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Current scenario, services, concerns, and restoration perspectives of ponds in India

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ABSTRACT

Ponds are self-sustaining and self-regulating ecosystems that are a vital part of the hydrological cycle and play a variety of roles in the biosphere. Ponds are diverse, extremely dynamic, and highly productive as they offer various services like harbor biodiversity, tool for combating water scarcity, have roles in pollution mitigation and carbon sequestration. Ponds also offer sustainable solutions to support climate change amelioration and aquatic resource management. However, ponds are the most neglected aquatic ecosystems, despite their huge ecological functions. Thus, ponds are debasing at an alarming rate as a result of increased anthropogenic activities and anthropogenically driven changes in natural processes, wreaking havoc on ecological health and water quality. In this context, the major threats to ponds include the dumping of solid waste, increased urbanization, pollution, encroachment and climate change which have resulted in the deterioration of ponds over the years. Sustainable management and restoration of ponds are crucial as this ecosystem offers a wide array of ecological functions. As a result, this research aims to assess the current state of ponds in India in terms of monitoring, ecological services provided, and the various threats to which they are subjected. Further, the discussions on management and perspective restoration strategies of this substantial ecosystem are also included. Thereby, this study suggests better conservation strategies for restoration, reclamation, and sustainable utilization of ponds.

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1. INTRODUCTION

The word pond means “artificially banked body of water” which is a variant of the word pound which means “enclosed space”. Ponds can be natural or man-made small water bodies that generally hold water for at least four months in a year. The size of ponds can vary from 1 m^2 to about 5 hectares (Zamora-Marín, Zamora-López, et al., 2021). Ponds can be found in almost all terrestrial ecosystems ranging from polar to rainforests. Since both ponds and lakes are lentic water bodies; it is difficult to differentiate between the two but there are growing shreds of evidence that functionally both are different (Taguchi et al., 2020). The temperature of a pond is comparatively constant as it varies with air temperature. In the case of lakes, the temperature variations take place in winters and summers. Like any other ecosystem, ponds derive their energy from the sun and phytoplankton act as primary producers. Naturally formed ponds are small and shallow and the depth of ponds can be half a meter. Many natural ponds are temporary and easily get filled with water over a period of time. Ponds are commonly found in areas in which water is nearby to the surface or in ample amount. Ponds can act as a habitat to several plants and animal populations irrespective of their shape, size, and depth.

Despite their small size, ponds are extremely rich in biodiversity (Williams & Fryirs, 2020). Ponds are well-known for their biotic complexity and lushness as they act as a habitat for aquatic flora and fauna. At the national and international levels, ponds are important for many endangered and rare species of aquatic organisms and they contribute to regional biodiversity as well. Moreover, the biogeographic turnover rate of aquatic species of ponds is higher than any other water body (Céréghino et al., 2012; Zamora-Marín, Ilg, et al., 2021). A perusal of literature indicates that natural and man-made ponds are ecologically similar and perform various ecological roles in the biosphere (Dalmolin et al., 2020; De Marco et al., 2014). Thus, ponds often create "biodiversity hot spots" within a region and show higher environmental and biotic amplitude than other water bodies (Deacon et al., 2018).

Ponds are an important part of the hydrological cycle which performs a miscellaneous role in the biosphere. In terms of biodiversity, ponds are usually considered insignificant in comparison to lakes and rivers (Fu et al., 2018). But recent studies have revealed that ponds contribute to regional biodiversity and act as a stepping stone between aquatic ecosystems and landscapes (Johansson et al., 2019). Ponds contain a massive diversity of biotic as well as abiotic components that contribute to regional biodiversity. There are about 2,77,400,000 small water bodies of 1 to 10 hectares present all over the world (Biggs et al., 2017; Khilchevskyi & Grebin, 2020). These small water bodies constitute 90% of the global standing water bodies and 30% of lentic water bodies by surface area.

Ponds have some historical value also, as the sediments record of ponds can tell us about the way of living of our ancestors. Ponds also play an important role in maintaining a relationship between wildlife and people (Dubey, 2013). Ponds can provide ample opportunities in teaching and research as they can be used as a model to validate scientific theories. The science subjects like conservation biology, evolutionary biology, climate change modeling, etc. are studied by taking pond as a model. They can play a vital role in offering a sustainable solution to climate change and freshwater resource management. In the context of agro-tourism and farm diversification, ponds can act as an asset to mankind. In addition, ponds perform numerous functions like regulation of temperature and humidity. Despite their small size, ponds act as stepping stone that shows a range of benefits to the surrounding ecosystems (Berg et al., 2016; Stefanoudis et al., 2017). Thus, ponds need special consideration because of their ecological and social importance. For the present manuscript, a systematic review of literature and web search was conducted and papers from the past twenty years were studied. The websites were mainly WoS and Scopus. This paper is an effort to review the status of ponds in India in terms of monitoring, ecological services they offer and several strains they are exposed to with management and restoration strategies of this substantial ecosystem.

2. Status of ponds in India

There are about 4111 water quality monitoring stations in India. The maximum water quality stations are for rivers and lakes. There is only 106 pond water quality monitoring stations in India (Table 1). The maximum monitoring stations for pond water quality are located in Assam (27) followed by Manipur (13) and Telangana (13) (CPCB, 2020).

Many biologists tend to overlook studies on pond ecosystems, maybe due to their small size. The monitoring of the pond ecosystem in India is scanty. The studies conducted on the pond ecosystem are also meager. Some researchers have independently conducted research on pond water quality throughout India. Most of the investigations have been analysed for the physico-chemical properties of water. Some of the studies conducted on the assessment of the physico-chemical properties of pond water are given in Table 2.

Table 1. Number of pond water monitoring stations in India

No.	State/UT	Number of monitoring stations
1.	Assam	27
2.	Manipur	13
3.	Telangana	13
4.	Madhya Pradesh	12
5.	Tripura	10
6.	Odisha	8
7.	Punjab	3
8.	Bihar	2
9.	Gujarat	2
10.	Kerala	2
11.	Uttar Pradesh	2
12.	Mizoram	2
13.	Chhattisgarh	1
14.	Jharkhand	3
15.	Lakshadweep	3
16.	Goa	1
17.	Haryana	1
18.	Rajasthan	1
Total		106

3. Environmental services of ponds

Ponds provide various ecological services and act as biodiversity hotspot in terms of species conformation and biological characteristics. Ponds can potentially provide a long-term viable solution to climate change and water management challenges. Many researchers have used ponds to remove phosphorous, sediments, and nitrogen from the polluted water (Alemu et al., 2018; Arbib et al., 2017). Ponds are also used to decrease the nutrient load of the drainage system through sedimentation and de-nitrification processes, and in some cases, uptake of nutrients is done through the selection of wetland plants (Lischeid et al., 2018). Ponds have also shown their importance in carbon sequestration like oceans (Gilbert et al., 2021). Ponds have similar features as that of small wetlands but have received little attention in terms of their conservation. Ramsar convention and literature studies have defined ponds as wetlands, and have revealed their role in biodiversity conservation (Greenhalgh et al., 2021; Labat, 2017). Management of pond ecosystems is vital because they provide habitat to numerous species of endangered plants, amphibians and invertebrates. Moreover, ponds also play an important role in learning about wetland wildlife (Brönmark & Hansson, 2017). So, as per the need of the hour, it is essential that conservation programs of freshwater resources should declare ponds as wildlife reserves or sites of special scientific concern. In spite of their great significance, ponds are under threat of extinction due to changes in land-use patterns, dumping of solid wastes, and negligence of Government authorities. In addition to this, climate change is also playing a miscellaneous role in the diminishing of natural ponds.

Table 2. Studies on the analysis of pond water quality in India

Study area	Parameter studied	Result	Reference
Orai, Uttar Pradesh	Physico- chemical	pH value ranged from 8.88 to 9.4; TDS 1007.69 to 1378.75 mg/L; EC 2270 to 2640 µS; DO 6.74 to 9.23 mg/L, BOD 2.21 to 2.81 mg/L; total hardness 246.96 to 273.62 mg/L	Yadav et al. (2013)
Sasaram, Bihar	Physico-chemical and biological parameters	All the parameters were within the permissible limits for fish culture except BOD which was under moderately polluted category	Choudhary et al. (2014)
Varanasi	Physico-chemical	The ponds were highly polluted and unsafe for human use as TDS, BOD, nitrate and phosphate were above the permissible limits	Mishra et al. (2014)
Bhimavaram Town Andhra Pradesh India	Physico- chemical	EC 1120 to 2820 µS; TDS 724 to 1607 mg/L; BOD 6 to 10.11 mg/L; chloride 678 to 823 mg/L; calcium 396 to 417 mg/L; total hardness 1002 to 1348 mg/L; nitrate 58 to 67 mg/L; sodium 335 to 409 mg/L; potassium 67 to 79 mg/L	Jhansilakshmi (2015)
BITS Pilani, Rajasthan	Physico-chemical	pH values ranged 7.4 to 7.9; EC 1300 to 1680 µS; TDS 283.72 to 394.67 mg/L; DO 5.51 to 7.12 mg/L; total hardness 85.86 to 118.63 mg/L; total alkalinity 150.41 to 193.22 mg/L	Verma and Khan (2015)
Bihar University	Physico-chemical and biological characteristics	pH value of water was maximum (8.5) during summer; temperature was maximum during summer; total dissolved solids were maximum (178 mg/L) during rainy season; dissolved oxygen was maximum (9.6 mg/L) during rainy season; BOD was maximum (2.88 mg/L) during rainy season; free CO_2 was maximum (15.50 mg/L) during summer, total hardness was maximum (117 mg/L) during summer and maximum total alkalinity (226 mg/L) was observed during rainy season	Kumar and Sinha (2017)
Chapra District, Saran, Bihar	Physico-chemical	The water was highly alkaline; rich in calcium with bicarbonate type alkalinity	Singh and Kumar (2017)
Kolkata, West Bengal	Physico-chemical	Temperature 29.62 to 33.8°C; DO 4.2 to 7.46 mg/L; BOD 1.6 to 2.5 mg/L; COD 56.8 to 75.1 mg/L; phosphate 0.17 to 0.23 mg/L; total alkalinity 40 to 90 mg/L	Goswami et al. (2017)
Odisha	Physico-chemical	Pond water quality of two stations PW1 and PW2 was good, while water quality of two stations PW3 and PW4 of study area was unfit for drinking purposes	Meher et al. (2018)
Amritsar, Punjab	Pesticides	40.02% of water samples were found contaminated with multi-residue pesticides, carbofuran was the most abundant pesticide which was present in 18.18% samples.	Rajput et al. (2018)
Mount Abu, Rajasthan	Physico-chemical	pH 7.12; TDS 142.0 mg/L; dissolved oxygen 5.45 mg/L; total hardness 104.83 mg/L; nitrates 28.57 mg/L; sulphate 122.28 mg/L; total alkalinity 98.50 mg/L	Gothwal and Gupta (2019)
Amritsar, Punjab	Heavy metals	Cu 564.55±9.057 µg/L; Ni 225.45±91.81 µg/L; Zn - 860±48.41 µg/L; Cr - 857.91±57.81 µg/L, As - 18.36±4.23 µg/L; Pb - 130.93±49.73 µg/L; Cd - 8.21±1.81 µg/L) Co - 631.96±77.09 µg/L; Se - 2315.45±67.18 µg/L).	Rajput et al. (2020)
Kolkata, West Bengal	Physico-chemical	Water temperature 22-21.3 °C, pH value 7.9, conductivity 218.50 µS/cm, DO 8.47 mg/l, BOD 5.69 mg/l, TDS 135.19 ppm, TSS 67.60 ppm, total alkalinity 181.15 mg/l, total hardness 145.66 mg/l and chloride 58.94 mg/l.	Sarkar et al. (2020)
Allahabad, Uttar Pradesh	Physico-chemical	pH 7.45-9.68; DO 3.85-6.45 mg/L; BOD 12-72 mg/L; Turbidity 68-312 NTU; Total nitrogen 2.56-5.46 mg/L; total coliform and fecal coliform 3000-13000 MPN/100 ml and 2400-10000 MPN/ 100ml.	Shukla et al. (2020)
Krishna District, Andhra Pradesh	Physico-chemical	Temperature, pH and total alkalinity mean values were highest in summer and lowest in winter whereas DO was maximum in winter and minimum in summer	Dey et al. (2021)
Aurangabad, Bihar	Physico-chemical	Overall pollution index ranged between 2.70 to 3.50 whereas water quality index ranged between 165.83 to 224.58 which indicate its high pollution load and unsuitability for animal and human consumption.	Pandit et al. (2022)

Remarks: data is extracted from various studies individually conducted in India and arranged in chronological order.

Change in land use patterns is the main concern for ponds, as they undergo easy encroachment by people in comparison to rivers and lakes (Vad et al., 2017). Moreover, the protection and conservation of ponds are vulnerable due to a lack of knowledge on pond ecology. In addition, due to their complex nature, the conservation of ponds has proved to be quite challenging to freshwater biologists. Biologists have developed some techniques to analyze the conservation value of ponds but it still needs improvement. Céréghino et al. (2014) suggested that ponds can play an important role in providing a sustainable solution to water management problems. Although ponds are small in size, their ecological roles are considerable.

3.1. A tool for combating water scarcity

Ponds provide enormous opportunities in combating water scarcity by managing the freshwater ecosystem (Stewart et al., 2017). Climate change has altered the precipitation pattern in most parts of the world. It has amplified the amount of rainfall in even water-scarce areas (Narayanan & Getachew, 2021). This change has affected all the major sources of water including aquifer recharge leading to a diminution in the water table. Thus, storing water even at a small scale can be useful in providing water security. This can make a significant contribution to safeguarding the livelihoods and reducing water conflicts in rural as well as in urban areas. During the dry months of the year, this stored water can be used for domestic and agricultural purposes.

3.2. Biodiversity hotspot

A pond is a common aquatic ecosystem that contributes to various processes of biosphere and biodiversity preservation (Sahuquillo & Miracle, 2019). Ponds contribute to aquatic biodiversity as much as lakes and rivers. Ponds serve as habitats for a diverse range of aquatic flora and fauna. Ponds preserve and protect a wide variety of organisms and are also known for their biotic complexity and richness (Jooste et al., 2020; Thornhill et al., 2018). Ponds have a range of aquatic plants, amphibians, aquatic invertebrates, and a few mammals. Even, if some ponds are situated in proximity, they show diverse hydrological behaviour (Lee et al., 2015).

3.3. Role in carbon sequestration

Small water bodies have immense potential for carbon sequestration. Ponds have shown their potential for maintaining the carbon balance by acting as carbon sequesters (Sahuquillo & Miracle, 2019). Ponds tend to have higher carbon sequestration capacity due to their lower oxygen concentration as compared to large water bodies. Ponds and lakes cover approximately one-third of the continental water, thus making them important carbon sequestration sites (Manoj & Padhy, 2015). Organic carbon burial in the form of sediments is more in small water bodies than in large ones (Al Sayah et al., 2020). For example, due to the infinite number of ponds on earth, they sequester more biological carbon in a year than any ocean. A single pond of 500 m^2 area can sequester 1000 kg of carbon per year (Céréghino et al., 2014).

3.4. Role in pollution mitigation

Ponds can be used to mitigate water pollution (Nélieu et al., 2021). Generally, large surface water bodies are at the receiving end of pollutants discharged by industries. Ponds can be strategically made in such a way that they intercept water from the drainage system before final disposal into receiving water bodies (Céréghino et al., 2014). This can be helpful in reducing the nutrient load on large water bodies (Mullins & Doyle, 2019).

3.5. Miscellaneous services

Ponds also perform miscellaneous services in the biosphere like regulating humidity and temperature. Ponds enhance the rate of groundwater infiltration and alter the evaporative loss of water (Sidhu et al., 2021; Stewart et al., 2017). Ponds are not restricted only in performing a role at the local or regional level, but also in global biogeochemical cycles (Sahuquillo & Miracle, 2019). They are also used by a freshwater biologist to test scientific theories on conservation and evolution biology (Hill et al., 2018). Some scientists are also using ponds as a model for studying the impact of climate change. Ponds have enormous value in terms of biodiversity and are essential for a sustainable environment (Dubey, 2013).

4. Environmental issues related to ponds

Ponds are of immense significance to human civilization as they act as a water resource for domestic, agricultural, and industrial use. Although, ponds are essential to humans, the structure and functions of these freshwater ecosystems are currently being threatened by several anthropogenic activities (Magnus & Rannap, 2019). This has resulted in the deterioration of the pond ecosystems. (Fig.1). The toxic waste of industries, agricultural runoff, and municipal waste disposal has made ponds futile and perilous. Ponds are also threatened by nutrient load resulting in eutrophication, degradation of buffer zones, pollutants inflow from industries, and numerous atmospheric processes (Alfonso, 2017; Grasel et al., 2018).

4.1. Encroachment

Various development projects like construction and extension of roads, buildings, railway tracks, *etc*. cause an alteration in the topography of surrounding areas including rivers, lakes, and ponds. Encroachment further causes habitat loss, a decline in water quality, disturbs equilibrium, and a reduction in ecological functions. It eventually increases nutrient availability, eutrophication, and an increase in water temperature, ultimately decreasing the water quality (Rodríguez-Rodríguez et al., 2021). Furthermore, increased urbanization, change in land-use patterns, road and housing development activities have led to the extinction of a large number of ponds throughout the world. Moreover, water from ponds is used for agricultural and domestic purposes which results in the untimely drying of ponds (El Madihi et al., 2017).

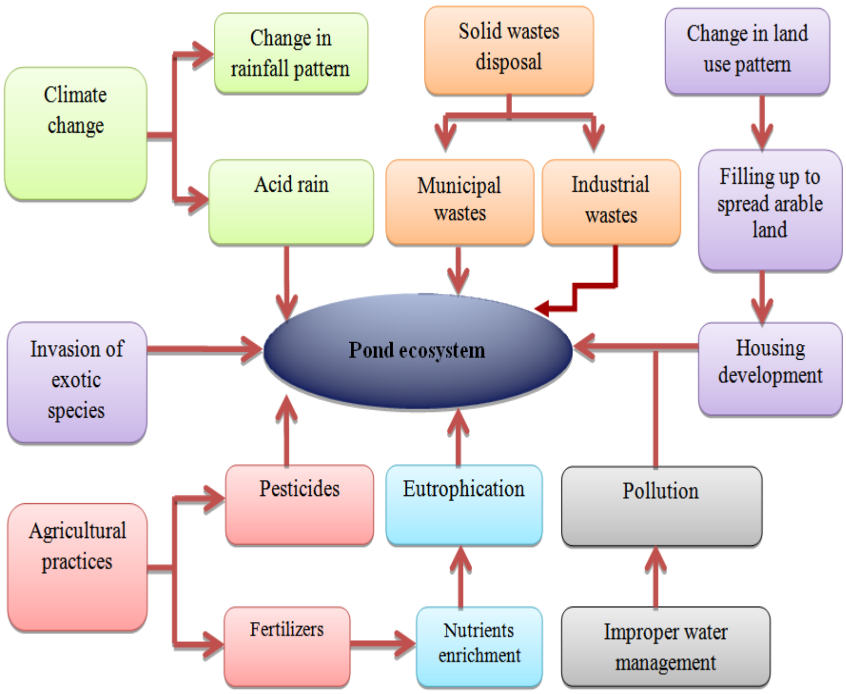

Figure 1. Environmental issues of pond ecosystem

4.2. Eutrophication

Eutrophication is derived from the Greek word "eutrophic". Eu means "well" and trophe meaning "nourishment". Eutrophication is defined as the totality of the effects of phytoplankton's unnecessary growth, which leads to an imbalance in primary and secondary productivity. Nutrients released from fertilizers and municipal wastes are carried into surface water through surface runoff, resulting in excessive plant growth by accumulating in ponds, lakes or other water bodies. Eutrophication occurs naturally in the environment but can be significantly augmented by human activities that increase the rate of nutrient input in a water body. Eutrophication results in decreased water transparency, accumulation of dead organisms, reduction in dissolved oxygen, and fish mortality, etc. (Fontanarrosa et al., 2019).

4.3. Dumping of municipal wastes

Municipal wastes released from households contain a variety of suspended and dissolved impurities. This waste also contains some organic and inorganic nutrients. Chemical soaps and detergent powders are the chief sources of nutrient pollution in water bodies. These chemicals upon entering into the water body affect aquatic organisms as well as human beings. Also, municipal waste contains a large number of disease-causing microbes which results in waterborne diseases. Moreover, when municipal waste enters the aquatic ecosystem, it increases the biochemical oxygen demand thereby decreasing the dissolved oxygen level which is necessary for the survival of aquatic organisms.

4.4. Pollution

Hyperbolic agronomic activities like extensive use of pesticides and fertilizers result in the increased pollution levels of ponds (Arenas-Sánchez et al., 2021; Kumari, 2020). Agricultural runoff comprising chemical contaminants such as pesticides and fertilizers drains into ponds and causes negative effects on the pond ecosystem. As a result of this, the water quality is lowered which ultimately threatens the aquatic life in ponds.

4.5. Aquatic invasion

Invasive species when entering into the water body disrupt the food webs which lead to loss of biodiversity as well as alter the structure and function of an ecosystem (Clevenot et al., 2018; de Vries & Marco, 2017).

4.6. Lack of adequate water management strategies

Poor legislation and lack of Government policies have resulted in improper water management. There are no formal agencies for pond water management. The Government has neglected these important ecosystems for decades which have led to deterioration of water quality.

4.7. Climate change

Climate change has caused variations in the timings and volume of water entering into a pond. When the temperature is higher than normal, runoff is reduced and evaporation of the pond water is increased. If the temperature remains high for an extended period, then cold water species may migrate to a more suitable habitat to survive (Dimitriou et al., 2017).

4.8. Human health impacts and the animal disease possibilities

In terms of microbial ecosystem, ponds have a complex structure which includes water, sediments and microorganisms which play a pivotal role in water quality. The structure of a microbial community can be easily affected by several factors like temperature, conformation of energy, disease stress, and intensity of human interference (Liu et al., 2020). In the study by Rajput et al. (2017), the eleven different ponds of the Amritsar area were analyzed for the inhabiting microflora. The mainly identified bacteria in pond water were *Klebsiella pneumonia*, *Escherichia coli*, *Enterococcus faecalis, Pseudomonas aeruginosa*, and *Citobactor sp*.. *E. coli* is present in the intestine of animals and human beings and the high pervasiveness of *E. coli* revealed that the water samples were highly contaminated with faecal pollution. These bacteria are pathogenic in nature and even low-level contact with contaminated water can result in an outbreak of gastroenteritis (Price & Wildeboer, 2017). Waterborne diseases pose a great risk to human and animal health and are related to environmental degradation making water as a source of transmission (English et al., 2018). Pathogens can be transmitted via drinking, washing, bathing etc. Various researches have reported outbreaks caused by *P. aeruginosa* by consumption of contaminated water (Baghal Asghari et al., 2013; Kerr & Snelling, 2009). It can cause number of diseases including Urinary tract infections, diarrhoea, wound and burn with blue-green pus, respiratory system infections, and eye infection and which may eventually lead to blindness, ear infection, a variety of systemic infections, vomiting, dehydration etc. (Alatraktchi, 2022). Enterococcus is a Gram positive, oval shaped bacterium. Due to their ease to adapt, it can occur in a variety of environments and are most commonly found in soil, wastewater, gastrointestinal tract of birds, mammals and even reptiles (Růžičková et al., 2020). Several studies have reported *Enterococcus* as an opportunistic pathogen causing urinary tract infection (Jafarzadeh Samani et al., 2021; Růžičková et al., 2020). To mitigate the microbial contamination and risk associated, it is important to determine the ways and route of pathogens entry into the ponds (White et al., 2021). To comprehend the nature and magnitude of hazards or threats existing under the specific contamination scenario, better management of the microbial safety of freshwater is required (Alegbeleye & Sant'Ana, 2021). The method like quantitative microbial risk assessment can be a useful tool for assessing the quantitative evaluation and numerical approximation of illness (Bozkurt et al., 2021). Also, integrated management and systematic planning of ponds, with a view to human and animal health, may contribute to prevent or reducing the negative health impacts of pond water.

4.9. Management strategies

To cater the need of the increasing populace, freshwater ecosystems are degrading logarithmically due to a multiplicity of stressors. As a result, many ecosystems are in a dire need of management and restoration. Management and restoration of any ecosystem requires a holistic approach and cannot be achieved through individual components. The purpose of management and restoration is to achieve a natural, self-regulating structure that is ecologically assimilated with the landscape in which it exists. Ecological restoration of the ecosystem requires various steps which include renewal of antecedent environment through physical methods, chemical addition to manipulate the physio-chemical characteristics of water, biological methods including the reestablishment of intrinsic flora and fauna (Fig.2).

5. Ecological restoration of ponds

The term "restoration" means "reoccurrence of an ecosystem to an adjacent condition before fracas" or "the restoration of physical, chemical, and biological characteristics of aquatic flora and fauna" (Robertson et al., 2021; Zhou et al., 2020). As per the perusal of literature, authors observed that there are scarce reports which have documented the techniques for restoration of such an indispensable aquatic ecosystem. Therefore, the basics of those strategies adopted for other aquatic ecosystems which are at the verge of deterioration can be utilized for the accomplishment of ponds' restoration as reported in the forthcoming section (Fig.3).

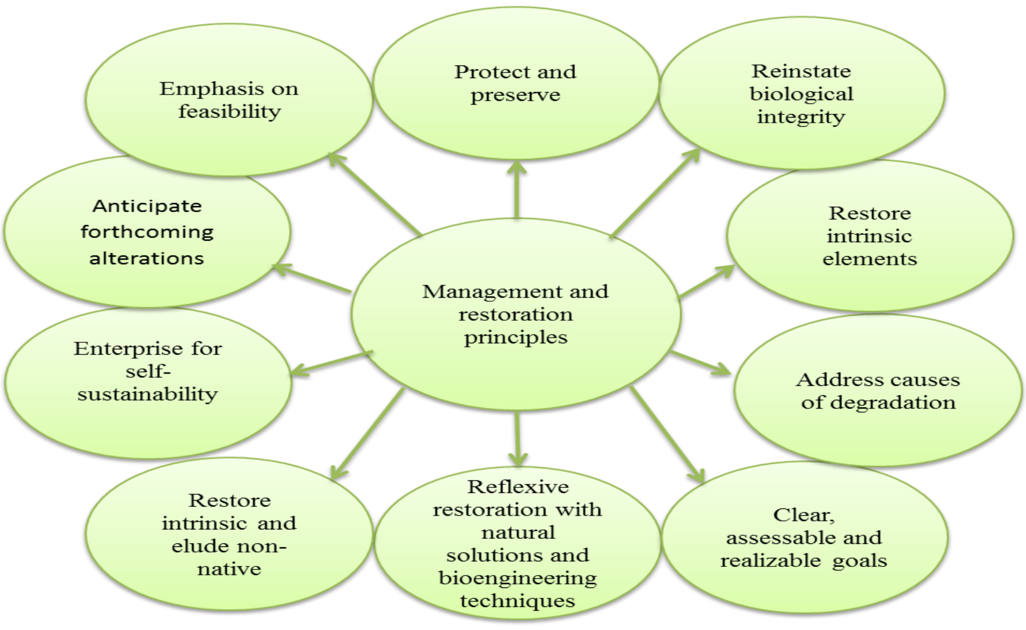

Figure 2. Principles of management and ecological restoration of disturbed ecosystems

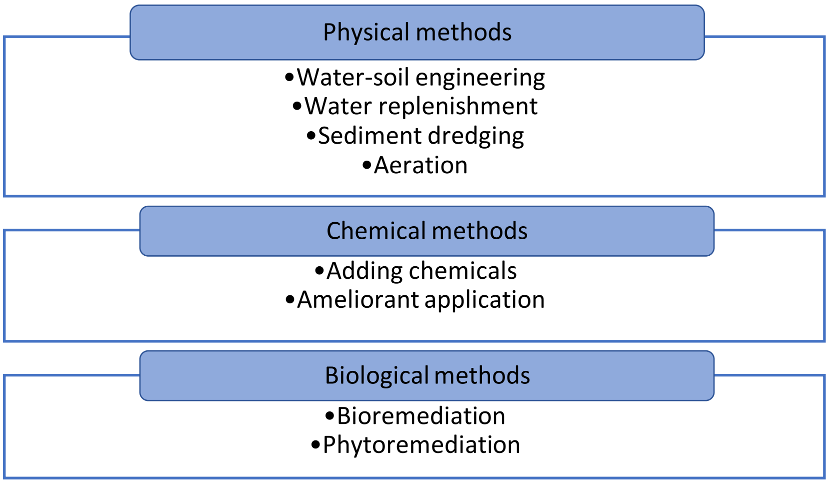

Figure 3. Various restoration techniques for water bodies

5.1. Physical methods

5.1.1. Water soil engineering

It consists of constructing drainages and water storage dams to create a favorable environment for the healthy development of the water body. This method also includes alterations in land-use patterns to govern hydrology and land utilization. Soil-water engineering is a method that encourages experts and researchers to utilize their skills and knowledge in ecosystem management with a mutual aim to maximize benefits to both humans and natural environment (Rey et al., 2019).

5.1.2. Water replenishment

This technique is usually applied to the areas suffering from water shortage or saline-alkali water problems. Water conservancy services are provided to increase water supply and eradicating the impact of water scarceness and salinity. Chen et al. (2020) analyzed the hydro-chemical and hydrological impact of water replenishment in Shahu Lake China. The result revealed a decline in salinity due to lake-groundwater interfaces, chemical reactions, ion exchange etc. The chemical reactions and groundwater outflow accounted for 30-70% decrease in water salinity. The study revealed that chemical reactions and groundwater-lake interactions should be given preference with more exploration and management practice for water replenishment as a method of restoration.

5.1.3. Sediment dredging

Through various equipment's sediments are scoured out to decrease the accretion of pollutants in sediments and avert discharging into water bodies (Garcia-Orellana et al., 2011). Oldenborg and Steinman (2019) successfully reduced the 95-99% total phosphorous, organic matter and phosphorous influx in a riparian wetland.

5.1.4. Aeration

It can be attained through compressors that introduce air to the bottom of the water body through perforated tubes. Cooke (2005) categorized the aerators into three categories: (1) power-driven agitation; (2) pure oxygen injection; (3) downflow injection design to fully or partially lift the air. Moore et al. (2012) reported successful application of hypolimnetic aeration in a eutrophic lake in the USA to control phosphorous recycling and prevention of phytoplankton and cyanobacteria bloom.

5.2. Chemical methods

By adding some precipitating agents and algaecide etc., the eutrophication can be controlled. It is a simple, effective and easily-operated method. To recover the physico-chemical characteristics of water bodies, coherent fertilization and the addition of some chemical modifiers can be done (Pan et al., 2016). Due to the colloidal chemical characteristics of the constituent, the pollutants can be flocculated and settled to the bottom of the water body. Chemical methods can be effectively used to reduce chemical oxygen demand, biochemical oxygen demand, ammonia, nitrogen and phosphorous load of water body (Zhang et al., 2020). Pan et al. (2007) applied the chemical method to treat the polluted river water of Dongguan China and found 91.1%, 77.4%, 71.2% and 68.7% decrease in total phosphorous, BOD5, COD and nitrogen content of ammonia respectively.

5.3. Biological methods

5.3.1. Bioremediation

Bioremediation involves using microorganisms to detoxify, degrade, transform or mineralize pollutant concentration to a harmless state by making use of their integral biological mechanism (Azubuike et al., 2016; Ekperusi & Aigbodion, 2015; Verma & Kuila, 2019). This technique can accelerate the degradation of various pollutants like pesticides, toxic metals, petroleum, etc., and also help in the amputation of nitrogen, phosphorous and other nutrients from water bodies. Resistant genotype for the specific contaminant is the basic requirement for the usage of microorganisms to be used for bioremediation. Stelting et al. (2010) identified basic features that a bacteria should possess for metal-processing:- bio-absorption; immobilization; complex formation and precipitation; uptake and reflux of contaminants; intracellular acclimatization and their release. Various researchers have used different microorganisms for the bioremediation process. *Pseudomonas aeruginosa* has been used to remove the organic and inorganic contaminants from polluted river water of Bangladesh. The study revealed that *Pseudomonas aeruginosa* possess a high potential for heavy metal removal from polluted water (Nupur et al., 2020).

5.3.2. Phytoremediation

Phytoremediation is another technique that relies on the physical, biological, chemical, and microbiological plant interactions to mitigate and degrade toxic effects of pollutants. Organic pollutants like hydrocarbons and chlorinated compounds are removed through volatilization, stabilization, rhizomediation, and degradation (Ali et al., 2020). Several aquatic plant species have been recognized and applied in removal of organic and inorganic contaminants from water through hydroponic as well as field application. Plant species belonging to families like Cyperaceae, Ranunculaceae, Lemnaceae, Hydrocharitaceae, Typhaceae, Juncaceae, etc. are widely used for the phytoremediation of aquatic ecosystems (Ansari et al., 2020). Various researchers have extensively used this method (de Campos et al., 2019; Sricoth et al., 2018). Aquatic weeds like *Spirodela, Wolffia, Eichhornia crassipes, Pistia stratiotes* L, *Lemna, Wolfiella, Chrysopogon zizanioides, Phragmites australis have been worked out by various researchers for the removal of contaminants from the aquatic body (*Escoto et al., 2019*;* Safauldeen et al., 2019*).*

6. Future perspectives

A national-level committee should be formed for the restoration, reclamation, and sustainable utilization of ponds. Different Government agencies, provincial agencies, and local departments should work in integrity for the effective execution of various plans to restore the ponds. Moreover, comprehensive plans should be developed by the Government to create a database regarding the number, status, and water quality of ponds in rural as well as in urban areas. Regular monitoring programs should be encouraged for the management of pond ecosystems. Awareness programs should be organized by the Government as well as Non-Governmental organizations to make the people aware of these important ecosystems. Also, a watchdog team of native people can be made to stop the disposal of municipal and industrial wastewater into the ponds.

7. Conclusion

Ponds are one of the most diverse and valuable ecosystems that are distributed throughout the world with diverged topographic and climatic regimes. These are imperative socio-economic assets and help in biodiversity conservation, aquifer recharge, and pollution mitigation. But nowadays these freshwater resources are diminishing at an alarming rate due to several anthropogenic activities. Urbanization, land encroachment, pollution are pushing these valuable eco-balancers to extinction. Robust management and restoration strategies should be adopted to preserve and protect the pond ecosystem to safeguard sustainable socio-economic and environmental assistance of ponds. More the soil surface was damaged at the forest felling and trawling, the higher the soil texture density is. This metric characterizes the degree of soil degradation well has been disturbed at the forest felling, and it persists after the termination of the impact for a long time. Ecological conditions (terrain elevation, climatic variables, relief conditions, forest type, etc.) significantly impact the evolution of Rendzik Leptosol soils in medium-altitude mountains in Adygeya that contain the dark humus where the soil is disturbed due to felling. The properties of Phaeozem soils of low-mountain relief of the West Caucasus on plots with different vegetation types are characterized by lower differences. Therefore, these soils are more resistant to the forest felling than Rendzik Leptosol soils of areas of medium-altitude mountains of the West Caucasus.

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Declaration of Competing Interest

The authors declare that no competing financial or personal interests that may appear and influence the work reported in this paper.

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