

Tidal coastal wetlands for wastewater management

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Abstract

Tackling the global water scarcity problem and inadequate clean water supply, caused majorly by various upsurging anthropogenic factors, must be addressed decisively by establishing a sustainable framework for effective wastewater treatment and

management. The tidal coastal wetland is a cost-effective and sustainable treatment ecosystem that is valuable in managing secondary treated effluents, as documented. It also ensures the delivery of safe water into the environment compared to conventional treatment methods. They have been labelled as one of the most productive ecosystems with high economic importance. However, factors such as climate change, sea-level rise, nutrient inputs and sediment delivery have impacted negatively on this wetland hence resulting in continuous degradation and loss. Therefore, this chapter first provides an overview of the various forms of tidal coastal wetlands and their economic importance. Next, case and modelling studies supported some key information on the essence of tidal coastal wetlands in the effective wastewater management process.

Keywords: Tidal coastal wetland, Ecosystem services, Wastewater treatment, Wastewater management



1. Background

Approximately 4% of the earth's land area is made up of coastal zones. These zones are important because they serve as a habitat for more than one-third of the global population and 95% of marine fisheries catch.¹ One of the most interesting features of coastal areas is the coastal wetlands. Some of the most economically important ecosystems have benefitted humanity with a range of ecosystem goods and services.²⁻⁴ In addition, they act as a buffer between terrestrial and aquatic ecosystems by preventing eutrophication in inland and coastal waters.⁵ Unfortunately, they are constantly being threatened by various factors such as a change in land use, rising sea levels, changes in global climatic conditions, increasing nutrient availability, overfishing, and many more.⁶⁻⁹ In addition, they undergo many environmental fluctuations over different periods because of their sensitive nature, making them more vulnerable, hence undermining potential benefits.² Changes in land use or alteration in hydrology caused by climate change or other anthropogenic factors are constantly having a devastating effect on these wetlands. Furthermore, coastal pollution caused by sewage and wastewater runoff has been described as a major hazard threatening human health and contributing to the cryptic degradation of coastal ecosystems.^{10,11} Meanwhile, tidal coastal wetlands (or other naturally occurring wetlands) can help reduce this sewage and wastewater pollution via sediment filtering and trapping, nutrient absorption, and reduction. Therefore, these ecologically sensitive ecosystems must be protected, particularly by implementing appropriate methods for sustainable management, especially in wastewater management.

Here in this chapter, an overview is first provided on some generally accepted definitions of wetlands and what tidal coastal wetlands represent. Different coastal wetlands were briefly discussed, such as marshes, swamps, bogs, estuaries, fen, and coral reefs. Some economic importance of this productive ecosystem: carbon sequestration, coastal protection, flood control, wildlife habitat, and food and water quality improvement were highlighted. A specific focus was then set on wastewater treatment and management fundamentals and how coastal wetlands can be helpful to wastewater management systems. This includes the review of some case and modelling scenarios. Some benefits of the wetland system as an effective wastewater management option were provided.



2. Wetland definitions

To start with, too many definitions have been used to describe what wetland means; some are even confusing, while others are contradictory. One of these confusions is caused by the nature of the environment, which is seasonally or permanently affected by water availability. Another source of confusion that seems more important is the specific requirements of the people engaging in the study and management of these wetlands. Although these contentions are not within this chapter's context, some definitions must be given to understand and manage the system properly. In subsequent sections, this will facilitate a better understanding of our discussion on tidal coastal wetlands.

The conservation and sustainable use of wetlands was made public by the Ramsar Convention during the Convention on Wetlands of International Importance, especially as Waterfowl Habitat, 1971. The convention unanimously defines wetlands as “Wetlands are areas of marsh, fen, peatland, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish, or salt, including areas of marine water, the depth of which at low tide does not exceed 6 m.”¹²

Wetlands are also defined concisely by Smith¹³ as “a halfway world between terrestrial and aquatic ecosystems and exhibit some of the characteristics of each.” This definition is relevant for regions where wetlands may only become “wet” for a short time during a year, with a perfect example being the tropics marked by wet and dry seasons.

Additionally, the Army Corps of Engineers of the U.S., in an effort to establish a uniform set of criteria, developed a three-criteria methodology hinged on vegetation, soils, and hydrology and later adopted it as national

standard. They defined wetlands as “areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions”.¹⁴

All the stated definitions show that wetlands largely encompass a wide range of hydrological and ecological factors. Whichever definition is adopted, it is essential to take cognizance of the presence of water, vegetation, and soil condition with respect to the prospective study to be undertaken.



3. Tidal coastal wetlands

Tidal coastal wetlands are in coastal areas usually influenced by alternating floods and ebbs of tides.¹⁵ They are generally identified as tidal salt marshes, tidal freshwater wetlands (marshes and forests), and mangrove swamps (Fig. 1). Mitsch and Gosselink¹⁶ reported that about 270,000 km² of coastal wetlands are available worldwide, representing almost 4% of all the wetlands in the world. More than half of this stated area of coastal wetlands are mangroves with tidal marshes.¹⁷ For example, the total reported extent of wetlands considered as coastal or estuarine wetlands in the U.S. is approximately 32,000 km² with salt marsh, tidal freshwater marshes, and mangrove swamps claiming 19,000 km², 8,000 km² and 5,000 km², respectively.^{16,18} Like other wetlands, tidal wetlands benefit humans by providing some goods and services



Fig. 1 Tidal coastal (freshwater) wetland. *Barendregt A. Tidal freshwater wetlands, the fresh dimension of the estuary. In: Finlayson C, Milton G, Prentice R, Davidson N, editors. The wetland book. Dordrecht: Springer; 2016. doi:10.1007/978-94-007-6173-5_103-2.*

(These goods and services are discussed later in the section). Unfortunately, they are constantly at risk of degradation or loss as a consequence of global change^{19,20} as rising surface temperatures drive accelerating rates of sea-level rise and also alter the intensity and frequency of tropical storms.^{21,22} To understand and match the common nomenclature given in literature, tidal coastal wetlands will be referred to as “coastal wetlands” in subsequent sections.

3.1 Coastal wetlands

As initially described in the introduction section, wetlands are highly productive ecosystems that can be seen in almost all places globally. They can either be natural or artificial (man-made). Coastal wetlands are transient zones between terrestrial and marine ecosystems,¹⁶ and depending on prevailing climatic and hydrological conditions; they can be grouped into several categories. We shall limit our discussion of the various form of these natural wetlands in this section. They include fens, estuaries, swamps, bogs, marshes, deltas, mires, lakes, coral reefs, lagoons, and floodplains. Below is a brief discussion of some of these wetlands as outlined by the Federal Geographic Data Committee.²³

3.1.1 Marshes

These wetlands have their soil constantly saturated with water and are mainly occupied with soft-stem vegetation. They act as protection by reducing the current flow of flood, storing excess water hence recharging the groundwater (Fig. 2). The slow migration of water in marshes helps the settlement of nutrients at the base form of high biodiversity, which the plants and microorganisms can utilize presents in marshes for their growth and development. Marshes are largely discovered or formed at the banks of rivers, particularly in regions where extensive deltas have been constructed.

3.1.2 Swamps

These wetland types are defined as flooded woodlands occurring in low-lying areas where the soil is supersaturated, especially during the growing season (Fig. 3). Swamps can be subdivided into forests, shrubs, and mangroves. Forest swamps occur at the coast region of water storage or reservoirs and are recipients of water from lakes and rivers. The nature of the tree growing in swamps are dry and deciduous. Meanwhile, mangrove swamps are characterized by halophytic (salt-tolerant) trees and plants. They are found chiefly in tropical and subtropical regions of vegetation.



Fig. 2 Tidal marshes. *Keddy. Freshwater marshes. In: Encyclopedia of ecology. 2008. p. 1690–1697. <https://doi.org/10.1016/B978-008045405-4.00338-4>.*



Fig. 3 Swamps. *Burton TM. Swamps: wooded wetlands. In: Likens GE, editor. Encyclopedia of inland waters. Amsterdam, The Netherlands/Boston, MA, USA: Elsevier; 2009. p. 549–557. doi:10.1016/B978-012370626-3.00063-6.*

3.1.3 Bogs

Bogs are characterized by peat soil/peat-deposited freshwater wetlands, having poor nutrients and weak acidic soil conditions (Fig. 4). They are created when organic materials such as leaves, litter, and other organic materials naturally decompose over time due to active microbial processes. The central parts of the bog are supplied by rainwater and are predominant in glaciated areas of the Northern United States of America.

3.1.4 Estuaries

These wetland types develop where freshwater from the river meets saltwater, thus creating habitats rich in nutrients and sediment from the land and sea, connecting the two for the growth of microorganisms and plants (Fig. 5). They are regarded as a habitat of high conservation value because of the varieties of conditions favorable for the living welfare of wildlife. However, they can be affected by climate change, inappropriate catchment development, increased algal bloom, degree of tides, and nutrient input. Some measures to tackle these problems include improving catchment areas, restricting fishing, and native vegetation, reducing pollution and sedimentation, and so on. Types of estuaries include deltas, salt marshes, tidal mud flats, and channels.



Fig. 4 Bogs. Butt MA, Zafar M, Ahmed M, Shaheen S, Sultana S. Types of wetland and wetland plants. In: Wetland plants. Cham: Springer; 2021. doi:10.1007/978-3-030-69258-2_3.



Fig. 5 Estuary. Balasuriya A. *Coastal area management: biodiversity and ecological sustainability in Sri Lankan perspective*. Biodivers Clim Change Adapt Trop Islands 2018;701–724. doi:10.1016/B978-0-12-813064-3.00025-9.



Fig. 6 *Carpha alpina* fen. Hope GS. *Nature of Alpine ecosystems in the tropical mountains of Asia*. In: Encyclopedia of the World's biomes; 2020, p. 300–310. doi:10.1016/B978-0-12-409548-9.11980-3.

3.1.5 Fen

These wetland types are characterized by low shrubs, sedges, and abundant grasses. Just like bogs, there is peat soil although alkaline in nature (Fig. 6). Their water table is usually close to the surface, and their surface often has a

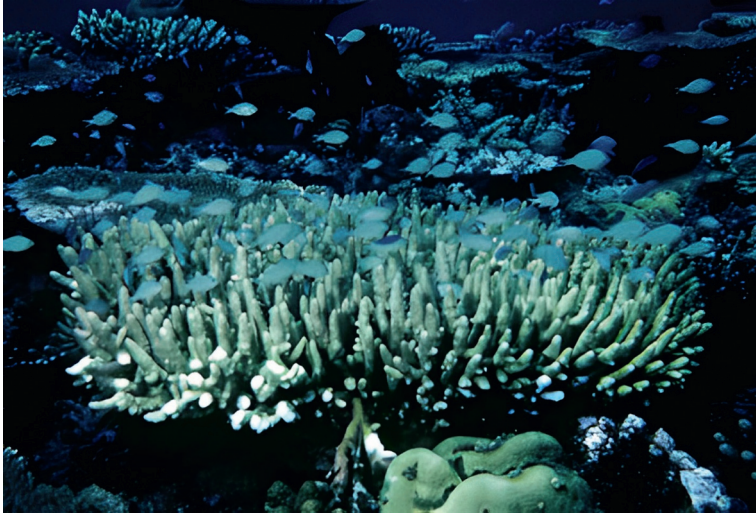


Fig. 7 Coral reefs. *Burkepile DE, Hay ME. Coral reefs. In: Encyclopedia of ecology. 2nd ed. 2008; vol. 2, p. 426–438. doi:10.1016/B978-0-444-63768-0.00323-1.*

micro-relief of hummocks, hollows, and pools. The nature of the fen largely depends on the geologic settings and the proportions of lateral inflow from surroundings water and not necessarily from precipitation. Like the estuaries, they are productive habitats having nutrient-rich condition that provides a diversity of plant life, which in turn supports several animal species that thrive in them.

3.1.6 Coral reefs

These are among the most productive and diverse existing ecosystems covering approximately 0.1–0.5% of the ocean floor (Fig. 7). Coral polyps (the animal responsible for building reefs) can take several forms. The reefs are known as the “rainforests of the sea” due to the diversity of life in the corals’ habitats. Many marine fishes depend on healthy coral reefs for their shelter, food, reproduction, and even raising their young.



4. Significance of coastal wetlands ecosystem services

Although tidal coastal wetlands have not been given the deserved attention and care, they have been beneficial in no small measure, especially in human well-being and economic development in the past Century^{24–26}. Many of them depend totally or partly on groundwater for their hydrological balance. Generally, some of the important services provided by the tidal

coastal wetland's ecosystem include carbon sequestration, flood protection, sediment accumulation for land accretion, habitation for wildlife, tourism resorts, water/wastewater quality improvement, management, etc. However, these services were better categorized into four classes by the Millennium Ecosystem Assessment,²⁷ as given in [Table 1](#).

Three of these critical ecosystem services are briefly described below with the exception of water and wastewater quality improvement and management. This will be covered in more detail in [Section 5](#).

4.1 Carbon sequestration

Coastal wetlands have been one of the most critical and cost-effective ecosystems used for atmospheric carbon(iv)oxide (CO₂) sequestration.^{28–31} This concept has been an excellent option for combating the climate change impacts in the world, and this has been achieved at no or limited costs.^{30,32} The process of sequestering CO₂ in natural or artificial sinks is generally referred to as carbon sequestration (C.S.), and this is achieved in such a way that it can be maintained within the sink for an extended period with minimal chances of returning into the atmosphere.^{33,34} This is the exact role of coastal wetlands. They help the reduction of atmospheric CO₂, and it is either sequestered as organic material in the soil or in plant and animal

Table 1 Tidal coastal wetland ecosystem services categories.

Ecosystem services categories	Structures and functions
Provisioning	This aspect of services deals with products such as food, fiber, timber, water, genetic resources, and other raw materials
Regulating	This aspect of services deals with flood protection, carbon sequestration, sediment stabilization, erosion control, coastal protection from storms, water purification and supply, pollution uptake, disease regulation, pollination, climate regulation, air quality regulation, and natural hazard regulation
Cultural	This service addresses the unique and aesthetic landscape of cultural heritage, spiritual enrichment, ecotourism, recreation, formal and informal education, and research
Supporting	This service includes nutrient cycling, reproductive habitat and nursery for fish, standardizing living space for diverse flora and fauna, and gaming

biomass. This usually results in massive organic carbon accumulation in wetland sediment.³⁵ The average long-term carbon sequestration rates in soils or sediments for swamps, marshes and mangroves are almost 20 greater than in the forest.³⁶ Although one of the sources of greenhouse gas emissions is the coastal wetlands, they are produced in small quantities owing to the sulfate-reducing bacteria in the saline water. These will subdue the methanogens bacteria by outshining them for energy sources.^{37,38} Several global-scale estimates of carbon sequestration and storage in coastal wetlands have been reported (Refs. 39–44).

4.2 Coastal protection and flood/erosion control

Dwellers of coastal regions are at greater risk of flooding because of continuous developmental activities resulting in intensifying storms and sea level rise. Up to 5% of the global population will be directly affected annually by coastal flooding.^{45–47} Seawalls' defense structures have been built to manage flood risks. However, it is more beneficial to adopt nature-based coastal protection, such as wave- and surge-absorbing coastal wetlands.⁴⁸ Coastal wetlands offer a natural protection against coastal flooding and storm surges mainly by dissipating wave energy. They represent buffers between the winds and waves of storms and the areas beyond. The salt marshes are the most effective natural coastal habitats for reducing wave heights, along with coral reefs, which represent areas drained by tides and coastal wetlands flood.^{49,50} In addition, wetland plants and trees can reduce flood water speed, thus helping to guard nearby property against flood damage. Coastal wetlands also reduce coastal erosion by strengthening the shore sediments and riverbanks of the region, and this is achieved by binding soil with their roots. This action helps dampen wave action and absorb tidal forces.⁵¹ When located between rivers and high ground, they aid in buffering shorelines against erosion.

4.3 Wildlife habitat and food

Another great potential and resourcefulness of the coastal wetland ecosystem are its high plant productivity rates in which the sun's energy is converted into plant materials. Thus, this represents a unique food web for wildlife species within and outside the wetland. In addition to being a source of food, these wetlands (especially the areas of dense vegetation) are the place of home and shelter for wildlife.²⁵ These abodes even represent a place of security for this wildlife to hide from predators. The nature of the water in these

coastal wetlands determines the kinds of plants and animals that survive and live there, which could be salty or fresh. Some of these wetlands remain wet, while some dry out after some seasons. Some plants that cannot tolerate salt wither and die when it is salty and moist, while salt-tolerant plants such as Pickleweed thrive. Tides sometimes migrate seawater from the ocean, and during this movement, tiny particles of plants and animal decay called detritus are transported alongside. Some animals, such as shrimp, bent-nose clams, and innkeeper worms, thrive on this detritus. Wetland is the primary habitat of some species like muskrats, bullfrogs, Canadian geese, wood ducks, great blue herons, beaver, snapping turtles, etc. In contrast, other species such as wood frogs, black bear, moose, deer, and marsh hawks do not primarily dwell in these wetlands but serves as an essential habitat for a part of their life cycle or during specific periods of the year.



5. Coastal wetlands wastewater management study

5.1 Preamble

Man's daily activities are filled with water-dependent situations that often lead to water pollution, making them available and limited useable water highly polluted. When water's chemical, biological or physical state or properties change due to the introduction of contaminants and pollutants to the degree that they render the water unsafe for use, it is termed wastewater.⁵² This polluted water must be treated and effectively managed to meet water demand and shield the environment.⁵³ Due to the various degree and types of contaminants present in wastewater, it is often difficult to identify and quantify them. Therefore, some universal parameters to assess the quality of water include pH, temperature, conductivity, total suspended solids (TSS), total Kjeldahl nitrogen (TKN), ammonium ($\text{NH}_4^+ - \text{N}$), nitrate ($\text{NO}_3^- - \text{N}$), total phosphorus (T.P.), biological oxygen demand (BOD) and chemical oxygen demand (COD).^{53,54} One of the undisputable roles of wetlands is the overall water quality improvement, which can be achieved through the treatment and management of wastewater.^{55,56}

Generally, wetlands are good water filters. They act as media for water storage and are highly relevant in improving the quality of water stored in them or water runoff coming into them from other sources.⁵⁷ They clean the water, replenish groundwater, and regulate the runoff in urban areas. Numerous plants that grow in wetlands serve as filters by purifying the water that will eventually be discharged downstream.^{58,59} Historically, the use of wetlands to treat, remediate and manage wastewater is dated back to the Indus valley civilization as far back as 2500 BCE before the industrial

revolution. Still, the inception of the industrial revolution enhanced technological advancement. At this period, the primary criteria for treating wastewater had been established.^{52,60} The self-cleaning ability of water via wetlands to naturally remove contaminants was explored, and this has been focused on for several decades as more systems were put in place to improve water quality.⁶¹ It is one of the most preferred systems for improving water quality emanating from different water pollution sources up to date because of their economic benefits. Although, the use of constructed or artificial wetlands for treating and managing wastewater could incur grave costs depending on some other factors (Refs. 55,62,63). Under wastewater management, coastal wetlands can either serve as a single treatment entity or may be incorporated as a part of an integrated wastewater treatment system. Meanwhile, their long-term stability in performing this management role effectively depends on the interaction between sea level rise, sediment deposition, vegetation growth, and human factors.^{64–66}

5.2 Wastewater treatment and management by coastal wetland

Coastal wetland renders many vital ecosystem services and functions, as highlighted in Section 4. Another such function is water and wastewater treatment and quality improvement. For an extended period, natural wetlands, including coastal types, have been a perfect substitute for conventional wastewater treatment systems, especially at the tertiary treatment level⁶⁷ after undergoing secondary treatment. This has been predominantly employed in the U.S. and Europe. In modern wastewater treatment evolution, it is required that wastewater can only be discharged into the environment after undergoing a three-level stage of treatment processes, namely primary treatment (which deals with the removal of heavier solids by gravity sedimentation),⁵³ secondary treatment (which entail using oxidation and microbial decomposition)⁵² and tertiary treatment (which involves the removal of nitrogen and phosphorus using wetlands system or alum/chlorination).⁶⁸ This is done to reduce the potential risk that discharged wastewater limited only to secondary-level treatment could pose on aquatic systems.⁶⁹ Economic treatment of wastewater at the tertiary level is thus made possible by wetlands.⁶⁸

5.3 Case and modelling studies

The scientific study of wetlands in treating wastewater commenced comprehensively a few decades ago, although they have been used to treat

wastewater for centuries. At inception natural wetlands were predominantly used for this purpose before the invention of constructed wetlands,⁷⁰ although the latter is mainly used today. Several natural wetlands have been reported as effective processors of wastewater effluent and wastewater assimilators, and they ascertain that they can physically, chemically, and biologically eliminate pollutants, sediments, and nutrients from wastewater flowing through or discharged in them.^{69–73} And for coastal regions like Louisiana in the U.S., often characterized by degraded water quality caused partly by inadequate sewage treatment, these wetland functions are paramount in addressing the issue.^{70,74} Although, only in a few cases have scientists (especially in the U.S.) conducted research in coastal wastewater facilities in states like Louisiana,⁷⁰ North Carolina,^{75–77} and South Carolina⁷⁸ and focused on the wastewater management aspect in the practical term. In this regard, most of the works in the U.S. and other countries are computational. Researchers adopt modeling studies as a form of best water quality management practice, and this has largely been used to address non-point source pollution control problems.⁷⁹ By this, a mathematical model can be developed and employed to simulate hydrodynamics, water quality, and the ecosystem. This can then be verified with the field data and, when in agreement, can be applied to predict the various conditions of hydrological and waste input related to the ecosystem dynamics. Some hydrodynamic modeling of the water column in the wetland system has been studied.^{80–82} Furthermore, water quality and ecosystem models have been used to model fate and transport phenomena for contaminant and water quality management in wetlands ecosystems.¹⁵

A one-dimensional simulation model of wetland hydrology and nutrient-driven interactions between wastewater and the wetland ecosystem was developed by Kadlec and Hammer.⁸³ The hydrology model predicted the overflow patterns, and mass balance calculations were engaged for the phosphorus, nitrogen, and chloride fluctuations. Their investigation also included environmental phenomena like plant biomass growth patterns. Also, Mitsch and Reeder⁸⁴ developed a wetland nutrient model in which hydrology, productivity, and phosphorus were calibrated using field data from a freshwater coastal wetland of Lake Erie, one of the North American Laurentian Great Lakes. The model was used to supplement field data to quantify the overall contribution of ecosystem metabolism, sedimentation, resuspension, and lake hydrodynamics to the cycling and retention of phosphorus in the wetland. Lung and Light⁸⁵ developed a numerical model and used it to simulate the fate and transport of copper in the Old Woman Creek wetland ecosystem in Northern Ohio, USA. Using Nielsen's nutrient

uptake equation, they calculated the relative contributions of sedimentation, macrophyte uptake in the removal of copper from wastewater, and copper speciation in the water column and sediment. Their findings demonstrated that sedimentation and macrophyte absorption promote copper elimination. Mitsch and Wise⁸⁶ estimated the phosphorus retention of existing and restored coastal wetlands in a tributary watershed (Quanicassee River basin) of the Laurentian Great Lakes in Michigan, USA. They discovered that a straightforward Vollenweider-type model could serve as a rational tool to give better information on how and what can be expected in terms of phosphorus reduction under various wetland restoration scenarios. The model also showed how important inflows, wetland depth, previous soil conditions, and restoration efforts were in relation to one another. Yang et al.¹⁵ developed a water quality and ecosystem model to simulate nutrients, heavy metals, and aquatic plants in the Erh-Chung Flood Way wetland in Taiwan. A sediment system was also incorporated into the model. RMA2 and WASP/EUTRO5 models were used to calibrate four water quality variables: macrophyte biomass, suspended solids, heavy metals in macrophytes, and heavy metals in the water column and sediment. Collecting site-specific water quality data supported the model calibration and verification analyses.¹⁵ Other works using mathematical models to simulate hydrodynamics, water quality, and ecosystem parameters in natural wetlands have been documented.^{86–88} Meanwhile, most of the modelling studies recently being carried out are geared toward constructed wetlands.^{89–92}

5.4 Benefits of coastal wetland wastewater treatment system

Some benefits accrue from using coastal wetland systems for water treatment and management aside from the low operating cost compared to man-made or constructed wetlands and conventional treatment methods. These benefits are briefly discussed as follows:

(i) Reduced cost of treatment

Proper wastewater treatment and management processes could be capital demanding as they require the initial installation capital cost and the continuous operating and maintenance cost. During wastewater treatment operations, specific treatment levels of water quality parameters such as pH, BOD, COD, and so on are set to ascertain the safe quality of the discharged effluents, and this is mostly associated with conventional treatment processes (including physical, chemical, and biological processes) which are considerably expensive. However, some of these treatments can be

undertaken at reduced rates if coastal wetlands are used as an initial approach to filter off and absorb nutrients and contaminants present in the wastewater.

(ii) Higher level of treatment

For continuous sustainability of natural wetlands (both coastal and inland), there is a need for a constant influx of nutrients for biomass growth. Wetlands' natural growth and decay may not be sufficient to maintain high-quality vegetation. Although the place of macrophytes in water purification and treatment is not direct, they remain a valuable structural medium.^{93–96} The primary removal of phosphorus and heavy metals is accomplished by chemical processes such as adsorption, chelation, and precipitation, which are facilitated by macrophyte vegetation's attenuation of water flow and sedimentation of particulate matter.^{11,97} They also stabilize the wetland soil surface while the soils themselves act as absorption mediums for pollutants.¹¹ Therefore, when vegetation quality is improved with respect to volume and health, the wastewater treatment ability is greatly increased, even to higher levels compared to conventional treatment methods.⁵⁵ For instance, wetlands often treat up to tertiary standards, while most traditional methods are stopped at the secondary treatment level. In addition, wildlife habitat and other visual characteristics are also enhanced.

(iii) Improvement in water quality

The water quality of existing receiving water bodies such as lakes, ponds, and so on may be improved when polluted water is rechanneled into wetlands before discharging into the surface or groundwater sources. This is more appropriate when the discharge made into the existing receiving waters meets the discharge standards. However, the economic value of this water quality improvement may be difficult to assess.⁵⁵



6. Conclusion

The wastewater management process, which essentially encompasses wastewater treatment, is not a choice but an obligation to ensure sustainable environmental protection. The use of wetlands (both natural and artificial) for effective treatment and management of wastewater has been established over the last Century. Coastal wetlands belong to the natural category of treatment which is effective in treating tertiary effluents of various categories. They have a cost advantage compared to constructed (or artificial) wetlands and other conventional treatments. In this chapter, an overview was provided on coastal wetlands as productive ecosystem services which are

beneficial to humans, wildlife, and the economic development of a nation. Although reports have been released on the continuous global loss of these natural wetlands, they have negatively impacted these productive ecosystems. In this light, some useful information was provided on the essentiality of wastewater treatment and management using coastal wetlands as a reminder. Some previous studies done in this respect were briefly highlighted, and the benefits of using this wetland system for water treatment and management before discharge are also explained. As limited studies have reported the use of coastal wetlands for water management, this chapter thus supplements the relevance of coastal wetlands in water treatment and management.

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