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Nutrient biogeochemistry of coastal soils

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Abstract
The interface between land and ocean is termed as coastal zone and possesses specific features like highly dynamic nature, heterogeneity, diversity and productivity, fragile and sensitivity ecological sites as it belong to the transition zone. Coastal areas are rich in natural resources, which attract human settlement. The availability of light limits primary productivity here and is highly valuable as well vulnerable earth's habitat. Bacterial denitrification is a significant process in the coastal zone that plays an important role in organic C degradation primarily occurring in muddy sediments. It necessitates a lot of organic matter, a limited supply of oxygen, and a nitrate source. It's difficult to correctly estimate the rate of denitrification in sediments, especially when it comes to coupled nitrification-denitrification, in which organic matter decomposes to ammonium, which is then oxidized to nitrate, which is then denitrified. This paper deals with biogeochemistry of different nutrients *viz*. carbon nitrogen, phosphorus and sulphur and role of microbes in regulating different nutrient cycles.

Keywords: Coastal areas, transition zones, biogeochemistry, nutrient cycles

Introduction
The Coastal Zone is the area where the land meets the sea covering shoreline environment and coastal water or is a transition zone between land and oceans where diverse elements in the form of sediments collected from numerous sources such as rivers, seas, and atmosphere. River deltas, coastal plains, marshes, beaches, reefs, mangrove forests, lagoons, and other water components that deposit sediment before reaching to the sea allow numerous biogeochemical processes taking place beneath deposited sediment. Natural activities in coastal environments shape the vegetation and habitat of the organisms that live there. The significant degree of natural variability and diversity that exists in this area is owing to constant changes in its physical, chemical, and biological features as a result of changes in wave and current regimes, climate, and morphological processes. Coastal areas are rich in natural resources, which attract human settlement. Within 60 km of the shore, about half of the world's population reside. People are still migrating from inland to seaside locations at a breakneck speed. The fortes of the coastal zones are as follows:

- Highly heterogeneous and dynamic nature due to unstable physical, chemical, biological, physiographic and geological properties.
- Highly productive and diverse habitat (shelter large number of marine organisms and species).
- River deltas, coastal plains, marshes, beaches, reefs, mangrove forests, lagoons are considered under this area.
- Absorbs nutrient toxicity, sediments, and other wastes that could be classified as possible contaminants.
- Fragile and sensitive ecological sites (poor soil development) with location-specific factors such as salinity, acidic soil, sandy texture, and anaerobiosis. Location specific problems that predominating in India are: *viz*. sea-water intrusion in unbunded low-lying areas, iron toxicity in Orissa, impeded drainage in coastal Andhra Pradesh and Tamil Nadu along the east coast as well as in parts of Kerala and Gujarat along the west coast, highly permeable sandy soils in parts of Gujarat, and highly leached low-fertility lateritic soils with severe erosion problems along with undulating topography in some parts of Maharashtra, Goa, Karnataka and Kerala. Soils of Lakshadweep Islands are primarily coral sandy, calcareous and alkaline, whereas those of the Andaman and Nicobar group of islands are acidic, as well as poor in organic matter and available phosphorus (Ray *et al*, 2014).

Due to high nutrient loss, particularly in saline and alkaline soils (via volatilization) and also in deeply wet places, crop nitrogen recovery is relatively low (by leaching and run-off). The following are the major factors limiting crop growth in the coastal plains

1. Soluble salts and alkalinity build up in the soil,
2. Predominance of acid sulphate soils,
3. Periodic inundation of soil surface by tidal water,
4. Accumulation of salts and sediments by natural calamities such as tsunami and cyclone,
5. Eutrophication and hypoxia;
6. Shallow saline ground water. Nitrogen is being lost in large amounts due to volatilization, leaching, and run-off. In coastal acid sulphate or acid saline soils, phosphorus shortage is also a prevalent occurrence.

Biogeochemistry of different nutrients and role of microbes in coastal region

Tidal wetlands are one of the most important global carbon pools because of their effective carbon sequestration capability (0.0426 Gt y^{-1}), as well as inputs from upriver and tidewater (Chmura *et al*., 2003) [13]. Luo *et al*. (2017) [24] observed that the availability of sulphate increases as salinity rises, whereas other electron acceptors, such as oxygen, nitrate, ferric oxides, and carbon dioxide, may rise briefly but then diminish as salinity and inundation rise. Because of the shifting electron acceptor pattern, microbial sulphate reduction may take precedence over other carbon mineralization processes. Sulfate enrichment, increased ionic and osmotic stress, decreased oxygen concentrations and redox potential, among other biogeochemical changes, all have an impact on organic carbon mineralization.

Repeated flooding in coastal areas deposit organic carbon and different nutrients making this fragile and sparse region highly productive. Microbes residing here act as ‘‘Biological engine’’ as playing a crucial part of the whole nutrition cycle and transformation (Azmi and Chatterjee, 2016) [6] such as fixing atmospheric nitrogen, solubilizing phosphates, producing ammonia, and triggering release of `the plant growth regulators. Halophiles and halotolerant microorganisms of this region produce hydrolytic enzymes such as amylase, nucleases, phosphatases, and proteases. These enzymes are involved in protein denaturation (Ventosa and Nieto, 1995) [40], as well as the generation of polyketide synthases (enzymes involved in the biosynthesis of secondary metabolites of erythromycin, rapamycin, tetracycline, lovastatin, and resveratrol). Riverine and groundwater inputs, atmospheric inputs, benthic interactions of nutrients (including denitrification), sediment suspension, upwelling, and sediment burial are all biogeochemical processes that affect coastal environments. Many biogeochemical transformations are mediated by microbes, in which electrons are shuttled from an electron source (e.g., organic molecules) to a terminal electron acceptor (TEA) via a complicated set of reduction-oxidation (redox) reactions, resulting in free energy that drives metabolic processes. Discussing various nutrient cycle in coastal areas are important as plant primary production is stimulated by various nutrient. E.g. Nitrogen boosts primary producers' carbon fixation, while phosphorus may impact heterotrophs' carbon turnover. Because nitrogen fixation is energy-intensive and typically limited by the availability of adequate carbon substrates, adding glucose to marsh sediments increased endogenous heterotrophic nitrogen fixation rates. Phosphorus-mediated reduction in heterotrophic nitrogen fixation observed it is most likely a function of secondary carbon limitation. Sulfate reduction is the major anaerobic metabolic route in seawater with salinities greater than 10 ppt (Sundareshwar *et al*., 2003) [35]. Additional SO_4^{2-} may be unlikely to induce large changes in microbial community composition once the sulphate limitation threshold has been exceeded (Borruso *et al*., 2014) [8].

Biogeochemical study of an ecosystem reveal how high is productivity of the system in low-nutrient region, and how this sustains a diverse food web. The study identified other sources of nutrients input including rain, groundwater, nutrient recycling through sediments, sporadic mixing events through internal waves, and endolithic upwelling. Atkinson, M. J. (2011) [5] pointed nutrient concentration in coastal region change only little as water travels through shallow reefs, despite the fact that various habitats and zones appear to have varied quantities of nutrient production and consumption. The explanation for this was that if productivity was low overall, then one would expect to find little change in nutrients. The biogeochemistry of different nutrients is discussed below:

1. Carbon cycle

The amount and fate of organic matter in coastal areas varies greatly, as it is influenced by local redox conditions (Friesen *et al*., 2018) [15]. Lack of oxygen under water logged condition in coastal areas impairs carbon mineralization resulting to high organic matter content accumulation and high productivity of the areas (Behera *et al*., 2014; Dutta *et al*., 2017) [7, 14]. Anoxic or sub-oxic conditions observed in the non-surface layers of coastal soil are often associated with sulphate or nitrate reduction (Varon-Lopez *et al*., 2014) [38]. Sulfate reduction is the most important respiration activity in mangrove sediments, accounting for more than 75 percent of total mineralization. Increased salinity promotes the mineralization of organic matter and the release of NH4+ as thermodynamically favourable metabolic pathways, such as Fe(III) or SO_4^{2-} reduction (Gao *et al*. 2014) [16]. Salinity has been reported to increase, decrease, or have no effect on organic matter decomposition in wetlands, according to the literature.

2. Nitrogen cycle

In marine environment because of high salinity a major portion of energy synthesized in microbial body is used in osmolyte production and the limiting oxygen concentration rather than complete nutrient mineralization favor fermentation where scanty of ATP is generated. Heterotrophic bacteria nitrogen fixation can be regulated by environmental conditions such as the presence of oxygen or a combined nitrogen and carbon source. Nitrogen-fixing bacteria may obtain nutrients from a variety of substrates found in coastal habitats, rather than relying on carbon and phenol concentrations (Pelegri and Twilley, 1998) [26]. Low N_2 fixation happens in marine water due to a lack of energy sources. Microbial N_2 fixation adds new N to the system by converting atmospheric N_2 to organic N. While mineralization regenerates N internally, microbial N_2 fixation introduces new N to the system by converting atmospheric N_2 to organic N. Due to sulphide inhibition of nitrifying bacteria (Joye and Hollibaugh, 1995) [19], nitrification reduces with greater exposure to salt water (Noe *et al*. 2013) [25]. Small increases in salinity (EC from 1,100 to 16,000 lS/cm) can drive nitrification in saline soils in the absence of increasing sulphide, but extremely significant increases (EC 16,500lS/cm) eventually hinder nitrification (Ardo n *et al*. 2013) [4]. Denitrification uses NO_3 as the TEA to convert NO_3 to N_2. Nitrification offers an oxidized substrate for denitrification.

In the nitrogen cycle, nitrate molecules dissolved in mangrove mud are transformed by bacteria from nitrogenous organic compounds to ammonia. Denitrification is highly high in regions where wastewater is discharged, indicating a favourable environment for microbial growth (Rivera-Monroy *et al*., 1995) [30]. Some nitrogen-fixing bacteria, such as Azotobacter and Clostridium species, are abundant in ecosystems and play an important role in nitrogen enrichment (Sahoo and Dhal, 2009) [31]. Microbes fix 40-60% of the annual nitrogen demand at the rhizosphere and surface sediments level (Holguin *et al*., 2001) [18]. Different kinds of nitrogen-fixing bacteria were isolated from mangrove habitats, including some of the most important species such as Azospirillum, Azotobacter, Rhizobium, Klebsiella, and Clostridium. The quantity of Acidobacteria was strongly correlated with NH_4^+-N. Gemmatimonadetes, on the other hand, showed a substantial positive connection with NO_3^--N and a significant negative correlation with catalase (Tianyun Shaoa, *et al*., 2019) [34].

3. Phosphate solubilization

In coastal areas submergence of soil reduce Fe(III) to Fe(II), increasing iron concentration in soil causing precipitation of P along with Fe (Sengupta and Chaudhuri, 1991; Holguin *et al*., 2001) [18]. As a result, the phosphate content drops dramatically, resulting in nutritional insufficiency. Anaerobic bacteria prefer nonsoluble phosphate dissolution. Vazquez *et al*. have thoroughly discussed bacteria's phosphate-solubilizing capability (2000). A vast variety of organic acids (lactic, fumaric, gluconic, succinic, and acetic acid) are produced during the phosphate solubilization process. These organic acids operate as chelators, binding to metals and removing phosphorus, allowing metals to be displaced (Vazquez *et al*., 2000) [39]. *Atrophaeus*, *Paenibacillus macerans*, *Vibrio proteolyticus*, and *Xanthobacter agilis* are some of the newly identified bacteria PSM. For saltwater and marine sediments, Bacillus spp. and Vibrio spp. have the potential to solubilize phosphate (Promod and Dhevendaran, 1987) [27]. In P cycling, the connection between S and Fe cycling is crucial. The dissolution of Fe-PO_4^{3-} minerals and the release of PO_4^{3-} result from the reduction of Fe(III) to ferrous iron [Fe(II)] and complexation with sulphide (Reddy and DeLaune, 2008) [28]. Following saltwater intrusion, iron-sulfur complexation releases lasting weeks to months, potentially contributing to eutrophication of overlying and downstream streams (Lamers *et al*., 2002) [22].

4. Sulphate reduction

In mangrove ecosystem sediments, sulphate reduction can occur both aerobically and anaerobically (Kristensen *et al*., 2008) [20]. It accounts for 75-125 percent of overall mineralization and is one of the most essential respiration processes (Alongi, 2014) [2]. The majority of microorganisms in mangrove sediments are anaerobic, although there is a small layer of an aerobic zone inhabited by aerobic microorganisms. Microorganisms in the aerobic zone can generally undergo aerobic respiration while degrading organic matter, whereas anaerobic degradation occurs by sulphate reduction (Algoni, D. M., 2005) [1]. Mineralization is aided by the reduction of sulphate caused by organic matter breakdown (Alongi *et al*., 1998) [3]. Sulfate-reducing bacteria create soluble sulphate molecules such as H_2S and HS during the sulphate reduction process. These soluble sulphates combine with iron(I) and iron(II) to form pyrite (FeS_2). Sulfur cycle is intertwined with Fe cycling, which is fueled by both biotic and abiotic interactions (Burgin *et al*., 2011) [12].

Sulfide can either directly impede denitrification by blocking the reductase enzymes that catalyse the final steps of denitrification, resulting in incomplete denitrification to NO_2, NO, or N_2O (Brunet and Garcia-Gil, 1996) [9], or indirectly by inhibiting nitrification, reducing NO_3 availability. Increased ionic strength can also cause denitrification enzymes to malfunction (Laverman *et al*., 2007) [23]. The utilisation of H_2S and FeS as electron donors can also induce substantial denitrification, but only in the presence of enough NO_3^- so if nitrification is hindered, no rise in denitrification is expected (Burgin and Hamilton, 2007, Burgin *et al*., 2012) [11, 10]. Both nitrification and denitrification can be inhibited by high Cl concentrations, but microbial populations appear to be able to adapt to high amounts over time (Hale and Groffman, 2006) [17].

Sulfide (H_2S, HS, S_2) is formed when sulphate is reduced, and it is harmful to many organisms (Lamers *et al*., 2013) [21]. Iron [Fe(II)] and reduced sulphur (e.g., H_2S) mix abiotically to generate iron monosulfide (FeS) and, eventually, pyrite (FeS_2) (Rickard and Morse, 2005; Tobias and Neubauer, 2019) [29, 36]. In wetland soils, salinization generally increases the concentration of Fe-S minerals (Schoepfer *et al*., 2014) [32]. Iron can act as a ‘‘buffer," preventing the development of reduced S molecules in porewater and the toxicity that comes with it (van der Welle *et al*. 2006; Schoepfer *et al*. 2014) [37, 32]. Sulfate reduction is the major anaerobic metabolic route when seawater salinities are more than 10 ppt. Additional SO_4^{2-} may be unlikely to induce large changes in microbial community composition once the sulphate limitation threshold has been exceeded. H_2S concentrations are higher in systems with high organic matter (electron donor) levels, whereas S is pyritized in Fe-rich systems, resulting in FeS_x production and low pore water H_2S buildup.

5. Conclusion

The ecogeomorphic and ecological classifications of mangrove wetlands are clearly delineated by natural boundaries. Geophysical processes across different geomorphological settings and their interaction with ecological processes that are regulating the diversity in mangrove community structure and ecosystem function ultimately control biogeochemistry of different nutrients. In addition, climate, landform and other basic characteristics of a coastal region together with local geophysical processes also have influence on altering nutrient cycles. Thus studying nutrient biogeochemistry of coastal soil and how it differ from terrestrial land is vital important.

Reference

1. Alongi DM. Mangrove-microbe-soil relations. Interactions between macro-and microorganisms in marine sediments 2005, 85-103.
2. Alongi DM. Carbon cycling and storage in mangrove forests. Annual review of marine science 2014;6:195-219.
3. Alongi DM, Ayukai T, Brunskill GJ, Clough BF,

Wolanski E. Sources, sinks, and export of organic carbon through a tropical, semi- enclosed delta (Hinchinbrook Channel, Australia). Mangroves and Salt Marshes 1998; 2(4):237-242.
4. Ardón M, Morse JL, Colman BP, Bernhardt ES. Drought- induced saltwater incursion leads to increased wetland nitrogen export. *Global change biology*, 2013;*19*(10):2976-2985.
5. Atkinson MJ. Biogeochemistry of nutrients. In *Coral reefs: An ecosystem in transition* Springer, Dordrecht. 2011, 199-206.
6. Azmi SA, Chatterjee S. Population dynamics of soil bacteria in some areas of Midnapore coastal belt, West Bengal, India. *3 Biotech*, 2016;*6*(1):37.
7. Behera BC, Mishra RR, Dutta SK, Thatoi HN. Sulphur oxidising bacteria in mangrove ecosystem: a review. African Journal of Biotechnology 2014;13(29).
8. Borruso L, Bacci G, Mengoni A, De Philippis R, Brusetti L. Rhizosphere effect and salinity competing to shape microbial communities in Phragmites australis (Cav.) Trin. ex-Steud. FEMS microbiology letters 2014;359(2):193-200.
9. Brunet RC, Garcia-Gil LJ. Sulfide-induced dissimilatory nitrate reduction to ammonia in anaerobic freshwater sediments. FEMS Microbiology Ecology, 1996;21(2):131-138.
10. Burgin AJ, Groffman PM. Soil O2 controls denitrification rates and N2O yield in a riparian wetland. Journal of Geophysical Research: Biogeosciences 2012;117(G1).
11. Burgin AJ, Hamilton SK. Have we overemphasized the role of denitrification in aquatic ecosystems? A review of nitrate removal pathways. Frontiers in Ecology and the Environment, 2007;5(2):89-96.
12. Burgin AJ, Yang WH, Hamilton SK, Silver WL. Beyond carbon and nitrogen: how the microbial energy economy couples elemental cycles in diverse ecosystems. Frontiers in Ecology and the Environment 2011;9(1):44-52.
13. Chmura GL, Anisfeld SC, Cahoon DR, Lynch JC. Global carbon sequestration in tidal, saline wetland soils. Global biogeochemical cycles 2003;17(4).
14. Dutta MK, Bianchi TS, Mukhopadhyay SK. Mangrove methane biogeochemistry in the Indian Sundarbans: A proposed budget. Frontiers in Marine Science 2017;4:187.
15. Friesen SD, Dunn C, Freeman C. Decomposition as a regulator of carbon accretion in mangroves: a review. Ecological Engineering 2018;114:173-178.
16. Gao H, Bai J, He X, Zhao Q, Lu Q, Wang J. High temperature and salinity enhance soil nitrogen mineralization in a tidal freshwater marsh. *PloS one*, 2014;*9*(4):e95011.
17. Hale RL, Groffman PM. Chloride effects on nitrogen dynamics in forested and suburban stream debris dams. Journal of Environmental Quality 2006;35(6):2425-2432.
18. Holguin G, Vazquez P, Bashan Y. The role of sediment microorganisms in the productivity, conservation, and rehabilitation of mangrove ecosystems: an overview. Biology and fertility of soils, 2001;33(4):265-278.
19. Joye SB, Hollibaugh JT. Influence of sulfide inhibition of nitrification on nitrogen regeneration in sediments. Science 1995;270(5236):623-625.
20. Kristensen E, Bouillon S, Dittmar T, Marchand C. Organic carbon dynamics in mangrove ecosystems: a review. Aquatic botany 2008;89(2):201-219.
21. Lamers LP, Govers LL, Janssen IC, Geurts JJ, Van der Welle ME, Van Katwijk MM *et al*. Sulfide as a soil phytotoxin-a review. Frontiers in plant science 2013;4:268.
22. Lamers LPM, Smolders AJP, Roelofs JGM. The restoration of fens in The Netherlands. *Hydrobiologia,* 2002;478:107-130.
23. Laverman AM, Canavan RW, Slomp CP, Van Cappellen P. Potential nitrate removal in a coastal freshwater sediment (Haringvliet Lake, The Netherlands) and response to salinization. Water Research, 2007;41(14): 3061-3068.
24. Luo M, Huang J, Tong C, Liu Y, Duan X, Hu Y. Iron dynamics in a subtropical estuarine tidal marsh: effect of season and vegetation. Marine Ecology Progress Series 2017;577:1-15.
25. Noe GB, Krauss KW, Lockaby BG, Conner WH, Hupp CR. The effect of increasing salinity and forest mortality on soil nitrogen and phosphorus mineralization in tidal freshwater forested wetlands. Biogeochemistry 2013;114(1):225-244.
26. Pelegri SP, Twilley RR. Heterotrophic nitrogen fixation (acetylene reduction) during leaf-litter decomposition of two man 1998.
27. Promod KC, Dhevendaran K. Studies on phosphobacteria in Cochin backwater. J Mar Biol Assoc India 1987;29:297-305.
28. Reddy KR, DeLaune RD. Biogeochemistry of wetlands: science and applications. CRC press 2008.
29. Rickard D, Morse JW. Acid volatile sulfide (AVS). Marine chemistry, 2005;97(3-4):141-197.
30. Rivera-Monroy VH, Day JW, Twilley RR, Vera-Herrera F, Coronado-Molina C. Flux of nitrogen and sediment in a fringe mangrove forest in Terminos Lagoon, Mexico. Estuarine, Coastal and Shelf Science 1995;40(2):139-160.
31. Sahoo K, Dhal NK. Potential microbial diversity in mangrove ecosystems: a review 2009.
32. Schoepfer VA, Bernhardt ES, Burgin AJ. Iron clad wetlands: Soil iron- sulfur buffering determines coastal wetland response to salt water incursion. Journal of Geophysical Research: Biogeosciences 2014;119(12):2209-2219.
33. Sengupta A, Chaudhuri S. Ecology of heterotrophic dinitrogen fixation in the rhizosphere of mangrove plant community at the Ganges river estuary in India. Oecologia, 1991;87(4):560-564.
34. Shao T, Gu X, Zhu T, Pan X, Zhu Y, Long X, Rengel Z. Industrial crop Jerusalem artichoke restored coastal saline soil quality by reducing salt and increasing diversity of bacterial community. Applied Soil Ecology 2019;138:195-206.
35. Sundareshwar PV, Morris JT, Koepfler EK, Fornwalt B. Phosphorus limitation of coastal ecosystem processes. Science 2003;299(5606):563-565.
36. Tobias C, Neubauer SC. Salt marsh biogeochemistry-an overview. Coastal wetlands 2019, 539-596.
37. van der Welle MEW, Cuppens M, Lamers LPM, Roelofs JGM. Detoxifying toxicants: interactions between sulfide and iron toxicity in freshwater wetlands. Environmental Toxicology and Chemistry: An International Journal

2006;25(6):1592-1597.
38. Varon- Lopez M, Dias ACF, Fasanella CC, Durrer A, Melo IS, Kuramae EE *et al*. Sulphur- oxidizing and sulphate- reducing communities in B razilian mangrove sediments. Environmental Microbiology 2014;16(3):845-855.
39. Vazquez P, Holguin G, Puente ME, Lopez-Cortes A, Bashan Y. Phosphate-solubilizing microorganisms associated with the rhizosphere of mangroves in a semiarid coastal lagoon. Biology and Fertility of Soils 2000;30(5):460-468.
40. Ventosa A, Nieto JJ. Biotechnological applications and potentialities of halophilic microorganisms. World Journal of Microbiology and Biotechnology 1995;11(1):85-94.