Microbial Prevalence in Soil Water in the River Deltas of the World

Abstract

There is a wide range of diverse soil and aquatic microbes reside in different deltas of the world that mainly exhibit in various forms such as bacteria, fungi, parasites, archaeans, actinomycetes, virus etc. They contribute to the environment in various ways to maintain the balance of natural elements, bio geological components and also help in protecting the ecological components. Microbes that are living in the soil provide plants along with environmental and natural protection from diseases and pests. They are very much essential for transforming nitrogen and nutrients into the forms that is consumable for plants. Decomposition, production of Oxygen, evolution, as well as symbiosis are the vital roles that are played by different soil and aquatic microbes. Some river deltas show maximum populations of saline soil dependent bacterial and fungal community, where as some river deltas are enriched with some specific microbes that are responsible for soil remediation. In some cases some species of hydrocarbon degrading microorganisms contribute to differences in C, N, P ratios. As the microbes are also responsible for producing different antigens as well as allergens that are mainly causative agentsfor varying infectious diseases, in need of its curative drugs and antibiotic medicines some microbes are involved in research studies for production of medicinal drugs and anti-allergens.

Keywords: Microbes, decomposition, hydrocarbon, parasites, fungi, causative agents, antibiotics, drugs.

Introduction

A delta of a river is just like a form of land which is created by the filtration, sedimentation and the depositions of solid particles by the flow of river. It is mainly formed by the slow river action that is always observed where the river or stream ends up or meets up to the ocean or lake or estuary or any other stream or water body(1). At the lower course of the river as the wave action and carrying capacity of solid particles of the stream becomes diminished, the maximum sedimentations as well as the depositions have been created and that contributes to the production of a land form of alluvium called delta. These deltoid land forms are enriched with nutrients like nitrogen, phosphorous, calcium, silicon, ammonia, nitrate, phosphate, sulfate and huge amount of organic compounds including oxygen and hydrocarbons. The accumulation of these nutrients occurs through the siltation process which helps large diversity of microbes to grow on along with food web and also provides as large habitat of microbes.

Microbes or the microorganisms are mainly unicellular organisms. But they possess diverse form of domains—Archaea, bacteria and eukaryota. Among them archaea and bacteria are unicellular while the eukaryote represents multi cellular organisms.Besides the protozoans, fungi and actinomycetes are also considered as the microorganisms. In the river deltas the microorganisms mainly reside in the soil and in the water. So they are classified as soil microbes and aquatic microbes. The soil microbes which are functional, are always embedded with silts or alluvium that is organic in nature. And soil microorganisms act in integrated way to hold nutrients into the soil and transfer them in nutrient locked in soil, such as nitrogen fixation etc.(2-4) Such microorganisms reside on the surface soil as well as on the subsurface with the depth ranging from some hundreds to thousand kilometers or meters inside the ground. As the soil depth increases, the number of microbes residing in soil also declines. And that is due to the decline of organic compounds which is rich in the surface and subsurface portion rather than the depths. So they play an important role to maintain the composition of the soil profile(5-9). The rhizosphere or the plant root region of the soil harbors maximum population of microorganisms than the other regions of soil as the rhizosphere is rich in nutrients. The prokaryotic microorganisms possess the width of 0.5-1 mm and length of at least 2 mm. Inspite of varying shapes of bacteria such as rod, comma, filamentous, spiral, spherical, the most available form is short sized rod shaped bacteria that is coccoid rods. The mostly available forms of bacterial genera found in soil are *Bacillus, Pseudomonas, Arthrobacter*, *Agrobacterium, Clostridium, Alcaligenes*,*Flavobacterium*, *Micrococcus*,*Corynebacterium*, *Mycobacterium,* and *Xanthomonas*. Aerobic bacteria undergoes direct respiration in the air with presence of Oxygen as electron acceptor, whereas anaerobic bacteria undergoes fermentation or indirect respiration with ferric ion, nitrate, sulfate, carbonate and organic compounds as alternative electron acceptors (10-12). The deltoid soil that is heavily compacted or waterlogged is rich in anaerobic bacteria than the aerobic populations. Besides the carbon-nitrogen ratio and pH in the soil also contribute to the soil microbial population and diversity(13-19).

Apart from this fungi also constitute a huge biomass in soil of all soil microorganisms. They belong to three groups like decomposers, fungi with mutual relations such as mycorrhyza and pathogenic fungi. These include *Tricholoma, Amanita, Descomyces, Torrendia, Thelephora, Phytophthora, Verticillium, Pythium* and *Rhizoctonia(20-25).* Besides some actinomycetes or filamentous bacteria that are either gram positive or gram negative which are abundant in neutral or alkaline pH and form extensive mycelia or colonies. These are *Streptomyces, Thermoactinomycetes, Micromonospora,* and *Nocardia.* Apart from these the soil microorganisms include yeast, algae, some free living or colonial protozoa such as flagellates, ciliates and amoeba. Others are blue-green algae or cyanobacteria which are phototrophic mostly found where water and light is abundant in the river deltas (26-28). These play a role mainly in nitrogen fixation in the absence of O_2. These include *Nostoc, Anabaena,Nodularia*, *Prochlorothrix*,etc(29, 30).

There is a wide variety of aquatic bacteria reside in the river delta such as *Vibrio cholerae, Vibrio parahaemolyticus, Salmone,lla typhi, Salmonella paratyphi, Salmonella enteric, Shigella dysenteriae, Shigella flexneri, Shigella boydii, Shigella sonnei, Escherichia coli (31-37) etc.*Other aquatic microbes also include cyanobacteria, protozoa, fungi, algae, archaea etc. The fresh water of streams and rivers having high velocity, consists of higher oxygen content that provides a large habitat of aquatic microorganisms.Besides a lot of organic compounds are accumulated here in the water body from the bank runoff and sediments that provide as food source of species.

There are a huge numbers of river deltas present in the world that harbor diverse types of microorganisms in the soil and in the river water. Such deltas include Pearl,Yangtze, Yellow, Red, Irrawaddy, Mekong, Ganges-Brahmaputra, and Indus(38-40).

Soil microbes

Yellow river delta

A research paper shows that some river delta like yellow river delta of China possess saline soil that undergoes different enzyme activities through microbial community residing the saline soil along with the halophyte plant communities such as *Phragmites australis, Suaeda salsa, and Tamarix chinensis.* The microbial composition and salinity of the soil enhances the enzymatic functions. Such as catalase that influence the redox potential, dehydrogenase, protease, urease that maintain the carbon and nitrogen cycle respectively. In this river delta the process of succession from herb community to woody plant community along with various mechanisms of salt tolerance a large biomass of soil environment influence the diversity of microbial growth as well as the enzymatic actions(41-44).

An important study on Yellow river delta also demonstrates how the potentiality of indigenous soil bacterial remediation has been used as broad way treatment for soil remediation. Here as the soil contaminators the petroleum hydrocarbon degrading microbes are identified and showed how the pH, salinity, optimal temperature, proportional ratio of C,N,P in the soil influence the degradation of polyaromatic hydrocarbons, n-alkanes, crude oil, diesel oil etc. with the help of these microorganisms(41, 44-49).

Yangtze River delta

Another study of Yangtze River delta of China revealsthat how the tidal wetland soil is transformed to a paddy field that involves the diverse microbial community. The continuous paddy cultivation and reclamation of wetland ecosystem impacts on microbial population, especially the succession process in deltoid soil. This pattern of succession is analyzed by using gene pyrosequencing of 16s rRNA. The result showed the abundance decrease of*Planctomycetes* and .*Gammaproteobacteria* and increase in number of*Firmicutes*and *Alphaproteobacteria*. The further research work discloses that rice cultivation with a long time period also enhances the growth of *Rhodospirillaceae* and *Clostridiaceae*which are intensely beneficial to huge paddy yielding at once. This predominantly changes the physiochemical properties of the soil, redox potential capacity of ion exchange and the pH level (50).

Colorado River delta

Again a study on Colorado River basin delta represents that siltation of sandstones and fine grained clay substances constitute the rocky soil composition of this delta. The detritus growth on drainage river basin dominates calcite, quartz and subordinate dolomites including plagioclase, illite, kaolinite, zircon, magnetite, clinozoisite, leucoxene, chlorite and biotite(51-54).

Mississippi river delta

Some studies on nitrogen fixation by microbes on river deltas and estuary deliver that river sediment N_2 fixation rate is lower than the N_2 cycling process due to fixation inhibition by potentially excessive concentration of Dissolved Inorganic N_2 (DIN) among the sediments that are bioavailable. These are mediated by Cyanobacteria, chemolithotrophs or photosynthetic bacteria, methanogens, different heterotrophs or sulfate reducers. This fixation occurs by the conversion from N_2 to Ammonia (NH_3) through production of nitrates and nitrites via different phases of chemical reactions (55-60). Some studies show that *Myrica gale* contributes 3 to 4 g N m^{-2} yr^{-1} through N_2 fixation to the *Sphagnum* bogs. That are common in the wetland ecosystem of river deltas. And here important role is played by some anaerobic, aerobic, nonsymbiotic and few blue-green algae. Thus the physiochemical changes in soil develop high acidic pH and lower nutrients availability (61, 62)

Lena river delta

Another study of Lena river delta demonstrates that the analysis of suspended particles, soil, dissolved organic and inorganic Nitrogen content along with ^{15}N isotope comprise to generate inventory of N_2. The study shows that the N_2 content in the soil is contributed by N_2 fixation from atmosphere by several microbes including planktons in the form of nitrates, later transported from the delta to the sea or water body in the form of dissolved organic nitrogen (DON), especially in the winter season and that is also in higher rate (approx. 10 μmol/L). In the season of summer, N_2 is transported in the form of DON and nitrogen particulate matter in the suspension where the amount of nitrate is less than 1μmol/L. Not only nitrogen but also different turnover of carbon, methane, methanotropic community and other substances have been seen that all are influence greatly by the soil microbes. (63-72)

Volga river delta

A study of Volga river delta demonstrates that the biomass and the quantity of microbial community at the upper portion of humus horizon is inferred in the alluvial type of soil which includes calcareous soddy desertified soil, mucky gley, and dark hydro metamorphic humus soil.

Algal cells and fungal mycelium are also abundant in the microbial biomass of the deltoid soil that ranges between 35%-47%. The prokaryotic microbial populations also determined as 2-6%, and the carbon amount as 1.4-2.3% in the soil as organic matter, especially in the spring season. The organic composition of the alluvial soil is characterized by high concentration of microbial mineral coefficient as well as oligotrophy(73-75).

Madagascar river delta

Another study on Madagascar river delta(Alaotra basin, red and other rivers of Madagascar) demonstrates how the climatic changesbecome the leading influencing factors for the microbial diversity in the deltoid soil. Temperature, humidity, rain fall effect the physiochemical composition of the soil including the organic matters and the mineralization. The stoichiometric decomposition exerts the prime effect that is boosted in the cold climate and that is due to less organic compound in soil along with fast growing microbial population. In contrast, the mining of the nutrient coefficients also influenced during warm environment as there is a loss of competition between slowly growing microbial population for mining organic compounds and fast growing population for the purpose of energy rich components in the soil (76-79)

Danube river delta

A research work on Danube river delta demonstrates the soil fungi community as abundant microbial population of the delta that influences its ecosystem and biodiversity. Almost seven different areas were studied to make a comparison on fungal community. The study also focuses on the effect of microbial growth in the soil that results in the changes of soil texture, soil profile, soil humidity, depth of sandy gravel components, ground water level, plant community as well as the other organic composition of the soil (80-88)

Ganga-Brahmaputra-Meghna delta (GBM)

Being the largest river delta of the world GBM river delta inhabits a huge population of biodiversity and impacts widely on the socio-economic field of the world. As the delta is maximally composed of alluvial soil of the flooded plain made up of river deposition and siltation, the organic constituents along with different microbes including bacteria, fungi, parasites, helminthes, virus play an important role for the cultivation of different vegetations in the soil(89). The maximal humid situation of upstream in comparison to the downstream provides variations in the fungi pollens that also changes the physio-chemical soil texturefor a long time period(90-106). Sundarban river delta is also an example of this largest deltoid soil microbial activity (104, 107-121)

Mekong river delta

Another study of Mekong river delta of Vietnam demonstrates about the fecal pollutants like *streptococcus*, *E.coli*, *coliform* bacteria that are also called as indicator bacteria. The study assessed the soil decompositions of these microbes in temperate and tropical region of the deltaand concluded that the *E.coli* population in summer is always higher than the winter population in soil (122-132).

Indus river delta

A different research work of Indus river delta of Pakistan, the study is focused on the 3 different tidal creeks which include Gharo, Phitti, Isaro creek for assessing the soil carbon flux that is mediated by bacteria in the ecosystem. During the study the bacterial carbon production, bacterial biomass, especially the primary productivity is measured to conclude he bacterial growth with other different organic substances like Phosphorus, Nitrogen, and Hydrogen along with carbon. The study also focuses on the mangrove community growth with organic matter that indicates the destruction of mangrove ecosystem with organic compounds in soil always leads to the negative or reduced development of the ecosystem structure and function indulging less production of sea fish and shrimps (133-145).

Krishna river delta

Some studies of Krishna river delta of the Peninsular India proposes the C/N ratio of the deltaic soil that is varied by the flood created by the heavy rain fall along with the release of the water from the dams of that region. And this C/N ratio also varies by the influences of different inhabited microbial decomposition of the soil. Not only that it is also assessed that the different organic debris also indulge in the C/N ratio of the deltaic soil that is influenced by the seasonal and non-seasonal flooding (146-151).

Mahanadi river delta

An important study on Mahanadi river delta shows that some soil bacteria such as *Serratia sp***.** that is isolated from the mangrove deltaic soil has phosphate solubilizing function along with phosphatase activity that helps in growth and development of soil decomposition.(106, 152-155)

Aquatic Microbes

Yellow river delta

A study on coastal microbial community and its ecological balance represents that a vast investigation on different tidal regions such as subtidal, intratidal and supratidal flat postulates diverse microbial population. This is experimented throughout four seasons of a yea(156)r by using 16s rRNA gene with PGM platform of Ion Torrent (44, 157-160).

Yangtze River delta

In an efficient research work on microbial planktonic composition on Yangtze Riveran assessment is done to evaluate the changes in water quality and dynamics along with its flow pattern. This is corresponded with RNA and DNA based 16S rRNA gene phylogenies over consecutive three different seasons. Different clone and cDNA libraries are prepared (161-166)

Colorado River Delta

Another study represents the effect of pre and post flood on the dynamics of carbon cycling over the dry Colorado River water flow. This also affect the microbial diversity and population in the aquatic environment. Human approaches of aquatic resources continues to increase, the series of dehydrating and hydrating of natural riverbeds as well as deltas that may predominantly alter the total processing as well as storage of carbon within the system (167-170)

Mississippi river delta

The study of Olivia Masson et al, represents the different microbial diversity and population which varies along with the salinity change in the river water. The assessment in the surface sector of the water body demonstrates the actinobacteria and proteobacteria whereas the deeper region of the water demonstrates the Thaumarchaeota(171).

Lena river delta

Another study of Lena River focuses on different enzymatic bacterial activities and their production. Determination of different organic matter that is recyclingand preservingalong with the organic carbon production, is done in this research work. Besides these are transported from continent to the ocean, and also sequestrated in the arctic environmental ecosystem (172).

Volga river delta

A different study of Volga river delta represents how enterobacterial halotolerance is isolated from aquatic fish and water sample, and assessed through meat peptone broth culture including 3, 7 as well as 10% sodium chloride incubating at 37^0 c. The assessment also demonstrates the bacterial specific classifications such as they are in proteus group, citrobacteria or enterobacteria(173)

Danube river delta

Another study on Danube river delta reveals that different enterobacteria, parasites, fungi etc. from fecal pollutants in the river fresh water give birth to maximum health hazards of river fauna as well as the human residence of the river delta. A detailed assessment of river fresh water and its different branches reveals that the potential indicator bacteria of aquatic pollution is Escherichia coli and intestinal enterococci for fecal pollutants (84, 174, 175)

Ganga-Brahmaputra-Meghna delta (GBM)

A research study on the largest mangrove and river delta of the world that is GBM encapsulates the prevalence, differential activities and interactions of different water born microbes. Sedimentation and siltation influences the microbial growth including bacteria, parasites and fungi. The study also focuses on the climate change activities of the river delta that plays a leading role in enhancing the bacterial growth in water source. The microbial population also changes the salinity and other water organic composition that effects the further biotic and abiotic processes(98). Some study identifies about marine anti-cancerous alkaloids that are extracted from some aquatic fungi, cyanobacteria, sponges, algae and tunicates (176, 177).

Mekong river delta

A vital research on the indicator bacteria of Mekong river delta depicts the relationship between the indicators as well as the chemical indicator microbes. Water sample is collected in different seasons throughout the year for further assessment and as a result it is determined that *E.coli* concentrations show higher and stronger logarithmic correlations along with coprostanols(122, 123, 178-183).

Indus river delta

An important study depicts that microbes of Indus river delta not only serve for biosphere creator but also provides sources for biotechnological vital valuable components and products. They help in destroying the pollutants, influence the global climatic changes, help to treat the anthropogenic wastes. They produce enzymes, medicinal drugs and compounds, anti-tumor agents, immune-suppressants, insecticides, anti-microbial agents, vitamins etc. (119, 130, 184-187).

Krishna river delta

As Krishna River faces different issues regarding sufficient water availability, various researches are being done and water linking projects are also going on. In this research study water sample has been taken from five different sectors of the river delta and various water qualitative assessments have been done, such as pH, calcium hardness, total hardness, sulphate, nitrate, nitrite, ammonia content analysis etc. It has been found that after utilizing water linking strategy when Godavari river enters in the Krishna river, then the water quality along with its pH and mineral contents also changed into different level that influences different microbial population growth and diversity (188-193).

Mahanadi river delta

Again a study on Mahanadi river delta postulates that the aquifers of the river delta involves mixing of fresh water and coastal ground water at layer wise which enhances the microbial population habitat and its growth. The interface depth that ranges between 10-120 m including fresh river water aquifers on the surface underlain by brackish and saline water aquifers (105, 153, 194-201).

Conclusion

Being an important part of the biodiversity and environment, microbes show their different activities, and prevalence in different river delta's worldwide. Some deltas show different antibiotic activities as well as antimicrobial resistance activities. Some provides bioactive potential compounds that helps in producing potential drugs and medicines that helps in recovering various infectious diseases as well as protecting human health. Some microbial species populations help in nitrogen fixation as well as increase the other organic and inorganic compounds and ionic composition that enrich the soil content enhancing the growth of vegetation and its cultivation. Deltoid microbes also provide applications in food industry for producing various food products. Not only for bioactive molecule production but also they contribute in maintaining bio-geological cycles of different natural elements and enrich the biodiversity and ecological environment. Besides changes in climate, bio-geological factors also alters the microbial species composition in soil and in water that leads to further modifications in biological and ecological activities.

Microorganisms can act as suppliers of ecosystem services that are vital to the nature and also to the human life and their activity. Enzymes of different Arctic bacterial body whose physiology has been adapted to extreme cold temperatures and also therefore it has enzymes that have various potential industrial utility, such as during the sustainable technical and industrial bio-food processing as well as during washing the specific powders that act very efficiently at energy or power saving very low washing temperatures.Interactions between micro-organisms that is inter-microbial interactions and between micro-organisms and plants that is intra microbial ineractions which can enrich people's understanding of utilization of environment's useful microbiological resources so that they can fight against plant pathogens. They also play as good bioindicators for microbes that destruct the food and food products under storage as well as refrigerated conditions or volatile metabolites.

Author's contribution

There are two authors who are solely owners of the content of the manuscript. Dr. Rituparna Acharya is the creator of the idea and the main guide of this review article. Prof. Rajrupa Ghosh is the corresponding author and contributor as who collected and formulated all the information from different published article.

Conflict of Interest

The authors have no conflicts of interest to declare. There are two authors who are solely owner of the content of the manuscript and there is no financial interest to report.

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