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Key Restoration Methods of a Polluted River Ecosystem: A Systematic Review

Chalachew Yenew*

Environmental Health Science, Social and Population Health (SPH) Unit, College of Medicine and Health Sciences, Debre Tabor University, Ethiopia

***Corresponding author:**
Chalachew Yenew

Chalachewyenew50@gmail.com

Environmental Health Science, Social and Population Health (SPH) Unit, College of Medicine and Health Sciences, Debre Tabor University, Ethiopia

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Abstract

Background: River is one of a freshwater ecosystem that plays an important role in people's living, aquatic and terrestrial living organisms, and agricultural production.

Compared to other ecosystems, rivers support a disproportionately large number of plant and animal species. However, excessive human activities have busted the original ecological balance by polluting the river ecosystem. As a result, partial or total affected the structure and functions of the river ecosystem. This review aimed to investigate the major ecological restoration methods of the polluted river ecosystem.

Methods: We have adopted the procedures from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The required data were collected via a literature search of MEDLINE/PubMed, Google Scholar, Science Direct, EMBASE, HINARI, and Cochrane Library from the 9th of September, 2019 to the 5th of March, 2020 using combined terms. Articles were included in our review; only if it assessed empirically and comparison and contrast between two or more different restoration methods. This review; it is mainly included published research articles, national reports, and annual reports and excluded opinion essays.

Results: Commonly used methods for restoration of polluted rivers around the globe could be categorized depending on the physical, chemical, and biological characteristics of the river. Restoration methods such as channel hydromorphic, aeration, watershed action, riparian, In-stream hydromorphic, and In-stream or wetland creation restoration account for 16%, 19%, 12%, 22%, 17% and 14% of river ecosystem restoration efficiency respectively. From the restoration methods: riparian, artificial aeration and In-stream or wetland creation are preferred for restoration of chemical characteristics. For the restoration of physical characteristics; watershed action and channel hydromorphic are preferred. While for the restoration of biological characteristics; in-stream hydromorphic is the preferred one.

Conclusion: Contaminated Rivers can be restored by using different restoration methods. The selection of the preferred restoration methods depends on the physical, chemical, and biological characteristics of the river.

Keywords: Polluted river; Restoration methods; Ecosystem

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Introduction

Water is crucial to life on earth, which is a determinant of biodiversity, ecological patterns, and ecological processes [1-4]. Freshwater ecosystems are hotspots for biodiversity [5-7], which are containing 6–10% of all species and One-third of all vertebrate species globally [1,5].

Despite covering less than 1% of the Earth's surface and amounting to less than 0.01% of its surface water, freshwater environments – including rivers – are globally important for wildlife [5,8-11].

Rivers, products of the evolutionary processes of the Earth, are the origin of survival and development of human beings, and are closely related to human civilization, culture, and history [12]. Compared to other ecosystems, rivers support a disproportionately large number of plant and animal species [13-16].

Rivers have been a valued part of human-dominated landscapes for thousands of years [4] because they provide diverse services, from drinking water to recreation, in addition to supporting habitats for plants and animals [2].

The communities of plants and animals associated with rivers are rich and varied, owing to the wide variety of shelter, breeding, and feeding opportunities that river habitats provided. river ecosystems are complex and can be characterized by a variety of

subecosystems such as river embankments, aquatic zones, and adjacent wetlands and marshs.

Unsustainable administration and use of these rivers has severely compromised their ability to offer ecosystem services threats including agricultural intensification and expansion, forest clearing, urban and industrial pollution, destruction of natural habitat, and reduction of river corridors as well as climate change [9].

The main problems which the damage drivers face are either altered hydrological processes affected by the construction of hydraulic facilities, or deterioration of water quality resulted from pollution emissions, or both [12].

In general, hydrology, topography, and hydraulics may considerably affect the ecological health of the River. Furthermore, discharging wastewater, overexploitation of water resources, building on floodplains, deforestation, the introduction of exotic animal and plant species, and construction of dams, water reservoirs, channels, and other hydraulic engineering projects also destroy the natural river ecosystem health.

The overconsumption of freshwater and direct wastewater discharge directly destroys river ecosystems. While water quantity shortage and water quality deterioration lead to the extinction of aquatic communities and subsequently the breakdown of the entire river ecosystem. River ecosystems can only maintain their natural biodiversity under excellent ecological habitat conditions.

Ethiopia covers a land area of 1.13 million km^2, of which 99.3% is a land area and the remaining 0.7% is covered with water bodies of lakes [11]. According to MOWR [10], Ethiopia has 12 river basins of which the total mean annual flow from all 12 river basins is estimated to be 122 BMC (Billion Metric Cube) [10]. Even though most of the river water is mainly affected by mainly human impact, healthy and self-sustaining river systems provide important ecological and social goods and services upon which human life depends [13].

River restoration does not imply that rivers should be restored to a pre-industrial revolution state, which can be impossible because rivers naturally change over time and because of societal constraints [6]. Therefore, reviewing the major ecological restoration methods of polluted river ecosystems is critical for sustainable management of the aquatic ecosystem.

Methods

We have adopted the procedures from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The required data were collected via a literature search of MEDLINE/PubMed, Google Scholar, Science Direct, EMBASE, HINARI, and Cochrane Library from the 9th of September, 2019 to the 5th of March, 2020 to combined terms “Key” OR “Major” AND “Restoration Methods of River Ecosystem” OR “Restoration Methods of the polluted River Ecosystem” AND “Ecological Sustainable Interventions of Polluted River”. Articles were included in our review; only if it was assessed empirically and compared and contrast between two or more different restoration methods. This review; it is mainly included published research articles, national reports, and annual reports and excluded opinion essays as shown in **Figure 1.**

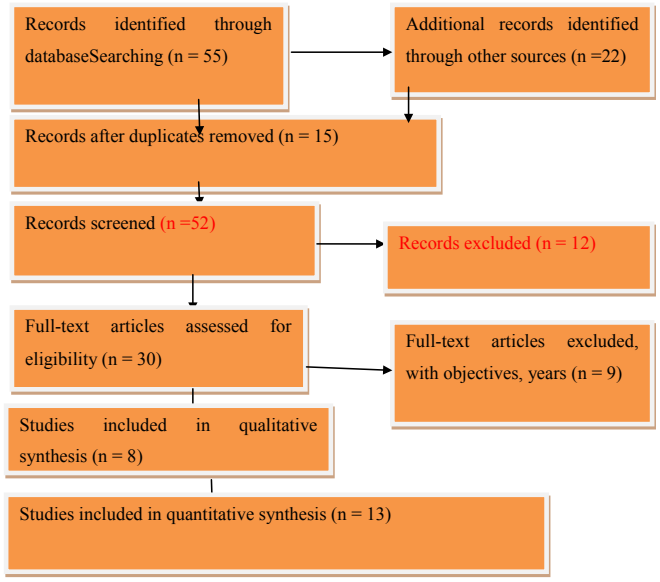

Figure 1 The flow diagram of the searching for the study.

Results

Water pollutants in Rivers mainly include chemical nutrients (i.e., nitrogen, phosphorus. and others), organic pollutants, heavy metal pollutants, and so on [12].

The improvement rates for river restoration parameters (categories/matrices) have been compared with the three characteristics of the river (physical, chemical, and biological). For the evaluation of the physical, chemical, and biological characteristics, different restoration methods have been compared **(Table 1).**

For the comparison of restoration methods, different published studies (published from 1999-2018) that have quantitatively evaluated river or stream restoration methods and categories which are preferred.

The results of the current study revealed that from the restoration methods such as channel hydromorphic, aeration, watershed action, riparian, In-stream hydromorphic, and In-stream or riparian wetland creation restoration accounts for 16%, 19%, 12%, 22%, 17% and 14% of River ecosystem restoration efficiency respectively **(Figure 2).**

From the restoration methods, riparian restoration (27.39%), artificial aeration (21.38%), and In-stream or riparian wetland creation (16.93%) are the preferred methods for restoration of chemical characteristics. For the restoration of physical characteristics, watershed action (24.37%) and channel hydromorphic (17.67%) are the preferred restoration methods of the river ecosystem, but for the restoration of biological characteristics; In-stream hydromorphic (19.46%) is the most preferred river ecosystem restoration method **(Figure 3).**

Table 1 Quantitatively evaluated the results of different river or stream restoration methods.

Category & metrics	Restoration Methods					
	CH	R	IWC	WA	IH	A: (O_2)
Physical characteristics						
Velocity of the river	40%	20%	20%	98%	46%	31%
Habitat	74%	79%	65%	50%	43%	83%
Stability	47%	3%	-	-	-	-
Biological characteristics						
Biological integrity index	10%	67%	18%	50%	45%	58%
Diversity indices	42%	33%	4%	89%	7%	54%
Richness	18%	55%	78%	61%	98%	48%
Algae & aquatic plant (primary production)	50%	98%	17%	27%	39%	56%
Secondary production	86%	45%	51%	23%	78%	56%
Chemical characteristicS						
Nutrient cycle	18%	90%	56%	13%	45%	57%
Organic matter dynamics	67%	100%	50%	45%	37%	56%
In-situ chemical reaction	23%	87%	46%	4%	56%	79%

CH: Channel Hydromorphic; R: Riparian; IWC: In-stream wetland creation; WA: Watershed action; IH: In-stream Hydromorphic; A: Aeration

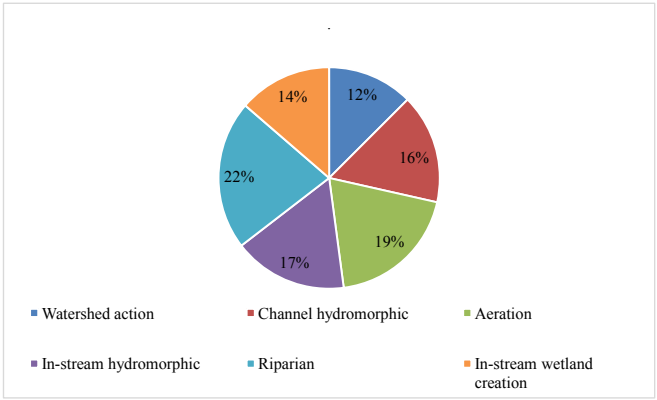

Figure 2 Efficiency (%) of different river restoration methods.

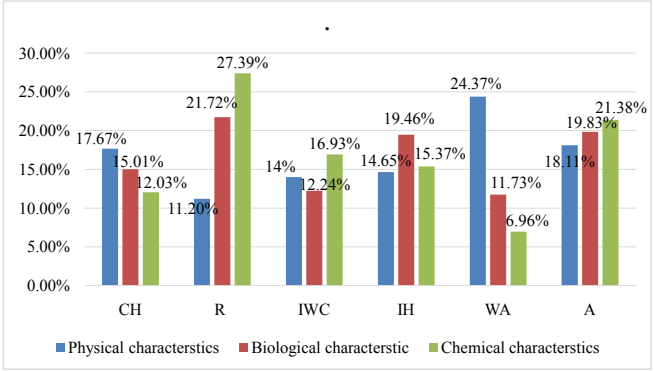

Figure 3 Effectiveness of different polluted river ecosystem restoration methods for the restoration of chemical, physical, and biological characteristics.

CH: Channel Hydromorphic, R: Riparian; IWC: In-stream wetland creation; WA: Watershed action; IH: In-stream Hydromorphic; A: Aeration

Discussion

According to the results, commonly used techniques for restoration of polluted rivers around the globe can be categorized into physical methods, chemical methods, and biological methods. The restored parameter of the river ecosystem categories is channel hydromorphic, riparian, in-stream wetland creation, In-stream hydromorphic, watershed creation, and aeration restoration [12].

The results of the current study revealed that the restoration methods such as channel hydromorphic, aeration, watershed action, riparian, In-stream hydromorphic, and In-stream or wetland creation account for 16%, 19%, 12%, 22%, 17% and 14% of river ecosystem restoration respectively [14] and reported that watershed-scale, out of channel management practices to restore urban streams can be quite successful: “measures of biodiversity in restored streams were 132% of those in unrestored urban streams, and indices of biotic condition, community structure, and nutrient cycling significantly improved”. The report of Smucker & Detenbeck [14] for biological diversity is 132% improvement after implementing watershed action, which shows greater value than t evaluating physical characteristics, such as habitat, velocity of the river, and stability were among the highest compared with other outcome categories/metrics. The result of the reviewed literature show that for the improvement of velocity of the river, habitat and stability, the most preferred restoration methods are watershed action (98%), aeration (83%), and channel hydromorphic (47%) respectively. For evaluating biological characteristics, categories/ matrices such as biological integrity index, diversity index, richness, algae & aquatic plants (primary production), and secondary production were among the highest compared, and for the improvement of river ecosystem, the most preferred restoration methods are riparian restoration (67%), watershed action (89%), In-stream Hydromorphic (98%), riparian (98%) and channel hydromorphic (86%). In contrast, for

evaluating chemical characteristics categories such as nutrient cycle, organic matter dynamic, and In-situ chemical reaction, riparian restoration is the preferred one.

The current study showed that for different restoration methods, the quantitative parameter measure of restored river ecosystem were different. Although, within the restoration methods, the quantitative value of restored river ecosystem varies.

Channel hydromorphic and watershed action river ecosystem restoration methods are the most preferred for restoration or improvement of physical characteristics (17.67%, 24.37%), followed by biological characteristics (15.01%, 11.73%), and chemical characteristics (12.03%, 6.96%) respectively. For the improvement of riparian restoration and aeration, the most preferred restoration methods are chemical characteristics (27.39%, 21.38%), followed by biological characteristics (21.72%, 19.83%), and physical characteristics (11.20%, 18.11%) respectively.

From the restoration methods; riparian, aeration and In-stream or riparian wetland creation are preferred for the restoration of chemical characteristics of the river ecosystem. For the restoration of physical characteristics; watershed action and channel hydromorphic are preferred. While for the restoration of biological characteristics; In-stream hydromorphic is the preferred restoration method.

Conclusions

Restoration methods of polluted rivers vary with the physical, chemical, and biological characteristics of the river. Chemical characteristics of the river can be greatly improved by riparian, aeration and wetland creation restoration methods, While the physical characteristics by watershed action and channel hydromorphic restoration methods. Besides, the biological characteristics are restored by In-stream hydromorphic.

Declarations

Ethics Approval and Consent to Participate

Not needed for this particular study.

Consent to Publish

Not applicable.

Availability of Data and Materials

All data generated and analyzed during this study are included in the manuscript.

Competing Interests

The authors declare that they have no competing interests.

Funding

No funds were obtained for this particular study.

Authors' Contribution

The authors were actively involved during the conception of research issues, development of research proposals, and writing of various parts of the research report. The final manuscript is prepared by Mr. Chalachew Yenew. All authors read and approved the final manuscript.

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