Chapter 6
Restoration and Rejuvenation of Rivers, Streams and Wetlands: Challenges and Way Forward

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Abstract It is vital for the existence and survival of humans to have access to the satisfactory quality and adequate quantity of water. Inland water bodies were considered as community asset or resource over the centuries. In recent years, several big cities have witnessed unprecedented flood and droughts. This can be attributed to depleting inland water storage systems such as ponds, lakes and streams. A five-phase planning and execution system has been discussed here for the restoration and rejuvenation of the water bodies. The five phases are recognition, restoration, protection, improvement and sustenance. These phases begin with preparing the inventory of the water bodies and identification of the water bodies that need to be restored, then the best designated use of the identified water body is decided, and then the water body is prevented from any type of pollution and unnatural changes, and later on, to improve the overall catchment of the water body, in situ treatment techniques, green buffer development and proper management of the drainage basin are being done. The last phase is to sustain the desired results in the restored water body, and it is the toughest of all the phases. To achieve the desired results in restoring the water bodies, public and stakeholder participation and government's initiatives are the key.

Keywords River · Ponds/lakes · Restoration · Rejuvenation · Wetlands

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A. K. Gupta et al. (eds.), *Ecosystem Restoration: Towards Sustainability and Resilient Development*, Disaster Resilience and Green Growth,
https://doi.org/10.1007/978-981-99-3687-8_6

6.1 Introduction

Access to satisfactory water quality and adequate quantity is the key for existence and excellence of all the living creatures. Ponds, lakes, streams, wetlands and rivers were considered as community assets or resources over the centuries. The observed structural shift in the state of mind of individuals towards their water bodies can be attributed not only to urbanization, industrialization, and the advancement in surface water supply chains but also to the increase in the number of tube wells and hand pumps used to abstract groundwater, leading to the initiation of pollution (Goyal et al. 2022). As a result, the locals and the government both had stopped caring, fostering and preserving these community resources and asset (Poonia et al. 2021; Paerl et al. 2014). Bourgeoning urbanization, industrialization and infrastructural expansion has altered the precious water bodies from precious natural resources of the community to a measly dumping ground for all types of domestic sewage, industrial effluents, solid wastes, religious offering, construction debris, etc.; as a result, these water bodies have degraded (Lyu et al. 2020; Dang et al. 2019; Goyal et al. 2018).

In the recent years, several big cities have witnessed unprecedented flood and droughts (NASA 2019). The recent studies have shown that worldwide there is a decline in the number of water bodies due to several factors such as ramped urbanization, developmental activities, increasing population, population density, land use/land cover change, increase in cash crop cultivation, decline in groundwater table and increasing unplanned urban outskirts. To restore and rejuvenate water bodies, the planners must keep the following points in view (Søndergaard et al. 2007):

1. The water bodies should be pollution-free, and they should meet the desired criteria of water quality.
2. The excess water available during the monsoon should be preserved.
3. The storage capacity of the water bodies should be restored and augmented.
4. The groundwater recharge should be increased.
5. The water availability should be enhanced for different intended purposes.

6.2 Restoration and Rejuvenation of the Water Bodies

The planners while planning the long-term management plans for the urban areas so that the water bodies may serve as a good resource require understanding on the following aspects:

(a) What is the current condition of the water bodies?
(b) For what purpose the water body is best suitable?
(c) Why the water bodies should be managed and conserved?

So the water body post restoration and rejuvenation will be able to serve for the future potential needs of the nearby urban communities facing problems due to water scarcity. Its planning and execution have the following five phases (CPCB 2019):

1. Recognition phase
2. Restoration phase
3. Protection phase
4. Improvement phase
5. Sustenance phase

6.2.1 Recognition Phase

The initial step in the restoration of water bodies is the recognition phase, wherein the existing or lost water bodies' problems are recognized and identified. The probable causes of the problems and their effects on the water bodies will be analysed. Suitable solutions to the identified problems will be identified. To do this exercise, the following information will be needed:

(a) **Collection and maintenance of historic information in relation to ponds or lakes:** It includes collection of geographical information of the water body using remote sensing and GIS such as GPS location, elevation above mean sea level, area, dimensions, address, ownership and boundary conditions and mapping the water body for its interaction with the indigenous people of that area. Additionally, information about its hydrology, including whether it is a natural or man-made water body, the description of its catchment area as the source of water, water depth during monsoon and non-monsoon periods, total storage capacity, and its classification based on water logging (permanent or intermittent) and bank overflows are essential aspects to be considered in this phase. Furthermore, understanding the purposes for which the community uses the water body, the status of open water, and the percentage of aquatic vegetation within the water body are crucial factors to be documented. Moreover, detailed data regarding the major towns surrounding the water body, including their total population, total sewage generation, and their contributions to water pollution, should be gathered to facilitate effective restoration efforts. Major industries, industrial clusters and estates discharging the pollutants in the water body. Existing STPs and common effluent treatment plants (CETPs) and their treatment capacities in the vicinity will also be needed. Total solid waste being generated and provisions for its scientific handling and management will also be needed. Other pertinent information such as biodiversity details and wetland Ramsar sites will also be needed.

(b) **Collection and maintenance of historic information in relation to river or streams:** The recognition phase of the stream or river under consideration will include preparation of digital maps of river or stream showing the GPS location of tributaries and their salient features such as its origin, confluences, length of

the river, average cross-sectional area (in m^2), average depth (in m), velocity (in m/s), volume or discharge (in m^3/s) and drains contributing to river pollution. The catchment details of the river will also be required, which include the purpose the river or stream is serving or was serving in the past. Details of major towns, industrial clusters, solid waste, STPs, CETPs and biodiversity will also be required the same as required for the ponds or lakes. Along with it, data on the status of the groundwater, its consumption and the quality will also be required.

(c) **Digital Mapping:** The information will be placed together on the maps, which also needs to be updated on a regular basis.

6.2.2 Restoration Phase

The restoration phase includes defining the designated best use of the water body in order to articulate strategies with regard to the level of treatment required for achieving the desired level of restoration of selected water body. The user who requires the highest level of water quality and purity among all the users is labelled as the "designated best use" for that area the water body is located or flowing. Restoration needs to be done on seven principles for sustainable use of lakes. Firstly, humans should develop a harmonious relationship with the nature; secondly, the starting point for planning and management of lake sustainably should be the drainage basin; thirdly, the long-term preventive approach should be directed towards prevention of the prime causes of degradation of water body; fourthly, scientific and best available information should be the base for decision-making and policy development; fifthly, while resolving the conflicts of the competing users, the needs of the nature should be taken into consideration along with the present and future generations; sixthly, public participation should be encouraged in identification and resolving problems specific to their local water body; and seventhly, the governance should be as such that it must work fairly and maintain a transparency in its actions and decisions and it should be targeted to empower its stakeholders and local community.

Detailed Gap Analysis During the restoration process of the water body in the catchment area, it is crucial to address the gaps in data related to the total generation of industrial effluent, municipal sewage, and waste generation. These projections should be made for a minimum of 15–20 years to anticipate future challenges accurately. Additionally, thorough assessment of the volumetric flow of all drains contributing to the pollution in the water body must be conducted to develop effective strategies for mitigating and managing the sources of pollution.

Additional site-specific measures that may be taken are as follows:

1. Development of buffer zone and maintaining the existing activities within the buffer zones.
2. Where there is an adequate land available close to the water body, feasibility to develop biodiversity park should be checked.

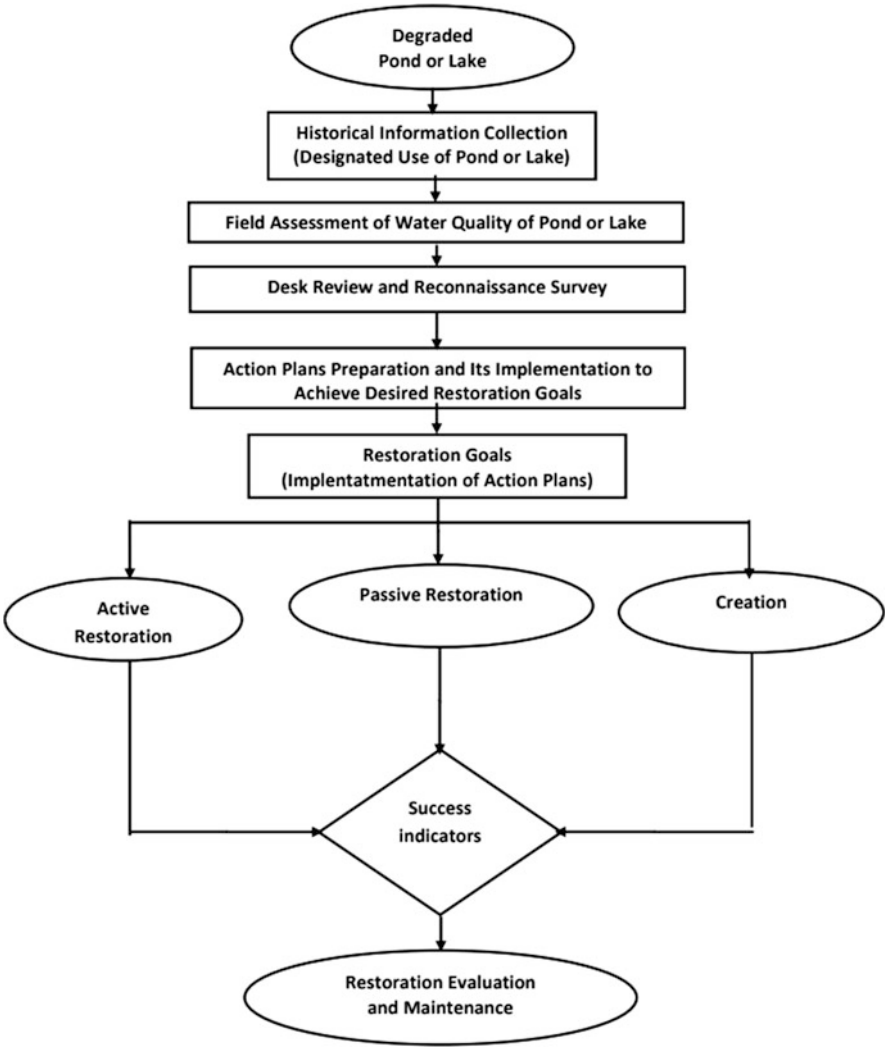

Fig. 6.1 Model flow chart for restoration of lake and ponds (CPCB 2019)

3. Develop greenery in the vicinity as well as introduce recreational facilities such as building jetty and paddle boats.
4. Arrangement of the man power and machinery for maintaining the water body after its restoration has been done.
5. Arrangement for the disposal of the de-siltation and de-weeding wastes.
6. Awareness and training programmes should be done regularly.
7. While preparing the action plans, room for inclusion of any other action required in the future should be analysed (Figs. 6.1 and 6.2).

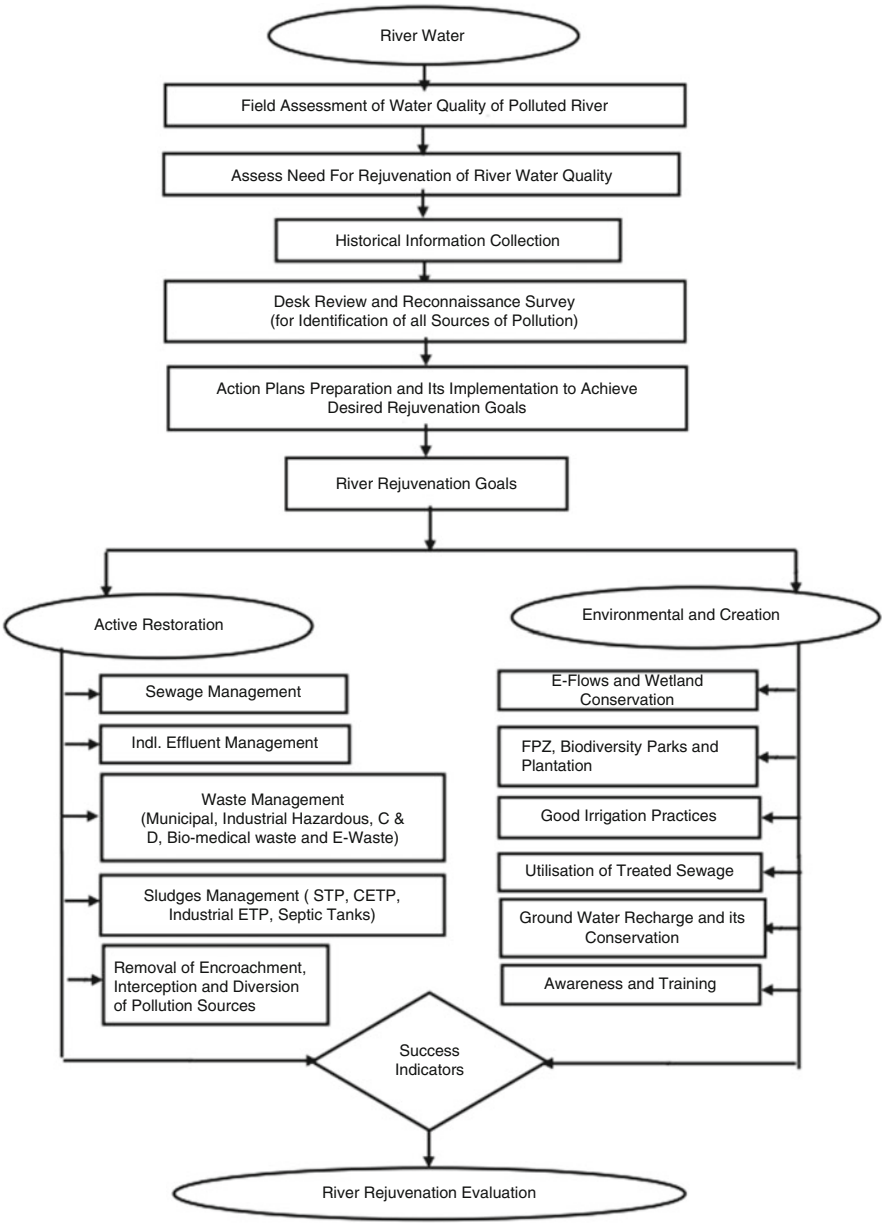

Fig. 6.2 Model flow chart for rejuvenation of polluted rivers (CPCB 2019)

6.2.3 Protection Phase

In the protection phase, emphasis is given on the general health and natural functioning of the water body. To prevent the causes of water body degradation, a long-term preventive approach is required. The action plan thus prepared must take into consideration the precise time targets, the budget estimates and the government body who will be implementing the action plans. The action plan should be sound enough to deal problems related to sewage management, industrial effluent management and waste management. To protect water body, periodic de-siltation will also be needed (Subramoniam et al. 2022). De-siltation is helpful in the removal of nutrient-enriched accumulated sludges, which promotes the elimination of contaminated sediments, increases the storage capacity of the water body as well as enhances the groundwater recharge potential (Zhong et al. 2018). Periodic dredging of the weeds is also required. Dredging 80% of condense and gruffly aquatic plant cover quarterly should be done, and regular de-weeding improves the overall water quality and water body's aesthetics, which can be done using manual or physical control methods, mechanical control measures and biological control methods (Zhang et al. 2018).

Controlling soil erosion is also essential for protecting the water bodies, which is under consideration for restoration and rejuvenation. As part of the restoration efforts various measures can be implemented to improve the stability and protection of the water body's surrounding areas. These measures may involve stabilizing earthen bunds, embankments, and shorelines. To achieve this, techniques such as vegetative cover, rock riprap, stone revetment, or pitching can be employed. These methods will help prevent erosion and provide effective shoreline protection for the drainage channels, contributing to the overall restoration and sustainability of the water body. All the inflow drainage channels should have silt barriers, sediment traps and sediment detention basins to trap the silt. The inflow of floating material should also be prevented using strains or traps.

Protection of a lake, pond or the river should also include protection of its drainage basin. To protect the drainage basin, all the drainage channels carrying water to the water body need to be restored. Restoration efforts can be undertaken using the following interventions: firstly, the inflow of untreated industrial effluent and municipal sewage should be stopped; secondly, based on the historical data, identification of major channels should be done, and to protect them, suitable buffer land needs to be kept free from any impervious cover; thirdly, any encroachment and blockage in its pathway should be removed (PPSCR 2016); fourthly, to naturally enhance the aeration in the water body, encroachments should be removed periodically from the drainage channels (PPSCR 2016); fifthly, to avoid unauthorized entry in the ponds or lakes, fencing should be done; and sixthly, for smooth passway of excess flow and monsoon runoff, well-designed spill ways along with control gates should be constructed, which will control the excess flooding from the drainage basin (Fig. 6.3).

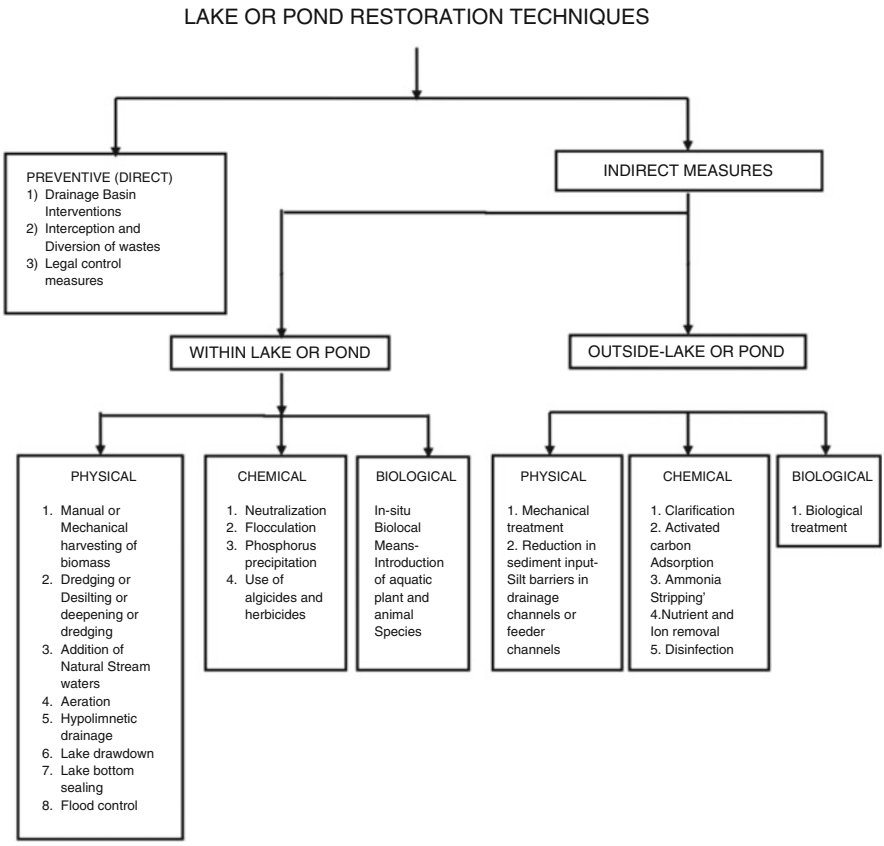

Fig. 6.3 Restoration technique for lake and ponds (CPCB 2019)

6.2.4 Improvement Phase

This phase is dedicated to the comprehensive improvement of the water body, with a focus on considering the needs of nature, present and future generations, and resolving conflicts among competing users. Various approaches can be employed in this phase, such as physical and chemical treatments, the use of aquatic macrophytes and animals, hydroponic techniques, floating treatment wetlands (FTW), and nutrient mixture to encourage algae growth, promoting oxygen release into the water. This, in turn, facilitates aerobic bacteria in reducing organic matter load and minimizing odors.

To manage the drainage basin effectively, efforts should be made to prevent non-point source pollution from entering the water body. Structural and land treatment measures, nutrient interception and diversion, sediment control, and the adoption of good irrigation and crop management practices are essential. Proper residue management, creation of shelter belts, and runoff control provisions for highly

contaminated agriculture runoff (containing fertilizers and pesticides) should also be implemented. Maintaining green buffer zones of at least 50–100 meters around the water body as green belt zones or no activity zones is vital. These zones should not have any impervious cover and should be planted with deep-rooted plants, trees, shrubs, and grasses to absorb nutrients from anthropogenic activities. Furthermore, creating a biodiversity-friendly environment that supports migratory bird species with adequate shelter and suitable conditions for laying eggs and successful propagation should be a key consideration in the restoration efforts.

Regular monitoring of implementation of action plans for restoration of water bodies should be done at least once in 3 months. For this purpose, the action plans should have clear action points for each activity along with specific timelines to complete the work, details of the organization responsible for implementation of work, estimated budget and Program Evaluation and Review Technique (PERT) chart.

6.2.5 Sustenance Phase

The sustenance phase includes good governance based on fairness, transparency and empowerment of the stakeholders. The ownership of the lakes and ponds should be determined, and the water body should be treated as "natural resource" which will be a potential activator for better community health, providing recreational facilities and improving tourism and source to meet the probable water needs. To sustain a restored and rejuvenated water body, it is important to have well-aware citizens, resident welfare associations, local organizations, activist groups and education institutes to protect the water bodies (Goyal and Ojha 2010, 2012; Das et al. 2020). Periodic trainings of all the stakeholders should be organized on aspects related to maintenance during post-restoration phase of water bodies. The public participation should be promoted at each and every level for identification of critical problems of the water bodies as well as for its maintenance. Dissemination of information related to the water body should be displayed publicly such as water quality and dos and don'ts.

6.3 Conclusion

The restoration and rejuvenation of a water body is a non-stop progressing process where sustaining the desired results is the toughest of all the phases. The five-phase water body management plan scheme discussed in this chapter can be of use to the planners and implementers for conservation and maintaining the lost as well as polluted water bodies. The industrial clusters and local communities can play a key role in maintaining their local water bodies and can not just get aesthetic benefits but can also get monitory benefits from these healthy natural water sources. Further, in

order to make any plan successful, there must be a room for strong feedback system as well as for improving the existing plan.

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