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Review

Natural Treatment Systems and Importance of Social Cost Benefit Analysis in Developing Countries: A Critical Review

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Abstract: This review article attempts to analyse the social issues that impact the performance of natural treatment systems (NTSs). An NTS is a decentralised wastewater treatment system found to be appropriate in developing countries due to its affordability and lower technicity. However, if socio-economic and institutional issues of community are ignored then NTSs may turn out to be unsuitable for developing countries. The article also takes a critical view on the extant literature which ignores the social cost of NTSs. The social cost of NTSs may be high as a decentralised system requires the engagement of various governmental agencies, research institutes and the community. The cost of engagement may make NTSs a socio-economically unattractive proposition. The article discusses the variables to be considered for the social cost-benefit analysis. It also discusses the implications of social cost-benefit analysis for appreciating the incentives and net benefits for collective actions at the community level. Social cost-benefit analysis can help overcome the initial difficulty of high financial cost and usher sustainability.

Keywords: natural treatment systems; social cost-benefit analysis; collective action; sustainability

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1. Introduction

Access to safe water is vital to human life, especially for quality of life [1]. However, water goes to waste as nearly 80 per cent of wastewater returns to the ecosystem sans treatment, irrespective of its vital significance in human life [2]. Hence, it is important to treat and reuse water [3]. Furthermore, if wastewater is not treated correctly, it can pose a serious environmental and health threat [4]. The problem is more acute in less developed countries than in developed countries due to the resource constraints and laxity in regulation. This article attempts to suggest low-cost alternative wastewater treatment systems for less developed countries based on the existing literature. Furthermore, it critically evaluates the notion of a low-cost alternative where unaccounted social costs may make the apparent low-cost systems unattractive. The cost-benefit analysis of low-cost alternative systems has been so far limited to financial cost-benefit analysis, where the social costs and benefits have not been considered explicitly. This review article draws literature from different domains of knowledge including wastewater management and social sciences to understand the importance of social cost-benefit analysis for taking a comprehensive view on low-cost alternatives. In this regard, the social cost-benefit analysis assumes importance not only for making decisions on technology but also for the sustainable management of resources through community participation.

A natural treatment system (NTS) is proposed as a low-cost alternative to high-cost traditional water treatment systems [5]. NTSs can be soil-based and aquatic with each one having different constraints, operating conditions, and design criteria [6–8]. Soil-based systems include decentralised wastewater treatment systems (DEWAT), subsurface flow constructed wetlands (SFCW), rapid infiltration (RI) or soil aquifer treatment, overland flow,

and slow rate systems. Aquatic systems include waste stabilisation ponds (WSP), aquatic systems with floating plants and wetland systems. NTSs have multi-objective contaminant targeting processes for the removal of turbidity and suspended solids, biodegradable bulk organic matter and trace organic compounds, microorganisms and nutrients (N and P) [9,10]. The systems require simple pumps and piping for wastewater conveyance and distribution.

There are different biological methods for the treatment of greywater including sequencing batch reactor (SBR), the membrane bioreactor (MBR), rotating biological contactors (RBCs), the moving bed biofilm reactor (MBBR), and the upflow anaerobic sludge blanket (UASB) [11]. The MBR is one of the most preferred alternatives for wastewater recycling in high-rise buildings [12]. Bacterial enrichment cultures are very useful in degrading haloacetic acids (HAAs) frequently detected in surface waters and in drinking water distribution systems [13]. Furthermore, biomass containing denitrifying polyphosphate accumulating organisms (DPAOs) may be used efferently to remove COD, nitrogen and phosphorus [14]. Hence, it can be used for the treatment of wastewater containing high nitrite and nitrate content.

The NTSs are decentralised systems, as opposed to centralised systems. A centralised system is less appropriate for low-income areas, rural areas with low population density [15–18]. NTSs require lower construction, operation and maintenance costs relative to traditional wastewater treatment facilities [19–21]. The contaminant removal procedure involves no significant quantities of energy and/or chemicals [22]. Their simple design and construction allow for easy replication [23].

These projects can be financed and managed through different arrangements: government-owned and managed or public–private partnerships (PPPs) [24]. The technological choice can be different depending on the local context. Kalbar et al. [25,26] propose a scenario-based multiple-attribute decision-making (MADM) methodology to include regional and local societal priorities including environmental and economic perspectives to select appropriate technology.

The local communities benefit from NTS projects but at the same time it requires community or beneficiary participation in operation and maintenance (O&M) and monitoring. As NTSs are decentralised systems, community participation is essential [27]. The cost of participation increases the indirect or social costs. This may make NTS economically unviable. Furthermore, making the community participate in collective action is a major challenge. Business models typically do not take into account social cost, but if community participation is one of the requirements or inputs in the management of the systems then social costs should be taken into account. In this context, this article highlights the importance of social cost-benefit analysis in developing business models for NTS.

Following Teece [28] (p. 179) "a business model describes the design or architecture of the value creation, delivery and capture mechanisms employed." However, sustainability is an important component of the business model. A "sustainable organization expresses its purpose, vision and/or mission in terms of social, environmental, and economic outcomes" [29] (p. 121). Hence, a business model for sustainability should take into account natural, social and economic capital beyond its organisational boundaries along with creating and delivering economic value to itself [30]. A similar idea is echoed by interactive business models where the firm has to combine, integrate and leverage the ecosystem's capabilities along with internal resources to create new business opportunities [31].

2. Materials and Methods

The review article includes mostly published peer-reviewed literature emphasising social cost-benefit, community participation and institutional issues for natural wastewater treatment systems. We have used some articles and reports published by reputed international organisations as well. The literature review has been conducted in two stages: search of published articles, reports, conference proceedings and abstract by keywords, and thematic selection of articles for peer review.

1. Search articles, book chapters, conference proceedings, reports and abstract by keywords: This search was carried out in EBSCOhost, Google Scholar, the Web of

Science database and Scopus. The keywords selected to find the literature were 'wastewater treatment: developed vs. developing countries', 'natural wastewater treatment', 'institutional issues of wastewater treatment', 'community participation and co-production', 'wastewater treatment: social cost-benefit analysis'.

As the number of research articles found in the search was very high, we relied on the Scopus electronic database for systematic selection of articles [32]. We have limited the articles to the social science area. The selection process of the articles is given in Figure 1. We have finally selected 87 articles for review according to their relevance for the topic of discussion.

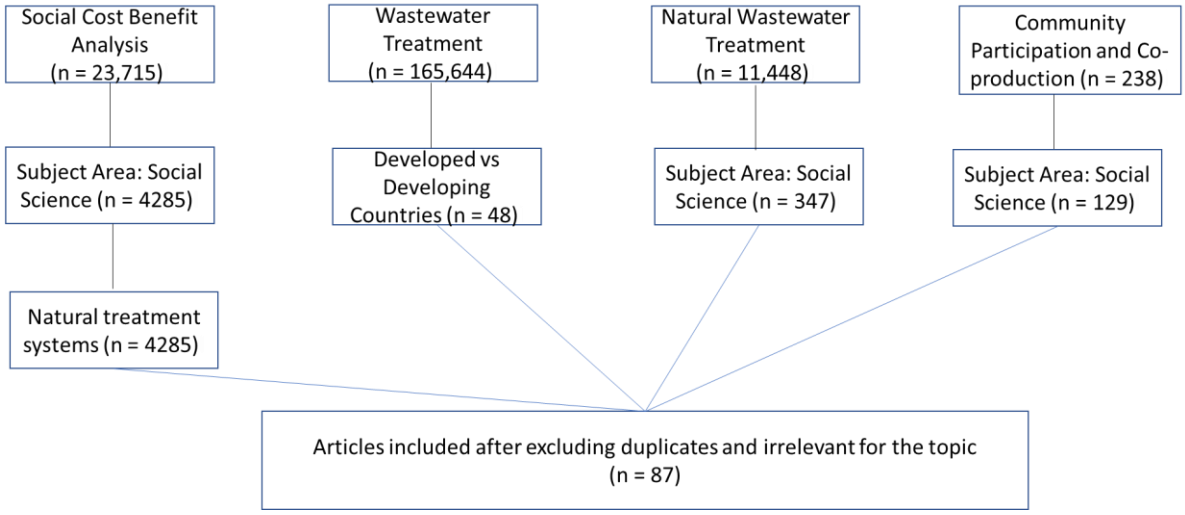


Figure 1. Selection of articles through Scopus.

Seven other journal articles and book chapter, two books, three conference proceedings, one published and five unpublished reports from reputed organisations, and one doctoral thesis was included for review of articles as these were found to be relevant.

2. Review of articles, reports and abstracts: The 106 materials selected for review were grouped by theme. If any article is spanning several topics, then it is grouped into more than one group. The articles were reviewed and the succinct knowledge was presented by themes.

3. Wastewater Treatment: Developed vs. Developing Countries

The practice of wastewater management varies across the globe. Inequality between the wastewater treatment facilities of developing and developed countries is stark [33]. The wastewater treatment is well established in developed countries but limited in developing countries [34]. Developed countries mainly use the centralised wastewater treatment system along with onsite wastewater treatment. While around 75% of the population in the European Union is connected to the centralised public sewage system, 10% population in Canada, 12% in Australia and 15% in Germany use onsite wastewater treatment systems [35]. Developing countries either use the decentralised wastewater treatment system or do not treat wastewater at all [33]. In developing countries, discharging untreated water into sewer systems or public canals is a universal practice [36,37]. High-income countries treat about 70 per cent of their wastewater; this proportion drops to 38 per cent for upper-middle-income countries and further down to 28 per cent for lower-middle-income countries [2].

The purpose of wastewater treatment also varies between developed and developing countries. Developed countries seek to eliminate all the pollutants while developing countries tend to protect public health by controlling pathogens and checking the transmission of waterborne diseases [38]. Therefore, natural treatment systems (NTSs) like constructed

wetlands (CWs) are suitable for developing countries like India due to their efficiency in BOD and pathogens removal despite their limitation in nutrient removal [33,39].

Developing countries follow the western nations' traditional model of centralised wastewater treatment in many places. Yet its implementation has not resulted in the provision of adequate and universal wastewater treatment services in developing countries [40–42]. This is because technologies were transferred from western countries without due consideration of the systems' suitability in a different culture, geography and climate [34]. As a case in point, lack of technical, financial and managerial capacity by communities had led to most of the sanitation treatment plants being non-functional in Ghana [43]. The standards of the centralised system are rendered inappropriate for execution since cost implications are not considered [44–50].

While conventional centralised system such as activated sludge process can produce good water quality, it is not suitable for developing countries. This is due to the high operating costs involved and much-needed assured power supply, both of present a major challenge in developing countries [33,38,43,51–54]. The conventional centralised technology also demands the requirement of specialised labour. In conventional systems in developing countries, domestic wastewater combines with rainwater and generates the flow of pathogenic wastewater, which causes health problems [34]. It also requires a high amount of water to the tune of 100 litres/cap/day for transporting the waste [15,17].

Owing to their unique configuration, conventional systems have high construction costs [18,55]. Therefore, constructing a centralised treatment system for small rural communities or peri-urban areas in low-income countries contribute to the burden of debt on the population [56,57]. Restricted local budgets, lack of local expertise and lack of funding were also observed as the factors responsible for the inadequate operation of centralised wastewater treatment plants in developing countries [58,59].

In choosing an effective wastewater treatment system for developing countries, the existing local contexts need to be considered as technologies that function efficiently in one industrialised country may not function well in a developing country [37]. The implementation of low-cost natural treatment systems for waste treatment and conserving biological communities is warranted in poor nations of the world [53,60]. The members of biological communities including aquatic plants like floating, submerged and rooted macrophytes help absorb pollutants. Gude et al. [61] argue that it is possible to introduce an ecological and low-cost alternative to conventional systems through onsite treatment and onsite processes.

Decentralised wastewater treatment is a feasible alternative to traditional treatment in developing countries. In decentralised wastewater management, the wastewater is managed, collected, treated and disposed of/reused at or near the point of generation [62]. At present, decentralised systems have the potential to integrate effectively with water-carriage waste removal [63]. This technology is feasible for low population densities and industrialised countries [54]. Decentralised facilities are more commercially viable than centralised wastewater treatment systems because of their lower net present value (NPV) costs [64]. NPV costs are a total discounted value of costs spread over the lifetime of the project. The discount rate captures the time value of money, whereby costs in the future is discounted more than costs at present.

3.1. Pros and Cons of NTSs

The NTS are simpler and usually reasonably successful in eliminating most pollutants, but they can differ depending on the climate [49,55,65,66]. Yet, even under extreme operating conditions, NTS can work although its efficiency level goes down in cold conditions [9,10,53,67,68]. An NTS is most competent in warm, sunny climates [69,70]. Different natural conditions like sunlight, wind, soil characteristics and geology, hydraulics, health and sustainability of vegetation and seasonal variations in water surface elevation affect the treatment capability of NTSs, specifically CWs [71]. Warmth and sunlight are freely available in many developing countries in Asia and Africa and hence these countries can use the technology at low costs. Furthermore, the contaminant removal procedure involves

no significant quantities of energy and/or chemicals [22]. NTSs have lower operational and maintenance (O&M) costs due to fewer pumping energy needs and less solvent usage in water acquisition, treatment, and disposal [72,73].

In spite of its advantages, the accessibility and price of the land is the main limiting factor of NTS, as systems require a significant portion of open space for treatment plants. Hence, NTS tend to be viable only in the small cities and suburban areas, where land is not a major constraining factor [40,67,74]. Starkl et al. [75] argue that NTS may appear to be inappropriate in urban and peri-urban areas due to high land prices. Moreover, the labour cost of NTS may be high, as observed by Sahu and Debey [76] in their study on land spreading wastewater disposal systems in Ethiopia.

The efficiency of the decentralised system over the centralised system depends on various parameters and external conditions [77]. The centralised treatment facility works better for the inner city, while the decentralised system is more appropriate for the urban fringe and suburban zones. This is because the city's wastewater can flow more easily to the inner city centralised treatment facility as compared to the urban fringe. Decentralised systems are more appropriate in urban fringe and suburban zones as it requires more land and space. The removal efficiency of the natural wetland treatment system, an NTS, depends on other factors including inflow concentration because it is a multifaceted process with irrigation of a tree farm, percolation ponds and wetland discharge [78].

The NTS's adaptability is another big problem facing NTS designers and operators. Disordered vegetation growth, nuisance control (e.g., insect vectors, nuisance animals), slow treatment rates, wastewater exposure and fast macrophyte growth rate pose a concern for NTSs [79–81]. Lack of awareness about tropical wetland ecology and species and lack of local knowledge about design and management along with the prevalence of mixed domestic/industrial wastewaters pose problems for embracing NTSs [38,82]. Routine maintenance of vegetation is another difficult task for the owner-manager of NTSs in tropical regions [83]. Wetland placement near human settlements presents significant problems due to disturbances created by bugs, rodents, clogging and foul smells. Due to operational issues, raw wastewater may reach streets during rainy seasons [70]. Post-construction safeguards like performance bonds, long-term post-supervision contracts and budget coverage are required to assist the local government in operating and maintaining the system to avoid risk for humans and the system.

Checking the microbiological content of treated wastewater is important when using treated water for irrigation. In the Italian study, Cirelli et al. [84] observed microbiological content in fruits product by irrigation water treated partially by CW. Rai and Tripathi [85] also found higher coliform counts in vegetables than the prescribed norm in their Varanasi-based report.

3.2. NTSs in India

We have looked into the NTSs with a special focus on India because of its geographical spread and variation. The East Kolkata wetland system, located in eastern India, is one of the most important NTSs having a waste stabilisation pond (WSP) followed by fish-pond [24]. The WSP generate solar energy, an ecosystem for fishing and discharge irrigation water. The NTS provides not only sanitation but also food and livelihood to the locals. The local community is an important stakeholder in operation and management. In return, they receive the economic benefits of the system. There are other important WSPs in West Bengal State [24]. The wastewater is used for fishing and finally discharged in the Ganga river. The local community is involved in operation along with the state government. The community is involved in the cleanup of rivers and lakes in exchange for the benefits of selling fish. Thus, community engagement developed a sense of ownership which is one of the important factors of long-term success.

In Western India, the NTS on Man Sagar Lake in Jaipur is a classic case of NTS being set up through PPP between the state government and a private company [24]. This system benefits the downstream community by lifting water from the river originating from the

lake. The filth of sewerage coupled with odour and mosquito menace is being reduced and transformed into a water resource for farmers and a place for tourism. Similarly, Duckweed Ponds is developed at Wazirabad which combines a duckweed-aquaculture system producing fish and shrimps along with treated water for irrigation. The system is operated by Sulabh International, a social service organisation. Duckweed ponds were constructed in of Punjab state of India [86]. However, most village ponds were constructed without proper location, planning and drainage systems. It was observed that the wetlands in the centre of the populated part of the village are hard to drain.

In central India, there is a CW in Bhopal. It made the lives of neighbouring slum residents stressful, owing to inadequate maintenance [87]. Despite CWs' issues, they can be effective in developing countries like India. For instance, the constructed wasteland at Sainik School, Bhubaneshwar, Orissa has been working efficiently and cost-effectively [88]. On an experimental basis, NEERI India, an environmental research institute in India, has developed phytorid technology [89]. The technology is very simple in design and operation, requires no skilled manpower for operation and maintenance and consumption of electric power is negligible.

In the northern part of India, up-flow anaerobic sludge blanket (UASB) reactor, final polishing unit (FPU) and down-flow hanging sponge (DHS) systems treating municipal wastewater located at Dhandhupura, Agra, Uttar Pradesh outperforms many other contemporary NTS technologies [90]. The treated water may be considered for cultivation, and safely discharged into water bodies. To improve the efficiency of wastewater treatment, Kalbar [91] suggest involving hybrid treatment systems (HTSs) in India. It is a combination of natural and mechanised treatment approaches that will save energy and deliver environmental benefits.

4. Institutional Issues

Decentralised processes are well established and are able to match low-income rural communities. However decentralised processes can be developed, operated and maintained only through community participation. The level of community participation should provide the community with the power to control the projects or institutions, instead of just placing people in rubberstamp advisory committees or advisory boards [92].

Community participation is required to understand the local context and design structures appropriately [49]. The process of community participation involving several steps or activities such as building institutional commitment and partnership for planning, understanding existing context and defining priorities, developing systems and implementation is required for the community to understand their own problem and trigger actions as illustrated by Parkinson et al. [93] for implementation of community-led total sanitation. Government and non-government organisations (NGOs) are entrusted to create favourable conditions and support ignition and lateral spread. In other words, programmes need to be co-produced and co-managed by the community, scientists, NGOs and government. In a study on DEWATS in Nepal, Bright-Davies et al. [94] argue that technically and financially more sustainable systems may have better O&M and user ownership through community-led urban environmental sanitation (CLUES) planning. Studies have delineated the institutional and technical feasibility as well as business models for NTS in developing countries, but none of them has considered problems and cost of community participation explicitly [95–98]. However, these studies have cautioned about lack of awareness and capacity, lack of financial incentives, and unwillingness to comply with regulations as major constraints in wastewater treatment and reuse.

4.1. Community Participation and Co-Production

The efficiency of the decentralised system depends on the local context, and community participation is essential for NTS. Engagement with the community is one of the mechanisms to understand the economic, socio-cultural and local context [99]. This can be achieved through co-production, which is the process where inputs are contributed by

individuals and citizens can play an active role in the production of public goods and services [100]. The larger needs of the community should be better integrated while designing wastewater management systems [101]. The benefits of co-production, especially in water and sanitation, are the development of hybrid and/or decentralised systems rendering service and resources accessible, where large, centralised and standardised techno-scientific systems fail [102].

Community participation in NTS is essential at all stages including technology selection and O&M [103]. The community needs to be informed about the O&M and management requirement of the technology. Non-governmental organisations (NGOs), consulting firms and universities may provide technical support during the initial phase. The cost of these interventions should be taken into account explicitly. The study by Muga and Mihelcic [101] takes into account indicators of public participation in the technology section and cultural acceptance of the technology but does not estimate the cost of public participation explicitly.

If the citizens are not involved from the outset of the projects, then co-production may end up passing on the cost to the poor [104]. Understanding the complexity of the O&M of the system and bearing the cost may become an unwanted burden for the poor if they are not consulted before entrusting the responsibility of O&M on them. To develop an accountable system users' perspectives should be combined with institutional commitment from the formal urban institutions, as observed by Iribarnegaray et al. [105] after studying decentralised domestic wastewater treatment systems (DWWTS) systems in Argentina. In this context, Joshi and Moore [106] suggest institutionalised co-production to include regular, long-term relationships between state agencies and organised groups of citizens for public service provision. The Participatory Action Planning Project (PAPP) is a useful means for institutionalised co-production [107].

4.2. Social Cost-Benefit Analysis

Financing and managing the NTS projects is one of the biggest challenges, especially from the standpoint of replication and scaling. There are models whereby international organisations, central, state and local governments have funded NTS projects. The problem with such financing is that they often do not have a sound business plan from the applicants before the release of funds. Alternatively, there could be an incentive-based financing model supported by grants and subsidies, community-based loans, revolving funds and microcredits [24]. A microcredit is a small loan taken from own saving group (also known as a self-help group) or loans disbursed by venture capitalists known as microcredit organisations.

Cost-benefit analysis is a standard tool to analyse the economic viability of a project. However, as NTS projects involve the environment and society, mere accounting profitability may not make the projects sustainable. It is important to take into account the intangible costs and benefits of the project through social cost-benefit analysis [108]. Social cost-benefit is a more holistic analysis encompassing financial cost-benefit analysis, economic cost-benefit analysis and distributional cost-benefit analysis [109]. Balkema et al. [110] have detailed the list of indicators to be considered for sustainability analysis of wastewater treatment. However, to assess a social enterprise like an NTS, it is also important to understand economic and distributional problems along with financial and environmental costs and benefits. Moller et al. [111] found that in Thailand the sustainability of CWs is determined by socio-cultural dimension; public perception, awareness and knowledge, local expertise and institutional clarity of roles.

Net present value (NPV) and benefit-cost ratio (BCR) are calculated for the social cost-benefit analysis of an environmental project [112,113]. The costs include initial investment and incremental operating and maintenance costs. The benefits are measured through willingness to pay (WTP) surveys following the contingent valuation method (CVM). The CVM is a survey-based elicitation method to estimate the WTP of goods or services not traded in the market. A hypothetical market scenario is formulated and described to the survey respondents to elicit their WTP for the good or service. This process of eliciting WTP is called the stated preference method. Eggimann et al. [114] take into

account settlement distribution and topography into the calculation of the cost efficiency of sewer systems. Kihila et al. [115] have suggested considering employment gains in cost-benefit analysis. Nevertheless, these approaches do not consider the cost of community participation explicitly.

The cost of community participation may be accounted as the transaction cost of NTS. Transaction costs are comparative costs incurred by agents or stakeholders for planning, adapting and monitoring of the task under alternative governing structures [116] and therefore the function of institutional designs [117]. Transaction costs may also be defined as costs associated with defining, establishing and maintaining property rights [118].

In estimating transaction costs, financial and non-financial costs of collecting information, time spent and documentation for submission and service can be considered [119,120]. Bostedt et al. [121] calculated transaction costs involved in the negotiations between two contestant parties. These calculations are essential in order to understand why community participation fails.

A few studies on NTS have examined the risk associated with the systems and social acceptability along with technical and financial feasibility [75,122]. Although they took information regarding social acceptance or receptivity in the assessment, they did not calculate the transaction cost of acceptability or monitoring costs of potential health issues explicitly. There is a need for training and capacity building to increase wiliness to pay and community participation [123,124]. The costs for these activities need to be accounted for in a cost-benefit analysis.

The variables to be considered to assess the social cost-benefit of the NTS project have been depicted in Figure 2. It includes measures for both direct and indirect costs and benefits. It would be difficult to measure people's perceived risk, hesitancy and discomfort for NTA projects or reuse of treated water in terms of monetary or economic value. However, there are techniques through which the economic value of perceived risk, hesitancy and discomfort can be measured. These techniques are averting expenses or WTP calculated through the revealed preference method (as opposed to the stated preference method). Averting expenses are the expenditure made to avert the ill effect of bad odour or nuisances [125]. The additional expense people are willing to incur to use water other than that supplied through NTS is the WTP for getting rid of the hesitancy of using NTS treated water. The averting expenditure reveals the WTP for having an environment free from the perception of risks and discomfort and therefore being less hesitant to use treated water. Finally, the net present value (NPV) or benefit-cost ratio (BCR) of the social cost-benefit can be calculated.

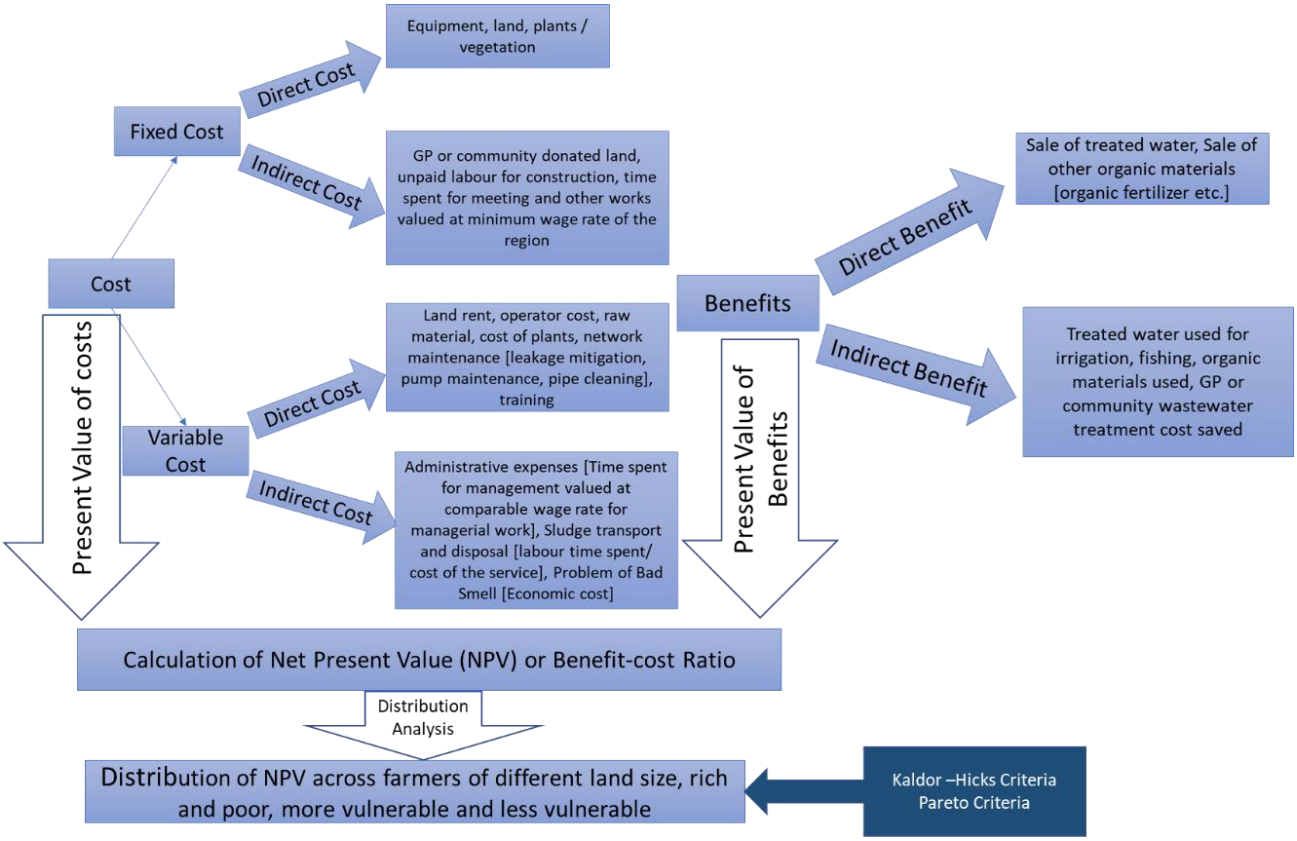


Figure 2. Calculation of social cost-benefit of NTS.

It is also important to conduct a distributional analysis of NPV or net benefits of the project. Due to the political and economic factors, the net benefits would vary across economic classes. Some stakeholders may incur a negative NPV or net loss in the project while others may have positive NPV or net gain. To make those with negative NPV participate, stakeholders having positive NPV need to compensate stakeholders having negative NPV. If the compensation is possible then the business model would be sustainable. The Kaldor-Hicks Criteria of distribution would be satisfied if stakeholders with negative NPVs can be compensated by stakeholders with positive NPVs [126]. In an ideal situation, no one should receive any negative NPV, which refers to the Pareto Criteria of distributional analysis. Distributional analysis of NPV amongst stakeholders should be considered after the overall NPV of the project is calculated as indicated in Figure 2.

4.3. Implications for Sustainability

Social cost-benefit analysis has implications for social entrepreneurship or community participation for sustainable management of resources through NTSs. Entrepreneurs and the community would be interested to participate and manage an NTS system if they find that their present value of financial benefits is higher than the costs. PPP arrangements and social organisations managing NTSs [24] are possible if net financial benefits are positive. These individual incentives may lead to sustainable environmental management. According to UNFCCC, the incentives may be market (creating a market for environmental good) and non-market-based (technology support, financial support, ecolabels, etc.) [127] (https://unfccc.int/topics/what-are-market-and-non-market-mechanisms, accessed on 1 March 2022). In the short run, if the economic returns are lower than the costs then perceived long-run social benefits may incentivise them for sustainable ventures. Subsidy or credit support in the short run may incentivise them. The social cost-benefit analysis assumes importance in this regard to assess the social sustainability of the NTS projects.

The community may participate in O&M of the NTS projects due to long-run incentives of adaption of sustainable practices. Local community participation is one of the key elements of WSPs in East Kolkata and other parts of the West Bengal state in India [24]. In this regard, the incentive-driven mechanism should be directed to more vulnerable communities, whose short-term costs are much higher [128]. Incentives could be voluntary such as certification of water footprint or carbon footprint under Clean Development Mechanism of UN. Environmental regulation can be construed as involuntary incentives. The success of voluntary incentives depends on the community's ability to organise collective action. Involuntary incentives may play a more certain role if the cost of monitoring is low. Information on both financial and social costs and benefits is essential for the community to assess and realise these incentives. Without clear prospects of adaptation of sustainable practices communities may not participate as they might not have any previous knowledge about long-run benefits. Initial knowledge about long-run social benefits may entice them to cooperate at the beginning and then cooperation would gradually built-up in the long run if they realise current cooperation is beneficial and other members are reliable [129].

Communities can participate not only because they have individual incentives but shared goal of sustainable development. Ostrom [130] suggested a mutually agreed binding constraint amongst the members to refrain from free riding and manage common resources for ecological and social sustainability. Communities would agree upon the binding constraining only when they find that the benefits of cooperation are higher than that of defection. A social cost-benefit analysis would enable them to appreciate the net social benefits of cooperation for NTS.

Blomquist and Ostrom [131] and Ostrom [130] argued that participants may not have information concerning the resource such as its capacity and growth for making decisions to participate in collective actions. This information must be gathered and disseminated amongst all the users. This information includes identification of users or participants, the capacity of the resource and its use. The systems should be able to formulate a communication strategy amongst the participants. The net benefit sharing amongst the participants should be equitable. The participants should be able to establish an enforceable and contingent contract with an effective monitoring system. As monitoring is not costless, the cost of it should be accounted for. The information on the capacity of resources, their use and monitoring cost should be accounted for through social cost-benefit analysis.

5. Summary and Conclusions

A centralised system is more appropriate in developed countries as compared to developing countries. Developing countries face challenges of cost overruns and operation and maintenance. The natural treatment system (NTS) is a feasible option in developing nations. It is a decentralised structure based on simple technologies which are less expensive to run and maintain. There are different types of NTSs, both soil-based and aquatic.

In spite of the benefits, an NTS has many other shortcomings. NTSs require large open space and the efficiency of an NTS is strongly dependent on the external environment. This study highlights that another major input of decentralised production is efforts made by beneficiaries in O&M including monitoring of the system, failure of which may lead to inefficient functioning of the system.

Community participation is required to co-produce the service in coordination with various actors: local and central governments, hydraulics institutes and the community. This can be achieved through a process of participatory planning that empowers the community to manage or even rectify the faults or deficiencies of the system. However, collective engagement costs can be high. This cost of community participation may reflect as the project's transaction cost.

Projects may fail—even when costs of technology, material and operations are low—if the transaction costs are high. Time spent in the process of negotiations, planning, and other activities of community participation, along with other indirect costs must be included in

the cost-benefit analysis of NTS projects. It is also very important to conduct a distributional analysis of the net benefits and compensate the net losers.

The knowledge of the costs and benefits of the project is important for decision-making as it has implications for individual and collective actions. Thus, it has implications on the ecological and social sustainability of low-cost alternative wastewater treatment. Higher financial costs may discourage the poor in the short run. In this regard, long-run social benefits may encourage them if they are successful in organising collective action. This is possible if information about long-run social costs and benefits are available. Hence, the social cost-benefit analysis can have a direct impact on environmental sustainability.

The NTS projects can be a low-cost solution for wastewater treatment in developing countries. It may help more efficient use of natural resources. The social and environmental costs of NTSs may be low due to the minimal use of electricity. The beneficiaries can manage and operate the NTS as the requirement of skills is low. Finally, it may benefit the poorest who cannot afford irrigation water or treat wastewater on their own. All these are possible if the beneficiaries find it economically beneficial considering both direct and indirect costs and benefits. In this regard, the social cost-benefit analysis of NTSs may directly contribute towards the economic and ecological sustainability of poor communities as well as reduce inequality.

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