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BEYOND THE REUSE: POTENTIALS AND BARRIERS FOR EXCHANGING TREATED WASTEWATER AMONG THE INDUSTRIES IN SRI LANKA

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ABSTRACT

A major drawback in the present industrial system is that the industries are directly discharging industrial effluent to nearest waterbodies in a linear way. Even though, a few of industries have considered reusing treated and untreated wastewater in their industrial premises, it can be further extended towards 'exchange' among the multiple industries under the concept of Industrial Symbiosis (IS). Initiating IS-based treated wastewater exchange networks is a novel approach to Sri Lankan industries and there is a lack of a study on potentials and barriers of implementing the concept. Hence, this research aimed to investigate the potentials and barriers for exchanging treated wastewater among industries. In order to achieve the aim, 16 semi-structed interviews were conducted with industry experts in the field of Industrial Water Management (IWM) to collect the data. Code-based content analysis technique was used to analyse the data by applying QSR NVivo.12 software. Findings revealed geographical proximity of industries, willingness of industries to engage in water exchange and industry level water management initiatives as major potentials for initiating water exchange networks. Lack of expected water quality for industrial needs, outdated technologies used in water management and lack of expertise and awareness were identified as major barriers. Accordingly, strategies, such as introducing national policy enhancements, ensuring cultural adaptation, enhancing technology & infrastructure, and empowering research & development, were proposed to overcome the identified barriers to ensure a successful implementation of treated wastewater exchange networks targeting the socio-economic development of the country.

Keywords: *Barriers; Industrial Symbiosis; Potentials; Sri Lanka; Treated Wastewater Exchange.*

1. INTRODUCTION

The main challenges with respect to water resources in Sri Lanka are the spatial variability of water availability and the increasing pollution of freshwater bodies due to domestic and industrial waste. The water uses in Sri Lanka mainly include household water supply,

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sewerage and sanitation, irrigation and industrial processes. There is an ever-increasing demand for freshwater in industrial processes, while direct discharge of industrial wastewater into surface and ground water bodies has created severe environmental and health issues in Sri Lanka. As stated by Imbulana, et al. (2021), the respective industrial water withdrawals indicated as 49 litres per day, point to a high density of industry use in the wet zone of Sri Lanka. Further to the authors, major causes of water pollution in Sri Lanka include sewage, industrial waste, agricultural pollutants and physical pollutants. However, the existing policies and guidelines are not supporting the reuse of industry effluent, where direct discharge is permitted within the given water quality limits (Board of Investment [BOI], 2011). Many industries are directly discharging untreated industrial effluent to the nearest waterbodies specially, which were located on riverbanks and upstream of water bodies (Wijesekara, et al., 2020). Therefore, it is important to develop a method to exchange the treated wastewater among the industrial entities in order to reduce the freshwater consumption and wastewater discharge. The concept of Industrial Symbiosis (IS) is an idyllic model to initiate the IS based treated wastewater sharing networks as an innovative water management initiative as it engages the traditionally separated and geographically proximate industrial entities to achieve collaborative benefits through the physical exchange of resources including water (Mallawaarachchi, et al., 2020).

Export Processing Zones (EPZs) in Sri Lanka are offered a great potential for such closed-loop industrial systems. Both new developments as well as the existing or obsolete industrial sites can be transformed into eco-industrial nature. The co-located industries in the EPZs could be realized as industrial clusters by moving them towards a new stage of environmental upgrading, becoming an eco-industrial park. The existing environmental degradation of EPZs due to the elevated freshwater utilisation can be overwhelmed through treated wastewater exchange.

Accordingly, this research aimed at analysing the potentials and barriers for initiating treated wastewater exchange networks in Sri Lanka, which can be served as a basis to call for actions from both industry professionals and policy makers towards empowering Sri Lankan industries towards eco-industrial collaboration. This paper is mainly focused on answering three sub research questions as follows:

1. What are the potentials for initiating treated wastewater exchange networks in Sri Lanka?
2. What are the barriers for initiating treated wastewater exchange networks in Sri Lanka?
3. What are the strategies for overcoming the identified barriers?

2. LITERATURE REVIEW ON TREATED WASTEWATER EXCHANGE NETWORKS ACROSS THE GLOBE

Wastewater reuse in industrial plant is a strategy, which has been considered by many studies in recent decades for Industrial Water Management (IWM) (Taskhiri, et al., 2011). The adoption of water minimisation strategy through wastewater reuse can effectively reduce overall freshwater demand in water using processes and subsequently reduce the amount of effluent generated (Zheng, et al., 2019). On the other hand, wastewater reuse can be extended to multiple industries in which the wastewater from one industrial plant can be reused directly by other plants as long as the quality requirements are satisfied

(Aviso, et al., 2010). Further, geographical proximity of the industries is a major concern in initiating IS-based water exchange networks (Weerasinghe and Sandanayake, 2017).

A number of IS initiatives have been launched across the globe (Tao et al., 2019), expecting to achieve benefits through the exchange of resources including water. Indeed, the IS networks in European countries have been impacted considerably on their environmental and economic development through water savings, reduction of raw material extraction and carbon emissions reductions. Specially, the industries with close proximity and those who have willingness to engage are mainly considered to initiate symbiotic relationships (Domenech, et al., 2019). Kalundborg Eco-industrial park, Denmark, Choctow Eco-industrial Park, USA, Qijiang Industrial Park, China, Songmudao Chemical Industrial Park, China are the examples for IS projects, which have been initiated to exchange the treated wastewater (Zhang, et al., 2017).

Similarly, the industries in industrial zones in Sri Lanka can obtain collective advantages, such as reduction of raw water extraction, ground and surface water pollution, utility and treatment cost reductions, and social enhancements, through this ecological engagement while contributing to the socio-economic and eco-industrial development of the country. Therefore, it is important to initiate treated wastewater exchange networks among the industrial entities in Sri Lanka in order to reduce the industrial demand for freshwater, which ultimately minimise the direct discharge of wastewater to the environment. Identifying barriers and potentials for initiating such treated wastewater exchange networks as well as the strategies to overcome the identified barriers is a fundamental step to be considered as it enables effective industrial engagement and commitment.

The methodology adapted to achieve the aim of this study is described below.

3. RESEARCH METHODOLOGY

Since this research aimed at investigating the potentials and barriers for initiating treated wastewater exchange network in Sri Lanka, qualitative approach was selected. Interviews with industry experts was applied as the suitable research strategy.

Semi-structed interviews was used as the data collection method as it is one of most important sources to collect qualitative data. As Yin (2009) stated, interviews can be either open ended, focused or structured interviews in which semi-structured interviews are highly used to maximise the flexibility of the interview by shaping it as per the need of the individuals. A semi-structured guideline was developed based on the research questions to be answered, which consists of four major sections as: (i) Overview of IWM in Sri Lankan context, (ii) Potentials for initiating treated wastewater exchange networks, (iii) Barriers for initiating treated wastewater exchange networks and (iv) Strategies to overcome the identified barriers.

Accordingly, 16 semi-structured interviews were conducted with industrial experts having more than five years of experience in the field of IWM in Sri Lanka. The respondents were selected through convenient sampling technique. The profile of interviewees is given in Table 1.

Table 1: Profile of interviewees

	Designation	Field of specialisation	Experience
E1	Project Director	Wastewater and water treatment	20 years
E2	Researcher	Civil engineering and water management	15 years
E3	Deputy General Manager - Sewerage	Sanitary engineering	13 years
E4	Project Consultant	Waste management	10 years
E5	Manager - Compliance and Sustainability	Facilities management and sustainability	9 years
E6	Facility Manager	Facilities management	6 years
E7	Executive - Compliance	Facilities management and sustainability	5 years
E8	Assistant Manager - Compliance	Sustainability	5 years
E9	Executive Director	Civil engineering and wastewater	30 years
E10	Senior Expert - wastewater	Environmental science	10 years
E11	Expert - Wastewater	Wastewater treatment	8 years
E12	Mechanical Engineer	Wastewater treatment	10 years
E13	Senior Expert - Resource Efficient and Cleaner Production	Water resources management	10 years
E14	Assistant Manager - Environmental Sustainability	Environmental sustainability and facilities management	8 years
E15	Director	Civil engineering and sustainability	20 years
E16	Mechanical Engineer	Wastewater treatment	8 years

The respondent's demographic information with the purpose of providing an overview of the expertise and experience of the respondents in the IWM field is described below as it generates confidence and credibility in the research findings.

The years of experience of the selected respondents in the field of IWM and relevant fields was first considered. Out of 16 respondents, 69% of respondents are having more than 10 years of experience while only 31% are having experience between 5 to 10 years.

Further, 28% were familiarised with water and wastewater treatment. Sustainability and Civil Engineering were the second highest area of expertise (17%), while water management and facilities management obtained 11% as the third highest area of expertise. The expertise areas of waste management, environmental science and sanitary engineering obtained 6% in each.

The collected data were analysed by using code-based content analysis technique. Content analysis is a technique, which is used for gathering data, involves codifying qualitative information into pre-defined categories (codes) in order to derive patterns in the presentation and reporting of information (Elo et al., 2014). Hence, code-based content analysis was used to reduce data and identify concepts from the data collecting evidences. The two-level coding, such as "internal factors" and "external factors" was used in analysis for identifying the common themes separately under potentials and barriers. Strategies to overcome the identified barriers were also explored. Based on the views of the selected industrial experts, strategies were also proposed to overcome the identified barriers. QSR NVivo.12 (Qualitative Solutions and Research Private Limited) software was used in data analysis as it manages all data very easily. Further, it saves time and energy used for data classification (Dollaz et al., 2017). Further to the authors, the process of data analysis via Nvivo employs six (06) key steps namely, (i) importing data, (ii) exploring data, (iii) coding (making nodes of key words), (iv) running search query for key words, (v) visualising and (vi) recording.

In this research, 16 interview transcripts were imported into the software and explored to identify the keywords. Accordingly, under three main nodes (barriers for exchanging water among the industries, potentials for exchanging water among the industries and strategies to overcome the identified barriers), sub nodes were recognised and coding structure was developed. As the next step, 'search query' was run by restricting the search to minimum three key words. The coding structure was then visualised as a list and recoded to use in data analysis.

The key findings derived through data analysis are presented below.

4. DATA ANALYSIS AND FINDINGS

4.1 OVERVIEW OF IWM IN SRI LANKA

It is noticeable that many industry level strategies are more towards improving the water efficiency, while reusing domestic wastewater (without pre-treatment) within the individual industry premises, such as industry/institutional level guidelines for water management, industry level agreements for water management, reuse of wastewater without pre-treatment, applying water efficiency measures, setting organizational level sustainability targets, investments targeting environmental return and conducting training and awareness programs. The control made over the industries by national policies and regulatory framework is one of the main strategies in IWM.

However, as derived through analysis, industries have become one of major consumers of freshwater as well as the polluter of water bodies. The pollution of surface and ground waterbodies due to industrial activities has created a severe health and sanitation issues in Sri Lanka. As stated by many experts, unavailability of an explicit national water policy can be identified as a main issue of IWM in Sri Lanka.

Further, it has led industries towards the heavy extraction and misuse of raw water for the industrial purposes. Lack of wastewater treatment technologies, their operational inefficiencies as well as the difficulty and ignorance of maintaining the quality of treated wastewater were identified as other issues that hindered the IWM in Sri Lanka.

Therefore, it is important to empower industries towards reusing the treated wastewater among the industrial entities in order to reduce the freshwater consumption and wastewater discharge by the industries in Sri Lanka. Since IS is a new concept to Sri Lanka, the potentials and barriers for initiating treated wastewater exchange networks in Sri Lanka as well as the strategies to overcome the identified barriers were recognised as described in subsequent Sections 4.2, 4.3 and 4.4.

4.2 POTENTIALS FOR INITIATING TREATED WASTEWATER EXCHANGE NETWORKS IN SRI LANKA

As derived through analysis, seven potentials for initiating treated wastewater exchange networks in Sri Lanka were recognised as shown in Figure 1.

Name	Files	Refer...
Barriers for exchanging water among the industries	0	0
Potentials for exchanging water among the industries	0	0
Existing infrastructure and facilities	3	3
Existing national policies for water management	4	4
Industries govering under one ownership	3	3
Industries located within the same geographical proximity	6	6
Industry level water management initiatives	6	6
Technologies available to use for water treatment	4	5
Willingness of industries to engage in water exchange initiatives	7	7

Figure 1: Potentials for initiating treated wastewater exchange networks in Sri Lanka

Willingness of industries to engage in water exchanging initiatives is identified as a significant potential for exchanging water among the industries in Sri Lanka by adopting the concept of IS. The motivation of industries to invest in water management initiatives by considering the environmental return is a significant way forward, which can be further promoted through government incentives and assistance. It is indicated by Deputy General Manager - Sewerage (E3) as:

> *"if industries are willing to use the treated wastewater for their industrial needs, we can supply it with a reduced price than the pipe born water."*

The existing national environmental policies and regulations available for environmental management including water are motivating the industries towards reuse of water as a good sign for reducing the industrial demand for freshwater. It is stated by Project Director (E1) as:

> *"In near future we may refine the existing policy to protect the catchment areas and ground water. Then industries cannot discharge water to the environment, and they must find their own way to reuse. Empowering the policies for motivating the industries is the requirement."*

As mentioned by Researcher (E2), existing infrastructure and facilities including common treatment and pipe networks as well as the technologies available to use for pre-treatment and central treatment of industrial effluent within the industrial parks is a good potential to initiate the water exchanges between industries, where it can be further improved through government and institutional financial support. It is further proved by Expert - Wastewater (E11) as:

> *"We have treatment facilities, pipe networks, etc. within the zone. So, we can use the existing facilities to initiate this kind of a system to reduce the direct discharge of wastewater."*

Further, industrial zone is an ideal environment to initiate the water exchanges, where it is convenient to identify the possible synergies between industries, which have been located within the same geographical proximity. It is highlighted by Deputy General Manager - Sewerage (E3) as:

> *"Since we have all required facilities and infrastructure within a one geographical location, industrial zones are ideal to initiate water and other resource exchange networks. Specially, factories are located close to each other, which may reduce the cost for transporting water and for laying pipe networks."*

Indeed, selecting industries, which are governing under one ownership is another potential to initiate water exchanging networks between industries. Assistant Manager - Environmental Sustainability (E14) stated that:

> *"I think we can even start this concept within our factories under one ownership. It will be a best way to begin this new strategy as it is manageable with the same ownership of industries."*

In summary, industries located within the same geographical proximity, willingness of industries to engage in water exchange, industry level water management initiatives and industries governing under one ownership, existing national policies for water management, technology available to use for water treatment and existing infrastructure and facilities were encountered as key potentials for initiating treated wastewater exchange networks in Sri Lanka.

As initiating IS-based treated wastewater exchange networks is a new approach and hence, Sri Lankan industries are facing various challenges and barriers in initiating treated wastewater exchange networks as described below.

4.3 BARRIERS FOR INITIATING TREATED WASTEWATER EXCHANGE NETWORKS IN SRI LANKA

As derived through analysis, 12 barriers for initiating treated wastewater exchange networks in Sri Lanka were recognised in the present context, which are shown in Figure 2.

Name	Files	Refer...
Barriers for exchanging water among the industries	0	0
Cultural impact of the industrial organisations towards water reuse	2	2
Difficulty in synchronising synergies from different types of industries	4	4
Expected water quality for industrial needs	9	11
Isolated industries situated in different geographical boundaries	1	1
Lack of expertise and awareness	5	7
lack of goverment incentives and financial assistance for industries	3	3
Lack of legal provisions for reuse of water	3	3
Less investment on water management by the industries	4	5
Less reusable quantity of water available for the exchange	2	2
Non-operational infrastructure	3	4
Outdated technologies use in water treatement	9	10
Unavailability of proper discharging strategies for reject water	3	3
Potentials for exchanging water among the industries	0	0

Figure 2: Barriers for initiating treated wastewater exchange networks in Sri Lanka

As shown in Figure 2, expected water quality is highlighted by experts as a major aspect that need to be considered in implementing water exchange between industries. It is stated by Executive Director (E9) as:

> *"Industries expect water with potable water quality standards for their industrial processes. It is because colour and odour are very sensitive as it can affect quality of products. So, water quality is a critical factor for exchanging water among the industries to use for their production purposes."*

Further, the non-operational existing infrastructure is another barrier as stated by Mechanical Engineer (E12) as:

> *"Even though we can initiate this with the existing infrastructure, it can be an issue in long term as the Sri Lankan industrial parks are still suffering from the outdated technology and non-operational infrastructure including pipe network."*

Moreover, industries are suffering from outdated technologies use in water treatment and lack of expertise and awareness to initiate new water management initiatives, especially the concept of IS. Assistant Manager - Compliance (E8) stated:

> *"First, industries should aware about these modern concepts. Otherwise, they are always using the older strategies and technologies even in the future. Therefore, outdated technology is a major barrier. It is required to have new technology in treating wastewater that will help to reduce the cost of treatment. Also, do not have expertise knowledge regarding this novel concept, so lack of expertise is another matter. It is important to obtain the expertise in this field even by observing the similar projects in other countries."*

It is further proved by Senior Expert - Wastewater (E10) as:

> *"A main barrier is that the industries are not aware about the concept as well as they could not continue their synergies as they have no experts to do any prior evaluations and analysis."*

Consequently, poor attitude and less interest of industries to engage in water management initiatives and cultural impact of the organization towards the reuse of wastewater are identified as other barriers. As stated by experts in the field, many industries are expecting economic return rather than considering the environmental return thus, investing less for water management projects. It is mentioned by Project Consultant (E4) as:

> *"Only very few industries have this reusing culture. Others just think about the economic gain only. The industries do not prefer to invest on those initiatives, if you cannot show them the financial return to them. So, it is very difficult task to initiate these kinds of programs in Sri Lanka. As I think those initiatives should come from the policy level. Then the industries must follow those provisions unless otherwise it is illegal. Industries are afraid to pay fines and for the cancellation of their industrial activities, so they will effectively engage."*

Other than that, both Senior Expert - Wastewater (E10) and Assistant Manager - Environmental Sustainability (E14) proved that the lack of government incentives and financial assistance for industries have hindered the industries' willingness for engaging in water management initiatives. It is stated by Senior Expert - Wastewater (E10) as:

> *"Earlier we had a workshop for industrial professionals to introduce this concept. They showed a willingness to engage in this concept. However, the programme was not continued since no funding was taken place. Even government can give a financial assistance for those who willing to engage in water management initiatives, that will be really good. It is lack in the present context."*

Furthermore, unavailability of proper discharging strategies for reject water, which were generated from the industrial water treatment projects and less reusable quantity of water available for the exchange are other barriers that could affect the water exchange network as stated by Deputy General Manager - Sewerage (E3) as:

> *"The issue will be on managing the reject water. When do the Reverse Osmosis (RO) treatment, 40-50% is rejected water. You cannot just discharge it to the environment as it contains more pollutants."*

The difficulties in initiating water network between the isolated industries situated in different locations and the difficulties face in synchronising water synergies from different types of industrial entities can also be the barriers for exchanging water between industries. It is mentioned by Assistant Manager - Environmental Sustainability (E14) as:

> *"There is a huge possibility to implement this strategy in industrial parks because the factories are closely located. If the factories are in isolation, the reuse is possible only within the same premises."*

In summary, lack of expected water quality for industrial needs, outdated technologies used in water management, lack of expertise and awareness, non-operational infrastructure, isolated industries situated in different geographical boundaries, cultural impact of the organizations towards water reuse, difficulty in synchronizing synergies from different types of industries and less investment on water management by industries were identified as key barriers that need to be considered in initiating treated wastewater exchange networks between industries in Sri Lanka.

Accordingly, the identified potentials and barriers were synthesised under two main codes namely, "internal" and "external" as shown in Figure 3.

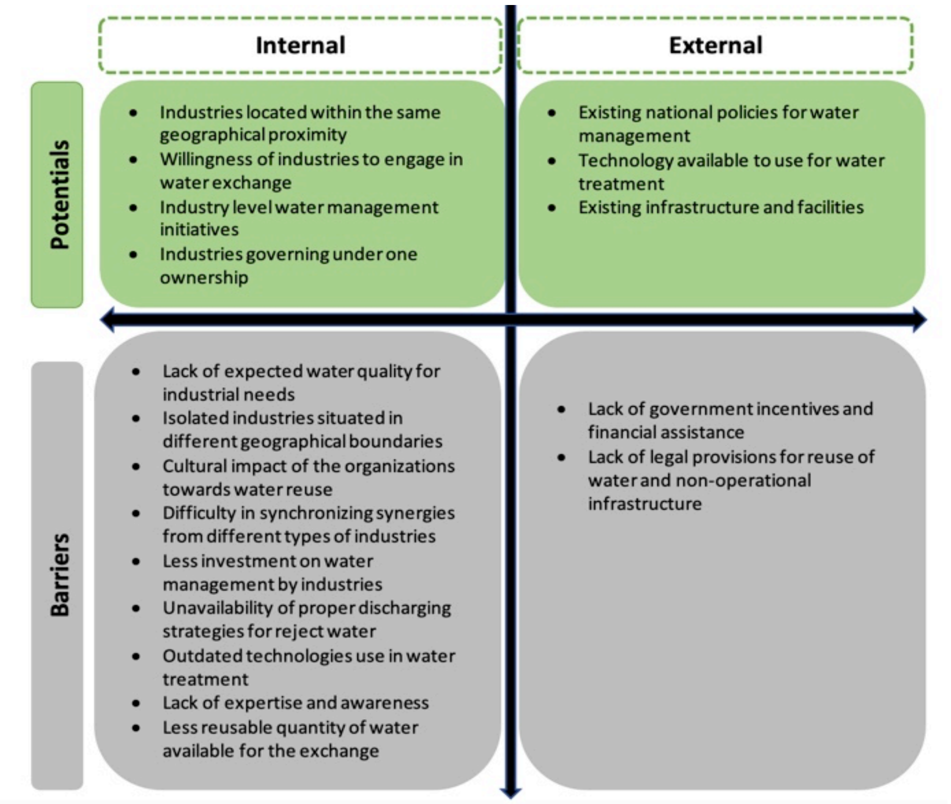

Figure 3: Potentials and barriers for initiating treated wastewater exchange networks in Sri Lanka

As shown in Figure 3, the internal potentials and barriers include the aspects that could be influenced internally or within the IS network while external potentials and barriers consider the aspects that could be influenced externally.

Accordingly, various strategies were also recognised through data analysis in order to overcome the identified barriers as described below.

4.4 STRATEGIES TO OVERCOME THE IDENTIFIED BARRIERS

The identified potentials can be further enriched while taking actions for overcoming the identified barriers for initiating treated wastewater exchange networks in Sri Lanka. Hence, following national and institutional level strategies were proposed as derived through data analysis. The proposed strategies can be taken into account in order to assist Sri Lankan industries, who are eager to engage.

As derived through analysis, 04 key strategies were recognised, which are shown in Figure 4.

Name	Files	References
Barriers for exchanging water among the industries	0	0
Potentials for exchanging water among the industries	0	0
Strategies to overcome the identified barriers	0	0
Cultural adaptation of wastewater reuse among the industries	1	4
Enhancing research and development	1	4
Introducing national policy enhancements for water intensive industries	1	8
Enhancing technology and infrastructure	1	13

Figure 4: Strategies to overcome the identified strategies

According to the analysis, enhancing technology and infrastructure was recognised as a key strategy that can be implemented to overcome the technology and infrastructure related barriers.

Executive Director (E9) stated that as:

> *"The existing infrastructure needs to be retrofitted if we are initiating water exchange networks within the zone. Further, we should have enhanced treatment technologies if we allow exchanging water from one industry to another as many of the industrial in the zone are water intensive industries. Many of them are reputed industries. Thus, they have their own manufacturing standards to be maintained."*

Hence, retrofitting of existing infrastructure & facilities, introducing modern technology for water treatment and obtaining expertise through similar projects are vital to consider. The existing industrial policies distress of having provisions for ecological relocation of industries, which has been resulted in improper location of industries in environmental sensitive areas.

As stated by Deputy General Manager – Sewerage (E3):

> "*We observed the current situation in many of industrial zones. Most of them are located without considering the geographical necessities. Industrial in*

> *environmental sensitive areas have been created a severe threat to the surface and ground water bodies. So, I think revising the existing policy is important by introducing provisions for properly locating the industries."*

Hence, the existing policies need to be enhanced in order to relocate similar industries within same geographical proximity, such as similar industry-oriented industrial zones, which also ensures effective reclamation and reuse of industry effluent. As stated by many experts (E7, E8, E15) it is important to enable a cultural change among the industry professionals through awareness programs exclaiming the need and importance of wastewater reuse and reshare. The industry is required to be adapted to follow new policies and guidelines introduced. Further, national and institutional level incentivisation is also vital to empower industries towards the reuse and reshare of treated wastewater for environmental, social and economic return.

Furthermore, enhancing research and development is another important strategy as proposed by many industry experts (E1, E4). Hence, strengthening the research and development on water synergy identification, synchronisation of various different industries in wastewater treatment, reuse and resharing of water and introducing national & institutional level funding scheme & resources utilisation plans can be considered.

5. CONCLUSIONS

In the current practice, many industries are operating as linear industrial systems, which includes extraction of freshwater, use and direct discharge to the environment with or without pre-treatment. No sharing of treated wastewater among the industries is taken place. Therefore, there is a necessity for reducing the freshwater utilisation as well as the wastewater discharge by the industries. Initiating IS-based treated wastewater exchange network is an innovative solution that empowers the industries for obtaining collective advantages through eco-industrial collaboration. This research facilitates a way for its successful initiation by overcoming the identified barriers and further strengthening the potentials. As key research findings, industries located within the same geographical proximity and willingness of industries to engage in water exchange were significant potentials for initiating treated wastewater exchange networks in Sri Lanka. However, lack of expected water quality for industrial needs and outdated technologies used in wastewater treatment could be influenced as major barriers. Accordingly, four key strategies were proposed to overcome the identified barriers, such as national policy enhancements, enhancing technology and infrastructure to name a few by considering the significance of initiating water exchange networks in Sri Lanka.

Beyond the reuse of treated wastewater within the same industrial boundary, treated wastewater exchange could create a huge impact on raw water extraction and water pollution by the industries as it reduces direct discharge of wastewater through maximum recovery. Further, the reduction of industrial demand for freshwater could facilitate an effective water allocation system within the country. Hence, the eco industrial collaboration of industries under the concept of IS towards the exchange of treated wastewater is an idyllic invention for socio-economic development of any country.

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