities directly influence the aquatic biocenosis namely the hydro-biological state(11,14,15).

Anthropogenic Effects on Abiotic Factors

The abiotic factors - temperature, light, river flow, velocity, depth and configuration of the riverbed - change significantly after hydro-technical implements. The velocity changes influence the stability of the river bottom mainly the benthos.

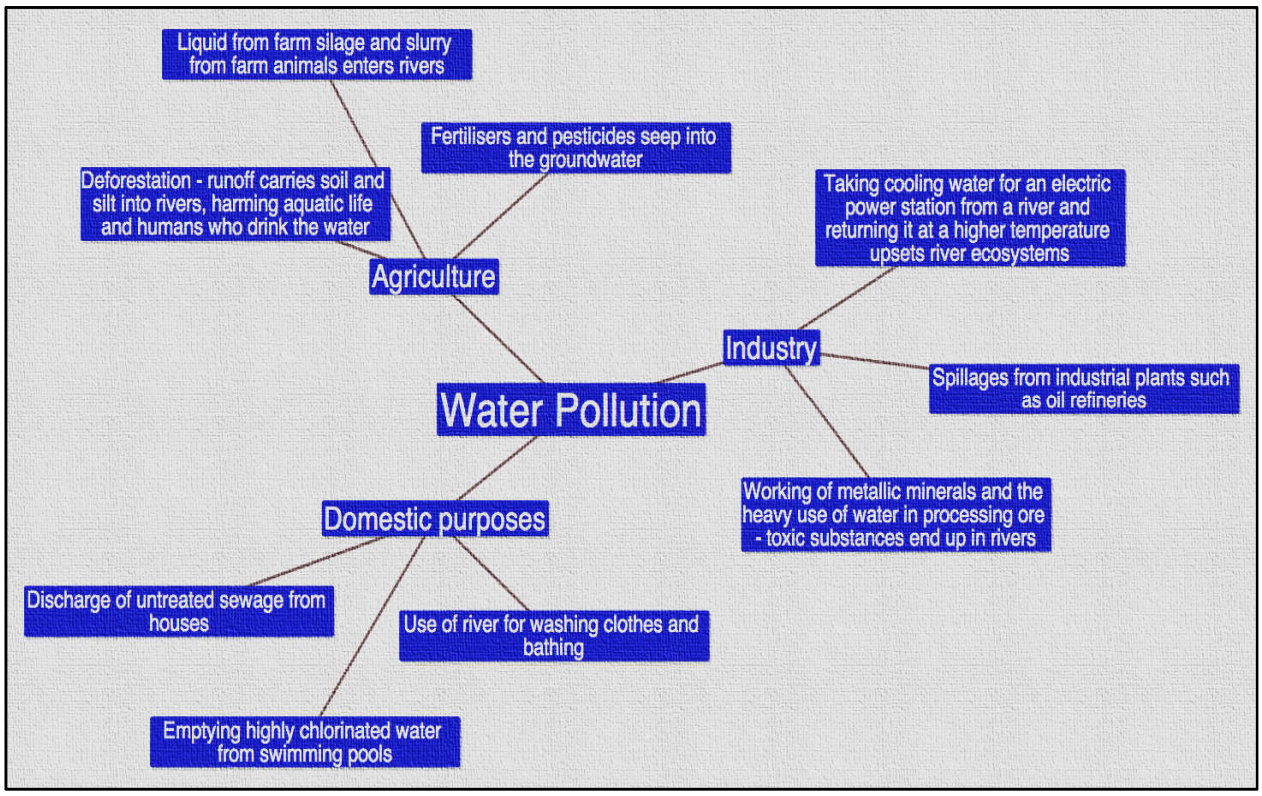

Figure 1 Sources of water pollution (3)

The increase of the river flow velocity determines the slow-down of the velocity of food substances absorption by organisms. When increasing the flow velocity only some algae create biomass; e.g. over 2000 cm/s is dangerous for the algae (9).

Hydro-technical constructions influence the diluting and assimilation ability of the water flows, the sedimentation of the insoluble organic and inorganic substances, the reaeration processes, which influence the dissolved oxygen. The hydro-ecological conditions change when waters from reservoirs

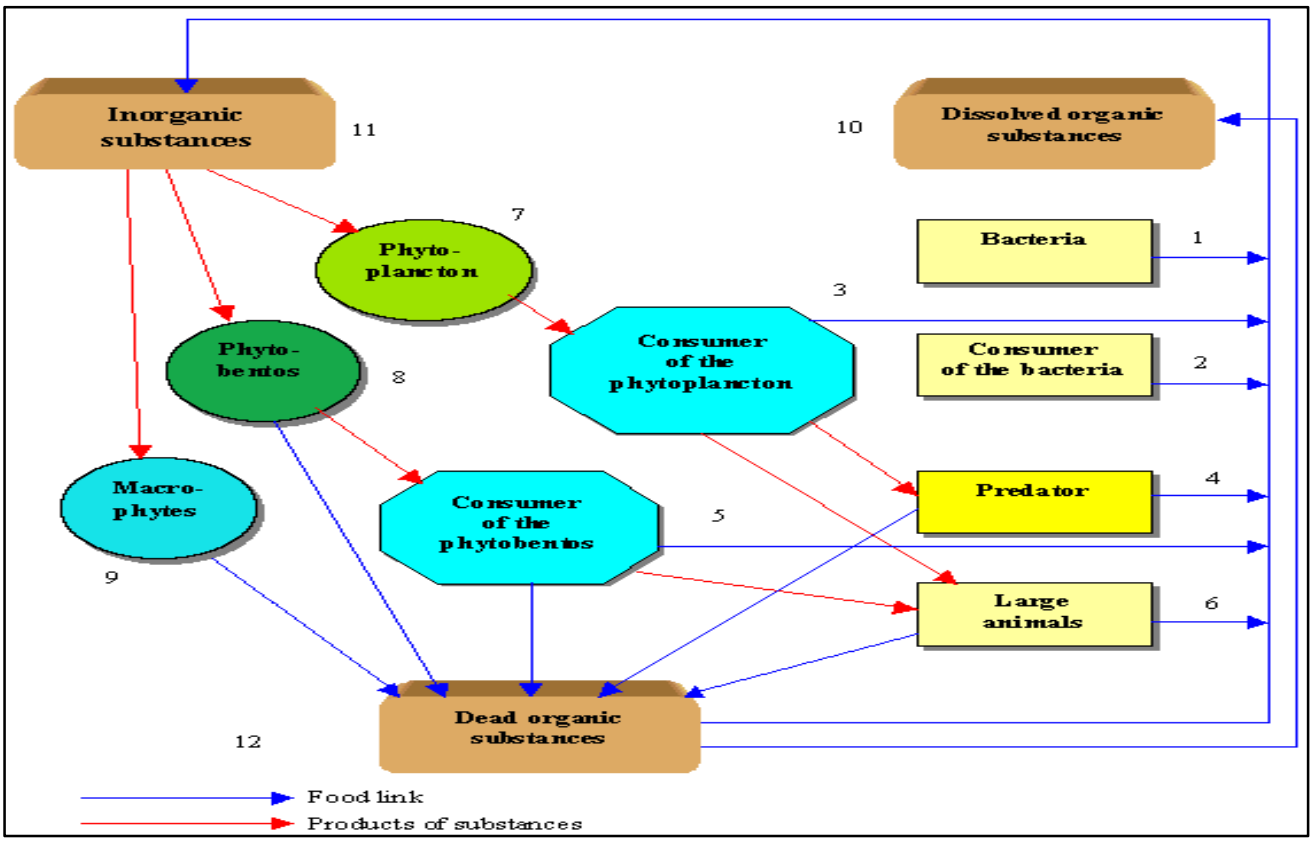

Figure 2 Biocenose model (14)

flow into the rivers (7,8). The changes are determined by the trophic and saprobic degree of the reservoirs, and by the temperature of the reservoir waters. Changes in the abiotic conditions occur also when dumping warm industrial waters into the water. When increasing the temperature of the river water and changes in biochemical processes occur and photosynthesis velocity increases (3).Development of some aquatic organisms is stimulated while others decrease in numbers. The development of bacterial flora increases, and fish are more exposed to diseases. Polluted waters have less light in deepness of the flow (3,4).

Anthropogenic Effects on Biotic Conditions and Processes

The biotic conditions - food substances, substances cycle, bioaccumulation etc. also change significantly under anthropogenic influence. These changes are in dependence of the structure of the polluting substances (conservative and non-conservative), the way they come into the water (through concentration release or diffusion, stationary or non-stationary), the conditions of mixing the river and polluted waters, the oxygen concentration, the temperature, the auto-purification, and assimilation capability of rivers (5,6).When industrial and agricultural wastes flow into the waters the concentration of organic and inorganic components increases - sulfates, nitrates, chlorides, heavy metals, oil products, phenols, cyanide and others. Also through fecal waters diverse microorganisms mostly- bacteria, viruses, algaflow into rivers (5,6,7).

Specificities of the River Biocoenosis in Rivers

The river biocoenosis is an open system with high intensity of the substantive and energy interaction between land and water, with heterotrophic type of metabolism. It includes the producers-autotrophic organisms, which through photosynthesis transform the inorganic substances into organic, consumers-heterotrophic organisms, reducers (bacteria and fungus), and diluted organic substances, detritus. (12,13). The organic substances synthesized by the producers are food for the consumers. From the biological activity of the consumers organic detritus is produced (16).

The organic detritus is used by the reducers, which release biotic substances, which again are used by the producers. In this way the substances circle of the aquatic ecosystems takes place. Hartmann (1993) introduces these processes in a scheme (Figure-2), which late was modified by Hartmann and Boes (1993) (Figure-3). According to this model, the aquatic cenosis consist of six heterotrophic and three autotrophic groups, a group of dead organic matter, a group of diluted and undiluted organic substances.The aquatic cenosis are dynamic communities, which interact among each other and the environment and in this way change the chemical parameters of the ecosystem (14).

Processes of Interaction with the Polluting Substances And Their Influence on Ecosystem

The influence of the pollutants are complex in mechanism and diverse in its direction and degree. It consists of hydro-chemical, hydro-biological, bio-chemical processes, and different ecological zones. The global impact of anthropogenic activities on river flows with polluted substances is introduced by a scheme (Figure -3) (14).The diffusion of pollutants into the food chain takes place in three different ways:

1. Increase in the concentration of pollutants from one level to the upper level of the food chain;
2. Transfer from one level into an other without increase of the concentration;
3. Decrease of the concentration from the lower level to the higher level. (11,17,19)

Polluting organic substances, heavy metals and other inorganic substances, changing the pH of the environment, have acute or chronic toxic influence on the different components of the water biocoenosis (9,10). The toxic influence of many of the organic and inorganic matter is blocking the enzyme systems or methylate (a process by which some of the products become unusable under the influence of toxic matter) the proteins. By degree of toxicity heavy metals have the following order:

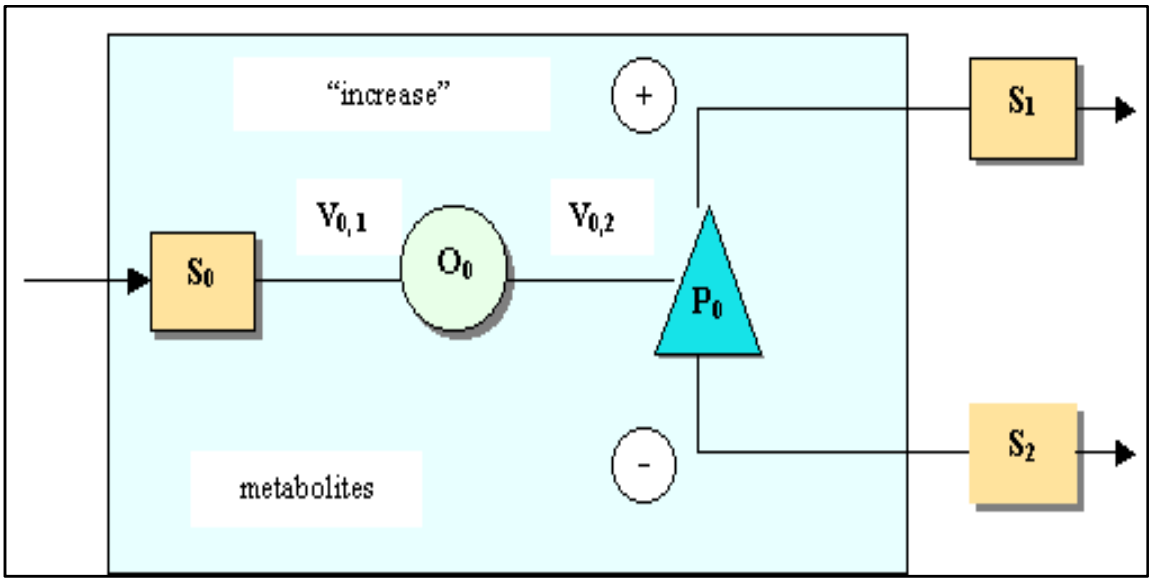

Figure 3 Modified element of the Hartmann model,(14)

S- Substances; O - Organisms; P - Product; V - Reaction rate.

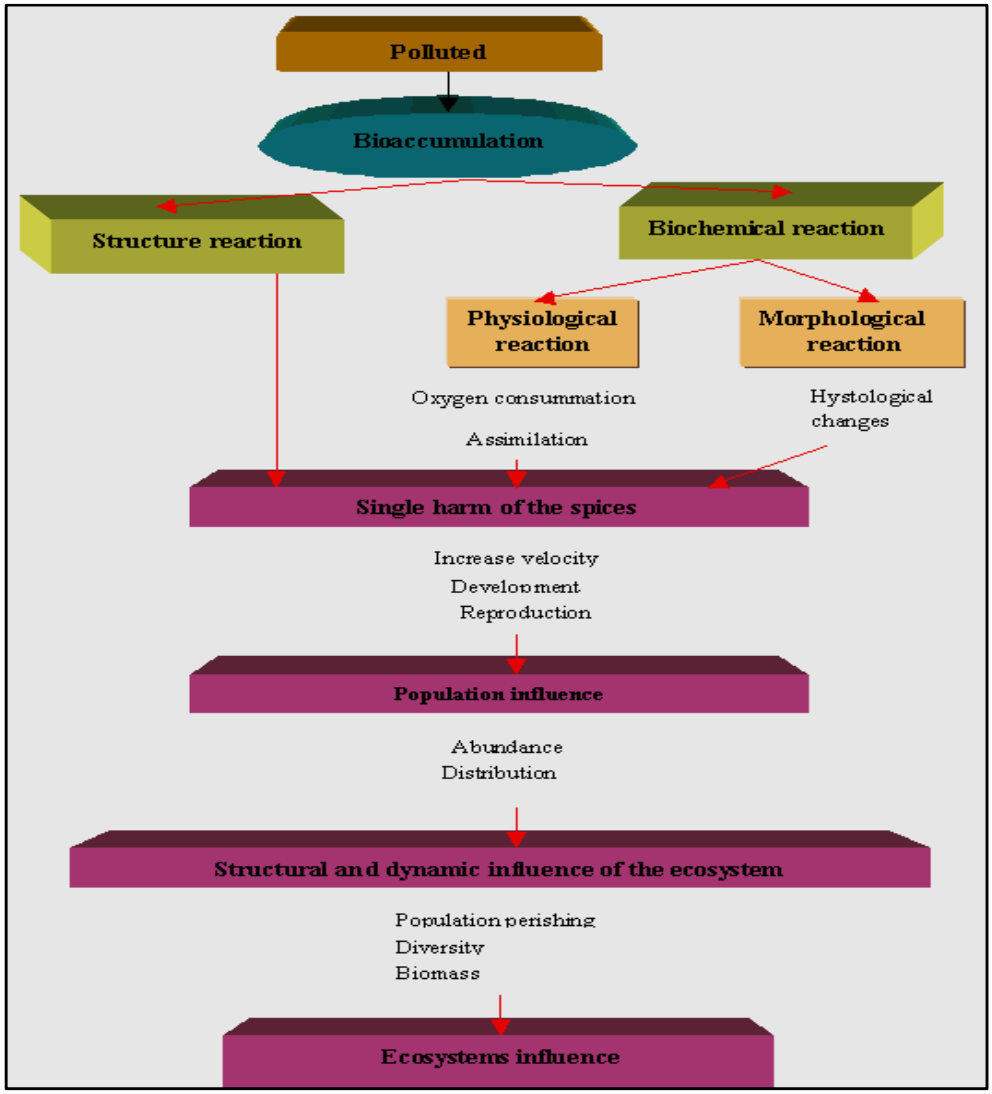

Figure 4 Influence of a pollutant on aquatic system (22)

Sb > Ag > Cu > Hg > Co > Ni >Pb> Cr^{3+} > Cd > Zn > F

Heavy metals are accumulated in the aquatic biocoenosis and influence the velocity of the interaction processes. The effect of the combined presence of several heavy metals may be worse than the sum of the effect of each one of them separately (e.g. the combined presence of zinc and cadmium increases the toxic degree of each one of them separately several times (16,18).The toxic pollutant in the organism experiences complicated bio-transformations - it transfers into two or more end products (17). There are two types of biotransformation: (a) first type includes reactions of oxidation, reduction and hydrolysis (phase-I) and (b) second type includes reaction of condensation (phase-II). The bio-transformations lead to metabolites, which have characteristics different from the primary matter. The result can be a more toxic matter or a medication substance. The concentration of pollutants in water and in organisms, the protecting potential of the biological system, and the time of influence determine the degree of toxic influence (20,21,24).
The aquatic biocoenosis destructs the organic compounds in the following order the use of organic matter by heterotrophic and autotrophic bacteria, increase in the zooplankton and phytoplankton, which use the bacteria, development of the phytoplankton and stimulation of the photosynthesis; development of high-developed aquatic plants.The heterotrophic and autotrophic microorganisms prepare the conditions for the other organisms of the aquatic biocoenosis (22,23).There is a relationship between the increase of the bacteria mass, its activity and the substratum concentration, which is described in many models by different authors. According to most of them the organic matter concentration is regulating the intensity of the microorganisms (25,27).

By entry of significant quantities of dissolved organic matter, two different ecosystem are formed, with compulsory assimilation of left over biomass in the food chain and inhibition of the reproduction. The first type of ecosystem is characterized by high intensity of the living action and great endurance towards the toxic matter (1,17,26). The second type of ecosystem is characterized by low intensity of the living action. Bacteria communities with developed zooplankton fall under the first type. Under the second type bacteria communities that are develop when flowering intoxicate the zooplankton. Anthropogenic radionuclides also change the eco-hydrological conditions in streams and rivers (28,29). They can be in different forms, ionic disperse (simple and complex, charged positive or negative, monomeric and polymeric ionic) molecular, colloid, etc. The assimilation can

be active or passive. The active interaction is determined by the ability of the organisms to perceive and secrete the mineral substances with the help of special organs or cells of the surface matter (2,28). The passive interaction is determined by the surface adsorption. It depends on the area of this surface matter. The adsorption is more intensive according to the difference between the ionic composition of the matter and the water environment. This process is more significant by the microorganisms. Radionuclides are accumulated in water organisms also through filtration(25,27,29).

Structural and Functional Changes in the River Ecosystems

Changes in Biomass

Under influence of polluting substances different changes occur. Some are in the biomass summary and others are in the structure type of the hydrobiontes. The polluted river flow is characterized by higher concentrations of the biomass and a relatively little type diversity (7,8,11). Biogenic elements and different microelements are used by heterotrophic and autotrophic bacteria and induce increase of the zooplankton and zoo benthos (which bacteria and organic substances use), and development of phytoplankton. The processes of photosynthesis reaction are stimulated and higher flora is developed. As a result of these processes production of phototroph and lithotroph biomass increases. Synthesized biomass damages the oxygen balance and the ecological conditions as a whole (22,16,19).

Changes in Diversity

Under the anthropogenic condition biomass is changing, as well as the type structure of the biocoenosis - phytoplankton, phytobenthos, zooplankton, zoobenthos, bacterio-plankton (13, 28). The influence of the pollutant is a change of effects in different trophic levels of the bio-accumulation of the pollutant, which are part of the fundamental ecological processes. The organic substances define the competition for food substances, as well as the food chain pressure. They shorten the trophic chain and damage the ecosystem (14,17,11). Theoretically the relationship between the type and the concentration of the organic substances and quantity of heterotrophic organisms is established. The polluting substances influence the relative competitiveness ability of the different types, which build the ecosystem. The individuals of one type or the population of different types change the relationship due to the decrease or increase of their abilities in the fight for food and habitat. This process is accompanied with changes in the special and trophic ecological niche (14, 15).By anthropogenic pollution over the limiting norms for concentration the aquatic ecosystems lose their characteristics durability and reliability (the ability of the aquatic system to keep the mechanism of self-purification and to ensure the water quality), which leads to progressive falling of the water quality (19). Under the influence of organic and inorganic compounds with anthropogenic origin certain population parameters change (5).

Indicators for the Ecological State of Rivers

Different indicators measure the natural quality of rivers. The hydro-biological parameters are characteristics of the river ecosystems. They reveal the biotic and abiotic factors. They are based on the number and structure of the aquatic organisms, because they react not only to one or two individual factors but to the whole ecological situation (7,14,19). More common indicators for biological prosperity are:

1. The relationship between the production and the destruction of phytoplankton, if the production is larger than the destruction hydro-ecological balance is violated.
2. The relationship between the autochthonic production of the phyto-biomass (P) and the oxygen consumption by the heterotrophic organisms (B). Dependent of the parameter values in the river three zones along the river flow can be defined. First zone were $P/B < 1$ - usually this is the upper flow, Second zone were P/B is $= 1$ - usually the middle flow of the river and Third zone, were P/B is > 1 (28, 24,19,21).

Bioaccumulation Potential of Pollutants

Successful attempts by researchers have paved way for hopes of healthy and pollution free future. P. U. Singare, R. S. Lokhande and P. P. Pathak advocated the habitat conservation and ecological studies with special reference to the pollution due to heavy metals and physico-chemical characteristics of the soil along the creek area. A study to estimate the levels of water pollution of the Upavan, Masunda, Makhmali and Rewale Lakes situated at Thane, the city on the North Eastern side of Mumbai was carried out. The study was performed to understand the physico-chemical parameters like pH, conductivity, alkalinity, salinity, hardness, chemical oxygen demand (COD), dissolved oxygen (DO) and biochemical oxygen demand (BOD) of lake water. The study was also extended to understand the level of heavy metals like Cu, Zn, Ni, Cd, Hg, As and Fe. These heavy metals have a marked effect on the aquatic flora and fauna which through bio magnification enter the food chain thereby affecting the human beings. P.U. Singare, R.S. Lokhande, P.P. Pathak. investigated the assessment of pollution status along the wetland of Thane Creek, which has been subjected to a lot of pollution from the Asia's biggest Thane-Belapur Industrial Complex located at the south of Mumbai harbor along the west coast of India. The soil samples were also analyzed for their heavy metal contents like nickel, zinc, cadmium, copper, iron, arsenic and mercury. It was observed that, the concentration of these heavy metals increases gradually in dry seasons, followed by sharp decrease during rainy season. These heavy metals have a marked effect on the aquatic flora and fauna which through bio magnification enter the food chain and ultimately affect the human beings as well. A similar study concerned with the pollution load monitoring along Vasai Creek of Mumbai with reference to the physico-chemical parameters of sediments was done. The study was carried for a span of two years from 2009-11 at four sampling stations namely Vasai bundar, Bhayandar west side below Railway Bridge, Bhayandar east side near Retibundar and Ghodbundar site along the flow of Vasai Creek. It was observed that most of the physicochemical parameters like electrical conductivity, chloride, sulfate, sulfide and phosphate content in the sediment samples were higher during the assessment year 2010-11 as compared to that during the year 2009-10. However the pH values recorded during the year 2009-10 were higher than that recorded during the year 2010-11. The results of the investigation suggested the present increasing pollution load along the Vasai Creek may affect sediment dwelling organisms and fish resulting in decrease survival, reduced growth, or impaired reproduction

and lowered species diversity. Authors P.U. Singare. S.S. Bhattacharjee, R. S. Lokhande in their paper advocated ecological studies with special reference to the pollution due to heavy metals in the sediments along the Thane Creek area. The sediment samples were analysed for their heavy metal contents. These heavy metals have a marked effect on the aquatic flora and fauna which through biomagnifications enter the food chain and ultimately affect the human beings as well.One of paper on water pollution study of Gove industrial area of Maharashtra, India with special reference to the physico-chemical characteristics of common industrial waste water effluent discussed the physico-chemical parameters like temperature, pH, solid content, total hardness, chloride content, dissolved oxygen (DO), biological oxygen demand (BOD) and chemical oxygen demand (COD) were studied by collecting samples bimonthly for 12 months. The authors point out that as India moves towards stricter regulation of industrial effluents to control water pollution, greater efforts are required to reduce the risk to public health as toxic pollutants which are mainly colorless and odorless are released into the ecosystems. The monitoring of physico-chemical parameters and heavy metals was performed along Vasai Creek by Lokhande et al in 1994-95 point out the high level of pollution due to surrounding industrial belt and discharge of domestic sewage waste. The results of their study suggest a strong need to carry regular monitoring of pollution load along the creek. The study of physico-chemical parameters of sediment samples of Thane creek of India was performed by Singare et al. The study was carried out with an objective to throw light on deteriorating condition of Thane Creek. The researchers suggested for regular scientific study will help to gauge the extent of pollution along Thane creek. It was observed that various physico-chemical properties studied and level of heavy metals in soil samples increases gradually in dry seasons, followed by sharp decrease during rainy season. The researchers emphasizes on the need of regular monitoring of water resources and further improvement in the industrial waste water treatment methods.

Importance of the Study

Water quality is fundamental for good river health. An ecosystem is a community of organisms-plants, animals, fungi and bacteria-interacting with one another and the environment in which they live. Protecting aquatic ecosystems is in many ways as important as maintaining water quality. Aquatic ecosystems are an integral part of our environment. They need to be maintained if the environment is to continue to support people. World conservation strategies stress the importance of maintaining healthy ecosystems and genetic diversity.Aquatic ecosystems play an important role in maintaining water quality and are a valuable indicator of water quality and the suitability of the water for other uses.Aquatic ecosystems are valuable resources. Aquatic life is a major source of protein for humans. If water quality is not maintained, it is not just the environment that will suffer. The commercial and recreational value of our water resources will also diminish.

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