RESEARCH REPORT

PROMOTION OF THE APPLICATION OF THE CIRCULAR ECONOMY OF WATER RESOURCES AND WATER REUSE IN THE CONSTRUCTION AND IMPLEMENTATION OF THE AMENDED LAW ON WATER RESOURCES

(Synthesis report)

Hanoi, March 2023

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(Synthesis report)

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Hanoi, March 2023

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LIST OF ABBREVIATIONS

CC	: Climate change
CEA	: Circular economic approach
CEWR	: Circular economy of water resources
CP	: Cleaner production
CPA	: Cleaner production approach
EIZ	: Eco-industrial zone
IZ	: Industrial zone
LEP	: Law on Environmental Protection
LWR	: Law on Water Resources
MARD	: Ministry of Agriculture and Rural Development
MONRE	: Ministry of Natural Resources and Environment
MOST	: Ministry of Science and Technology

INTRODUCTION

1. Significance of research

One of the Government's focuses on water resource protection, management, and control in 2022 is to amend the Law on Water Resources (Law No. 17/2012/QH13, approved by the 13th National Assembly, 3rd session on June 21, 2012, hereinafter referred to as 2012 LWR for short) to suit the new development context of Vietnam and improve the efficiency of water resource use and conservation. Therefore, the Amended Law on Water Resources will focus on perfecting the legal framework, overcoming existing limitations and problems of the 2012 LWR, and integrating some international and local experiences in water resource management and protection. The drafting of the Amended Law on Water Resources has been carried out since 2022 until now. This is the right time for organizations, scientists, and communities to contribute ideas, support, and research and propose recommendations to the drafting agency of the Amended Law on Water Resources to ensure practicality, feasibility, and effectiveness in formulating and implementing legislation on water resources.

The Law on Environmental Protection No. 72/2020/QH14, approved by the National Assembly on November 17, 2020 (hereinafter referred to as the 2020 LEP for short), mentioned the issue of ensuring water security and circulating water reuse through the circular economic approach (CEA). The law encourages the circulation of resources in general and water resources in particular. However, up to the present time (the 5th Draft of the Amended Law on Water Resources), the contents of the circular economy of water resources and water reuse have not been given or mentioned in depth in the Amended Law on Water Resources. Therefore, the research of the potentials for water circulation and reuse from a technical and practical perspective, on the basis of the CEA to water resources to ensure water security, has important significance, making practical contributions to the drafting and implementation of the Amended Law on Water Resources.

2. Research objectives

General objective: The fundamental and general objective of the research is to propose a number of specific contents for the formulation and implementation of the Amended Law on Water Resources on water circulation and reuse and encourage the application of the circular economy of water resources (CEWR).

Specific objectives include:

- Synthesizing the theoretical and practical basis of the CEWR and water reuse circulation;

- Reviewing the policy system on the CEWR and water reuse circulation in Vietnam;
- Evaluating the current situation of the application of the CEWR and water reuse in Vietnam;
- Evaluating the potentials of wastewater treatment technology (WTT) in supporting the water reuse circulation techniques in Vietnam.

3. Research subjects and scope

Research subjects include theoretical and practical issues on water reuse and the application of the CEWR.

Research scope focuses on water reuse circulation and the CEWR in industrial production.

4. Research process

The research applies a systematic approach to study and evaluate water reuse circulation and the CEWR. The research process is shown in Figure 1.

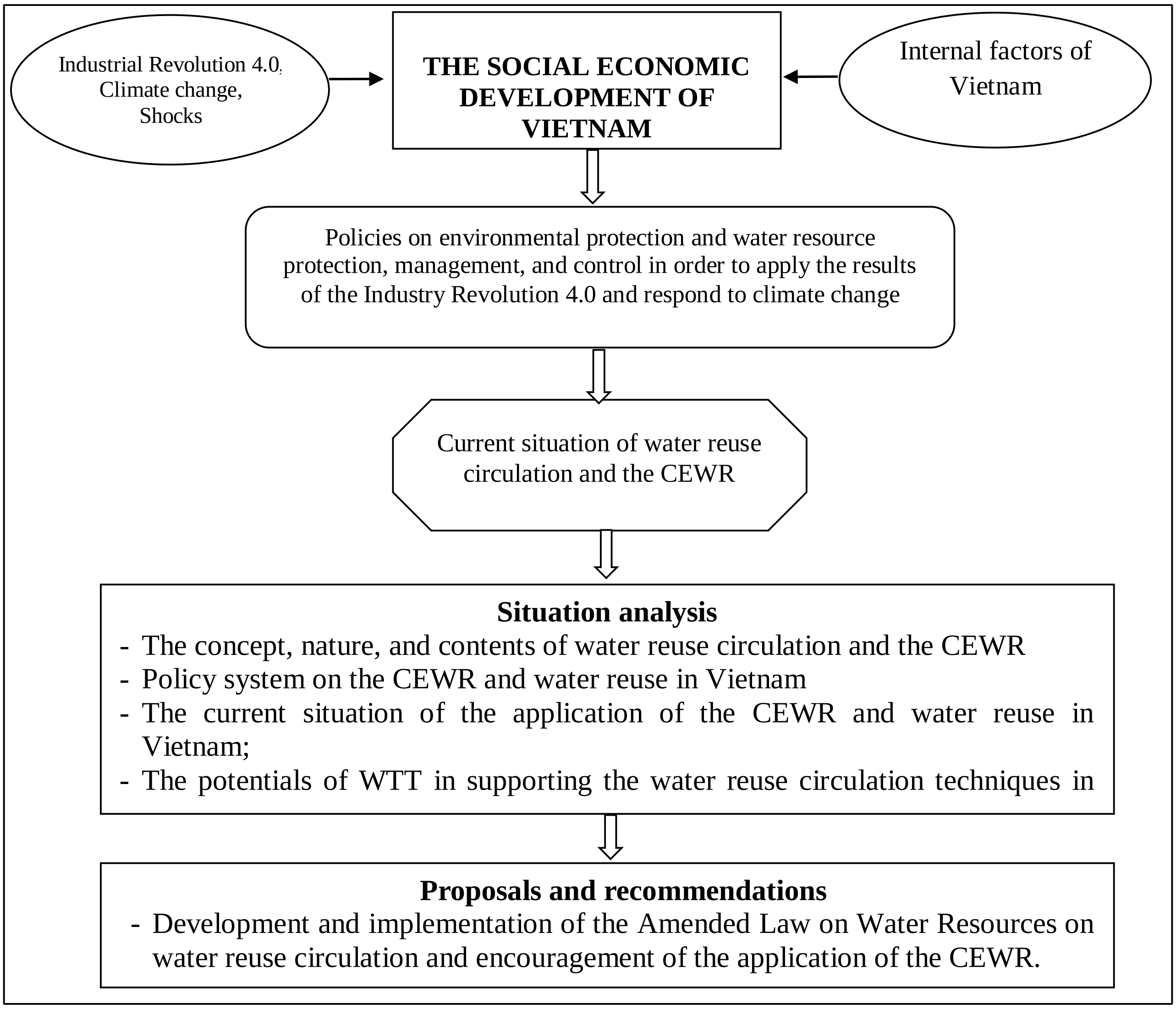


Figure 1. Research implementation process

5. Research methods

Qualitative research method

The research team used qualitative research methods (expert interviews, group discussions) to learn about the views and comments on the current situation of water reuse circulation and the CEWR in Vietnam; clarify the causes, shortcomings, and inadequacies of the 2012 LWR, the impact of Industry Revolution 4.0 and climate change on the exploitation and use of water resources, as well as orientations for future management and development of water resources in Vietnam.

Desk research method

The research team gathers and collects published documents related to the implementation of the 2012 LWR, international experiences on water reuse circulation and the CEWR, and international and Vietnam evaluation reports of Vietnam on research issues. These documents are collected from the following sources: the Ministry of

Natural Resources and Environment (MONRE), the Ministry of Industry and Trade, the Ministry of Agriculture and Rural Development (MARD), the Ministry of Planning and Investment, the General Statistics Office, and reports of international organizations, prestigious domestic and foreign topics, and journals, relevant secondary data sources.

Expert method

In-depth interview. The research team conducted in-depth consultations with managers from relevant ministries and sectors, experts, and policy-makers on water resources. In-depth interviews aimed to collect information on views and comments on the implementation of the 2012 LWR and opportunities on water reuse circulation and the CEWR.

Expert group discussion associated with research contents in the order described above. Discussions help to clarify the results of the evaluation and propose appropriate recommendations and solutions.

6. Report contents

In addition to the introduction and conclusion and recommendations, the report consists of 4 chapters:

- Chapter 1. Theoretical and practical basis of the circular economy of water resources and water reuse circulation
- Chapter 2. Policy and legal system on the circular economy of water resources and water reuse circulation in Vietnam
- Chapter 3. Current situation of the application of the circular economy of water resources and water reuse circulation in Vietnam
- Chapter 4. Evaluation of the potentials of wastewater treatment technology in supporting the water reuse circulation techniques in Vietnam

CHAPTER 1

THEORETICAL AND PRACTICAL BASIS OF THE CIRCULAR ECONOMY OF WATER RESOURCES AND WATER REUSE CIRCULATION

1.1. General concept of the circular economy of water resources and water reuse circulation

1.1.1. Concept of the circular economy

The concept of the circular economy was first used formally by Pearce and Turner (Pearce & Turner, 1990) to refer to a new economic model based on the principle that "*everything is an input to something else, completely unlike the way view of the traditional linear economy*". There are now more than 100 different definitions of the circular economy used in scientific materials and specialized journals (Kirchherr, Reike, and Hekkert, 2017), of which the most widely known definition was provided by the Ellen MacArthur Foundation at the 2012 Global Economy Conference (Ellen MacArthur Foundation, 2013). Accordingly, "*the circular economy is an economic system developed on the basis of renewable and regenerative business models through proactive planning and design, shifting towards using renewable energy, not using toxic chemicals that harm the reuse and reduction of waste. It replaces the concept of the end of a material's life with the reduction of use, reuse, recycling, and recovery of materials during the production and consumption of the product*".

The United Nations Industrial Development Organization (UNIDO) in 2017 also gave a view on the circular economy, which is "*a new way to create value, and ultimately prosperity, that works by extending product life through design and service improvements, at the same time moving waste from the end of the supply chain back to the beginning, thereby using resources more efficiently by using them again and again, not just once*" (UNIDO, 2017). The 2020 LEP stipulates that "*the circular economy is an economic model in which the design, production, consumption, and service activities aim to reduce the exploitation of raw materials and materials, extend the life cycle of products, limit waste emissions, and minimize adverse impacts on the environment*" (Article 142, 2020 LEP). The basic idea of the circular economy is a closed model, based on regeneration and recovery, through repair, reuse, and recycling instead of immediate disposal as well as sharing and leasing instead of physical ownership for the purpose of extending the product's lifecycle, increasing efficiency in the use of input materials, moving waste from the end point back to the starting point, minimizing negative impacts on the environment, and improving the quality of the ecosystem, economy, and society in the long run.

Thus, the basic principle of this model is how to make the most out of the amount of resources used to produce that product. When a product has reached the end of its lifecycle, it must become an input source for the production of another product, thereby minimizing the overexploitation of resources for production. The circular economy brings many economic, environmental, and social benefits (Table 1.1).

Table 1.1. Benefits of the circular economy

Economic benefits	Environmental benefits	Social benefits
Increasing productivity (increasing efficiency in using resources)	Reducing environmental impacts	Improving health
Reducing production costs and improving competitiveness	Reducing greenhouse gas emissions and pollutants	Creating new jobs and incomes
New business activities and models	Reducing pollution and waste at the end of the product cycle	Improving people's health/working environment
New markets and investment opportunities	Higher quality of ecological services	Improving the health of plants and animals
Enhancing consumer confidence	Natural resources conservation (water, land, materials)	New partnerships and collaborations
Reducing resources scarcity	Protecting biodiversity	New partnerships and collaborations

Source: UNIDO, 2020

For production activities of enterprises, the basic contents to implement the circular economy include:

- *Product design:* including enhanced material selection and product design. One potential way to do this is to change the standardization of components, material flows, and product designs to make them easier to repair and recycle.
- *Linking ability:* the application of the circular principle requires transparency in the use of materials and defines standards of industries. Enterprises and production facilities must create links and be willing to share information about the market and materials in production activities.
- *New business model:* the shift from a linear economic model to a circular process requires changes in the use of materials, the business structure and model, and the responsibilities of the manufacturers. This content focuses on changing business models, with manufacturers responsible for product design and management throughout the product's lifecycle.

For consumers, changing product consumption behaviors is one of the contents of the circular economy. By using more durable products, the impacts of product consumption on the environment can be reduced. Besides, increasing and raising awareness about waste classification to increase waste recycling efficiency in the next steps.

1.1.2. The circular economy of water resources and water reuse circulation

Water is a special ingredient in the circular economy. It can be in both storage and flow form; in the solid, liquid, and gaseous states; and can change some properties according to the salt content and chemical substances in the water. These diverse forms have made water a resource that, although important, is more difficult according to the CEA (Morseletto et al., 2022). Water can be a resource, a product, or a service, depending on the circumstances, an indispensable component to sustain life, and an essential input resource for the world economy. Water is also a product because it can be sold directly or as a hidden product (hidden in biological origin products). Water is a service in the case of energy storage or production (kinetic, thermal, and biothermal), a solvent that dissolves substances that provide services to organisms, and a habitat and activity for many species of organisms, including humans.

If the natural balance is not affected by external forces, water is a sustainable and renewable resource. However, the water resource crisis is one of the biggest challenges of today. Worldwide urban population is estimated to nearly double by 2050. This increase has a serious impact on the demand for water. Increasing urban water use will also lead to water pollution and wastewater increase. Climate change exacerbates pre-existing water stress and impacts the water cycle – including the quantity, distribution, timing, and quality of water available (Delgado et al., 2021).

Water circulation is the existence and movement of water flow according to a cycle (production, living). ***Water reuse*** and recycling are often used interchangeably in many materials (Morseletto et al., 2022). It is the proactive process of capturing wastewater, stormwater, saltwater, or greywater and purifying that water (Morseletto et al., 2022; Kakwani and Kalbar, 2020). The water, after purifying, can serve many necessary purposes, such as drinking water, industrial water, surface or groundwater replenishment, and river basin restoration. The above interpretation is also consistent with the meaning of water reuse in the CEWR.

The CEWR is an economic framework to reduce, conserve, and optimize water use through waste avoidance, efficient use, and water source quality maintenance and assurance as well as environmental protection (Morseletto et al. event, 2022). The circular economy can contribute to minimizing many challenges and pressures on water resources in terms of environment and socio-economy, reducing pressures on natural resources, and reducing waste (Ministry of Foreign Affairs, 2018). The principles of the circular economy provide an opportunity to realize and capture the total value of water (as an input to processes, an energy source, and a carrier - carrier of nutrients and other materials), help access and use water resources more rationally and effectively, accelerate the transformation of consumption patterns, and help decouple economic growth from water use and water pollution (UNEP, 2015). The circular economy can also help engage the private sector in these activities through the creation of new business models and funds/grants. Thanks to this model, urban water systems also become more resilient, able to provide water utilities and services that adapt to changes or shocks (such as the Covid-19 pandemic), withstand factors causing pressures on water resources (climate and non-climate issues) (Delgado et al., 2021). The circular economy and its associated restoration activities can provide enormous benefits in the urban areas it covers and elsewhere through spillover effects (UNEP, 2017). Instead of the current linear approach (Figure 1.2), the circular economy determines how to use resources such as water, energy, and other materials (IWA, 2016), to utilize and use the benefits exploited from water resources, adding revenue to the water supply industry (Rodriguez et al., 2020).

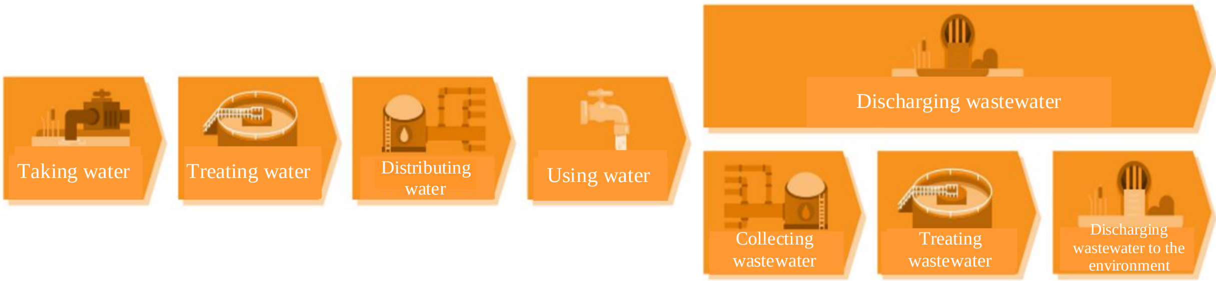


Figure 1.2. The linear approach to water resources

Source: Delgado et al., 2021

Current circular economy initiatives and activities are largely focused on industries and solid waste. Water resource circulation and water reuse have not been exploited much (IWA, 2016) but are being concerned with great potentials and benefits.

The circular economy considers water resources as a finite resource. Based on the natural water cycle, the circular economy avoids the use of water when possible; closes the loop on several levels by improving water efficiency (together with other resources), minimizing waste and focusing on the Rs – Reduce, Reuse, Recycle, Replenish, Recover, and Retain (Jeffries, 2017; WBCSD, 2017). The CEWR strategy is also known as the Rs strategy (Morseletto, 2020; Blomsma and Breman, 2017). Depending on the case, the implementation of the Rs may be different.

Morseletto et al. (2022) proposed a Strategic Framework for the CEWR with 9 strategies: Rethink, Avoid, Reduce, Replace, Reuse, Recycle, Cascade, Store, and Recover (Figure 1.3).

Rethinking	•Configure and conceptualize how water is used to serve needs more circular
Decreasing	•Avoid: limit the use of water •Reduce: use less water while ensuring production and business •Replace: replace water use with other sources
Optimising	•Reuse: use water as many times as possible (do not treat before reuse) •Recycle water: use water many times after treatment •Cascading: divide the order of continuous use of water resources according to priority purposes
Retaining	•Store: transfer usable water to storage areas •Recovery: recover valuable biochemical compounds and maintain energy

Figure 1.3. The CEWR strategies

Source: Morseletto et al., 2022

The above-mentioned CEWR strategy also has many similarities with the Water in Circular Economy and Resilience framework (Delgado et al., 2021). Delgado et al. (2021) have developed the Water in Circular Economy and Resilience (WICER) framework based on knowledge and implementation experiences from projects and case studies of the World Bank. The WICER framework develops based on three distinct outputs: (i) delivering resilient and inclusive services; (ii) designing out waste and pollution; and (iii) preserving and regenerating natural systems. Each output depends on the actions shown in the two outermost circles of Figure 1.4.

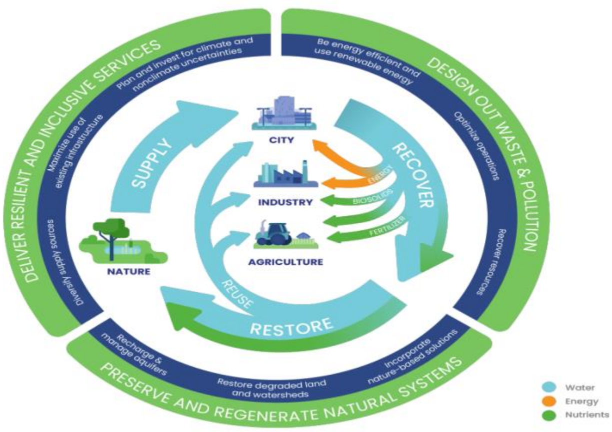


Figure 1.4. the Water in Circular Economy and Resilience framework (The WICER Framework)

Source: Delgado et al., 2021

Depending on the case, one considers the outputs and actions because the system being described is a circular system, and all the outputs are linked together. There are also some additional actions throughout the Framework.

Outputs:

(i) Delivering resilient and inclusive services: Water supply and environmental sanitation services are designed, planned, and implemented to be resilient and inclusive. Utilities, networks, and systems that predict, absorb, adapt, and transform are available and can quickly recover if something goes wrong. Services that ensure everyone in society and all sectors of the economy have access to hygienic water sources. Vulnerable groups are involved in the development of strategies and policies.

(ii) Designing out waste and pollution: Water supply and environmental sanitation systems operate efficiently, producing more outputs (water, energy, nutrients, etc.) with fewer inputs (energy, chemicals); close the loops of materials and resources as much as possible; and minimize the impacts on the environment, while also contributing to improving system resiliency.

(iii) Preserving and regenerating natural systems: The water circulation and recovery not only minimizes waste and negative environmental impacts but also actively restores natural systems, recognizing their economic value and importance to sustainable development. The value of water resources is fully recognized; aquifers and river basins are managed, conserved, regenerated, and restored. Nature-based solutions are prioritized for implementation.

In fact, many enterprises have carried out projects related to water resource circulation. However, some have not voluntarily taken up initiatives related to this content, especially in low- and middle-income countries, because the projects are too complicated or the costs are too high. Some argue that the circular economy is suitable for high-income countries where basic needs have been met. Although it is not possible to meet all the requirements in the short term, low- and middle-income countries can opt for a circular economy at an early stage of development instead of having fallen into a purely linear economy like some high-income countries (Delgado et al., 2021).

According to WICER, water is a resource serving many different fields, so it is possible to carry out one or more water resource circulations at the same time. For example, in agriculture, it is possible to improve irrigation techniques, collect rainwater, manage land, or use fertilizers more efficiently. In industry, water can be reused and recycled in industrial activities; water use can be limited; and a zero-waste process can be implemented. At the household level, equipment that saves water, recovers heat from wastewater, and collects rainwater can be used (UNEP, 2015).

1.2. From the linear economy to the circular economy

Following the development process, there are currently three economic models, namely the linear economic model, the recycling economic model, and the circular economic model (Figure 1.5).

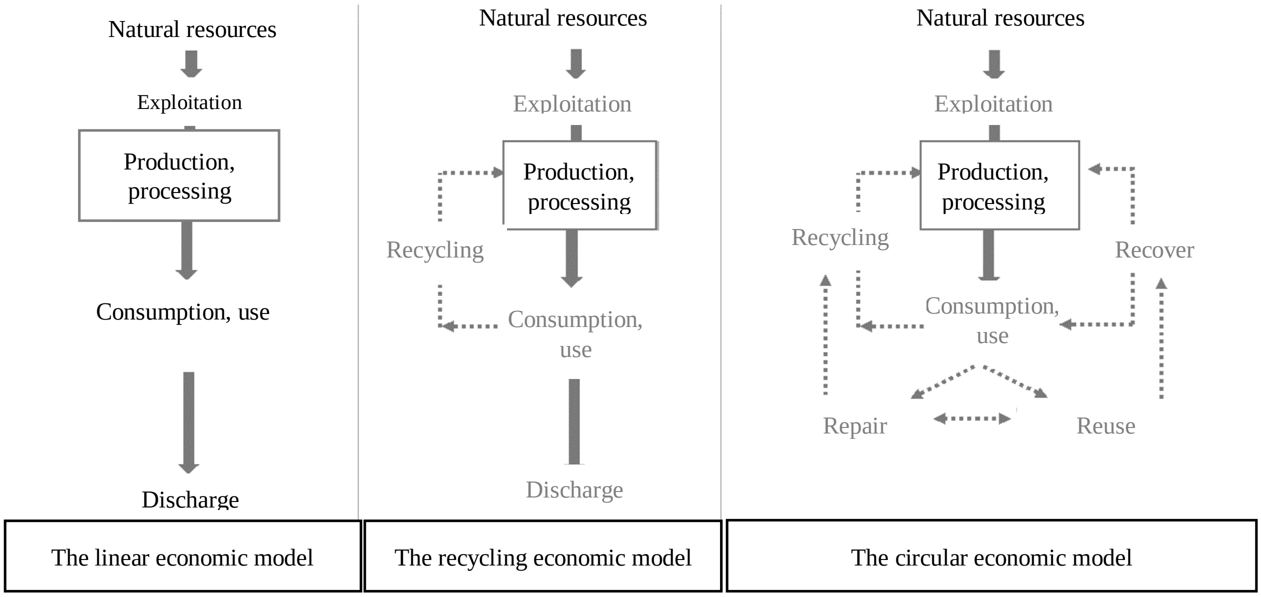


Figure 1.5. Economic models

Source: Jo Lorenz (2019)

The linear economic model is a traditional economic model in which economic activities usually start from the exploitation of raw materials, production, processing into products, use, and, finally, disposal. The linear economy is the transformation of resources into wastes. This is a model that causes natural resource depletion and environmental pollution. The recycling economic model overcomes a limited part of the traditional economic model by recycling a part of the value of the waste. A part of waste is seen as a secondary resource to replace natural resources. The circular economic model is a "zero-waste" operating economic model that completely overcomes the disadvantages of the linear economy. The circular economy is considered the preeminent economic model because it is a restorative and regenerative system through proactive planning and design. In addition to activities that increase recycling compared to the recycling economic model, materials and products are extended their use life through repair, reuse, and redistribution of the production process.

The economic model has two significant differences compared to the traditional economic models as follows:

- First, differences in how goods are produced and maintained. The traditional economic models follow the process of "*take - make - use – dispose*" or exploitation - production, processing - use, consumption - disposal. This means that raw materials are exploited, then transformed into products, and used until finally discharged as waste. Value is created in these economic models by producing and consuming as many products as possible. Meanwhile, the circular economic model operates based on the criteria of "*reduce - reuse - recycle - recover materials*" or reduce demand - reuse - recycle - recover materials in order to reduce the sources of materials exploited for production and processing. The model aims to extend the use or reuse life of goods and products, maximize the value of resources through recycling waste and by-products into new products, and recover materials such as product packaging, returning waste from the end point back to the starting point. In addition, the circular economic model can also be implemented by optimizing resources, such as using the same logistics system when transporting, distributing, or converting products into services.

- Second, differences in sustainability perspectives. In a linear economy, sustainability is considered economic efficiency, which means trying to minimize the negative impact on the ecosystem. This only prolongs the time the system becomes overloaded or only solves the immediate problems of the ecosystem. In the circular economy, the view of sustainability focuses on increasing the efficiency of the ecosystem. That means not only preventing and minimizing adverse impacts on ecosystems but also improving economic, social, and environmental systems.

Some economic models with the characteristics of the circular economy were present quite early in Vietnam, such as the GPC (Garden-Pond-Cage) model and variations such as Forest-Garden-Pond-Cage; combined crop-fish farming system (helps to recover emissions or utilize feed and nutrition); Zero Waste to Nature initiative initiated by the Vietnam Chamber of Commerce and Industry (VCCI); eco-industrial park initiative towards a sustainable industrial park model in Vietnam by the Global Environment Facility and the Swiss Federal Department of Economic Affairs, Ministry of Planning and Investment in collaboration with UNIDO; initiative to recycle Tiger beer caps into iron to build a bridge in Tien Giang (helps recover iron); straws made from grass and rice as an alternative to plastic straws (helps reduce plastic emissions); model that supports the collection and recycling of all plastic bottles from Coca-Cola products sold; Heineken's model of using or recycling up to 99.01% of by-products and waste in manufacturing[1]; DOW's model of using plastic packaging to make traffic roads; Unilever's model of collecting, recycling, and reusing 100% of plastic packaging waste[2]; model of processing aquatic by-products (shrimp shells, shrimp heads...) to create Chitosan and SSE with the potential of 4-5 billion USD annually; some cleaner

[1] Heineken Vietnam has set a target that by 2025, 100% water will be compensated (which means returning to nature the amount of water consumed for the product and the amount of water that evaporates in the production process), 100% renewable energy, and 0% landfill waste.

[2] Unilever Vietnam has set a target that by 2025, all the company's product packaging will use recycled or biodegradable materials, reduce the use of virgin plastic by 50%, reduce the amount of plastic used and use recycled plastic (PCR), and collect and process more than the number of products sold on the market.

production models deployed in enterprises... (Ministry of Planning and Investment, 2020). It can be said that the circular economy helps promote economic development while reducing resource exploitation and waste discharged into the environment. The circular economy is considered an inevitable development trend in the future.

1.3. Some models of water reuse circulation

The CEA in water reuse can be done at three levels: (i) the micro level (enterprises, factories); (ii) the medium level (symbiotic groups, industrial zones), and (iii) the macro level (cities, provinces, and regions) in some key areas such as industrial systems, environment construction, urban infrastructure, and ecology.

1.3.1. Micro level (enterprises)

Applying the circular economy in water reuse at the micro level is the water reuse approach that directly serves enterprises. Enterprises can directly reuse clean enough wastewater or standard-treated wastewater for different reuse purposes. Water used in cooling and heating processes usually contains few contaminants, so it can be reused for production. The treated wastewater can be used to wash equipment, water plants, wash roads, or grow crops (circulating ponds). Rainwater can be reused for purposes such as watering plants, washing roads, and fire protection and prevention... Reusing greywater for watering plants.

The United Nations Environment Program (UNEP) offers a cleaner production approach (CPA). Cleaner production focuses on preventing waste at sources by affecting the production process. To implement cleaner production, it is not necessary to change equipment or technology right away but can start by strengthening production management, controlling the production process according to technological requirements, changing materials, and improving equipment. In addition, solutions related to recycling, recovery, and reuse of waste or improvement of products are also solutions for cleaner production. Cleaner production is applied in many industries and services, making a significant contribution to preventing pollution and ensuring economic benefits. The main techniques in cleaner production include (i) Reduction at sources; (ii) Circulation and reuse, and (iii) Product improvement. Thus, cleaner production has many similarities with the concept of the CEWR, and one of the approach and implementation ways of cleaner production is water reuse circulation.

Potentials to improve water use efficiency, water reuse circulation in cleaner production

Domestic water

Many enterprises find that cutting down on water usage for sanitation purposes can result in cost savings. Water-saving opportunities are easy to implement in areas where sanitary water consumption, such as toilets, cisterns, and showers, are easy to overlook. The daily consumption demand of each employee ranges from 75-130 liters/day. Saving 25-35% of water in sanitation needs is totally doable.

Production water

Boiler. Contaminated water can increase the cost of efficient boiler operation. When steam is used, lost, and water is added to the boiler, the concentration of contaminants increases, making the treatment chemicals insufficient to remove them. To prevent this problem, hard water must be removed from the boiler through a "blowdown" process. However, the blowdown not only discharges the hard particles in the water but also flushes out the money of the enterprises. In addition to the amount of money for water costs, enterprises will have to pay additional money for heating water and chemicals to treat the amount of water released during the blowdown process. Enhancing condensate recovery is a method of minimizing the blowdown process and maximizing the concentration at which the boiler remains in good working order. By enhancing condensate recovery, it is possible to reduce chemical use and water loss and conserve heat in the condensate.

Cooling. Using open cooling systems in industrial and commercial applications consumes a lot of water resources. Self-contained water cooling systems with cooling towers can reduce the heat generated by air conditioning systems and industrial processes and thus save more water. Cooling towers can consume 20%-30% of the water used in factories. Optimizing the operation and maintenance of the tower system can enable enterprises to save a large amount of water and find ways to reduce the amount of salt in the cooling water.

Cleaning and washing process. Most industrial and commercial enterprises have cleaning and washing processes. This is a process that consumes a lot of water. The solution includes dry cleaning, water recovery and use, and chemical and detergent use control for optimal water use. "Clean in place" e.g. plants that recover soda solution for reuse and use the final rinse for the initial rinse of the next washing process. In the electroplating or powder coating industry, a reverse washing process can also be applied to reduce water consumption.

Reuse and Recovery. Maximizing the use of water in processing means using water more than once in the process. Water quality will determine whether water can be reused during the processing to meet product quality assurance. A simple method to save water in the washing process is to use reverse stratification tanks. Depending on the water quality requirements of the processes, water can be simply recirculated or need to be treated through several steps, such as sedimentation, skimming, and/or filtration using filter boxes, bags, and discs or sand.

1.3.2. Medium level (industrial zones)

Eco-industrial zone (EIZ) is a "community" of manufacturing and service enterprises that are closely related to the same interests, in the same location, towards a high-quality social, economic, and environmental activity, through cooperation in the management of environmental and natural resource issues. By closely cooperating activities with each other, the EIZ "community" will achieve a greater overall effect than the activities of each individual enterprise. An EIZ is an industrial system that exchanges energy and materials to achieve the goals of minimizing the use of energy and raw materials, minimizing waste, and creating sustainability in economic, ecological, and social relationships. The concept of EIZs shows that the goals of EIZs and the circular economy are both toward reducing energy and raw material consumption and minimizing waste. Simply put, in both models, the waste can be used as input materials for another process. EIZs create a circular production cycle between enterprises in the industrial zone (IZ). While the circular economy covers broader and closer to the industrial ecosystem, which is the connection between enterprises in the IZ and other enterprises or functional areas on the outside.

According to Oh et al. (2005), four principles of planning and designing EIZs include: (i) Designing each EIZ as a small ecosystem and correcting the current non-closed material flow in the direction of forming a more independent, circular, and closed system; (ii) Changing the monotonous character of the existing IZ; (iii) Forming an industrial symbiosis network; and (iv) Raising awareness of stakeholders to ensure the voluntary implementation of common commitments and maintaining the existence and development of the EIZ. For the industry in general, EIZs are a driving force for the industrial economic development of the whole region, increasing the value of industrial production and services, attracting investment, increasing employment, and promoting the process of innovation, research, and application of new scientific and technological achievements in IZs. For the circular economy in industrial production, the innovation, research, initiative, and application of new scientific and technological achievements are mandatory conditions.

Industrial symbiosis

The concept of industrial symbiosis (IS) in IZs is specified in Clause 2, Article 2 of Decree 82/2018/ND-CP regulating the management of IZs and economic zones, whereby IS in IZs is a cooperative activity between enterprises in one IZ or with enterprises in other different IZs in order to optimize the use of inputs and outputs, such as materials, water, energy, waste, and scrap... in the production business process. Through cooperation, enterprises form a network to exchange factors for production, use common infrastructure and services for production, and improve technological processes and production business efficiency.

The above definition shows that IS is enterprises implementing small circular models in an IZ or with a single enterprise, such as water use circulation before discharging or the exchange of by-products, waste, and scrap,... in which the circular economy includes a series of circular business models such as circular supply chain; recovery and recycling; product life extension; sharing platform; consideration of products as a service for all sectors, fields, and the society as a whole. Thus, it can be said that IS is one of the small circular business models of the circular economy.

1.3.3. Macro level

In the economy in general, the implementation of water reuse circulation is often combined between different fields/regions, most often seen are industrial-urban, industrial-agricultural, or agricultural-urban models.

This model works similarly to the Water in Circular Economy and Resilience framework mentioned above. Accordingly, wastewater from industrial or urban areas after treatment can be used for many different purposes, such as for activities in urban areas (watering roadside plants and trees in parks, cleaning, toilet flushing,...); irrigation in agriculture; reuse in the industry (cleaning, cooling,...); and return to the ecosystem (compensating for missing water sources, avoiding drought, and supplying water to lakes and ponds,...) (Figure 1.6).

Description in detail the flows of water in the economy

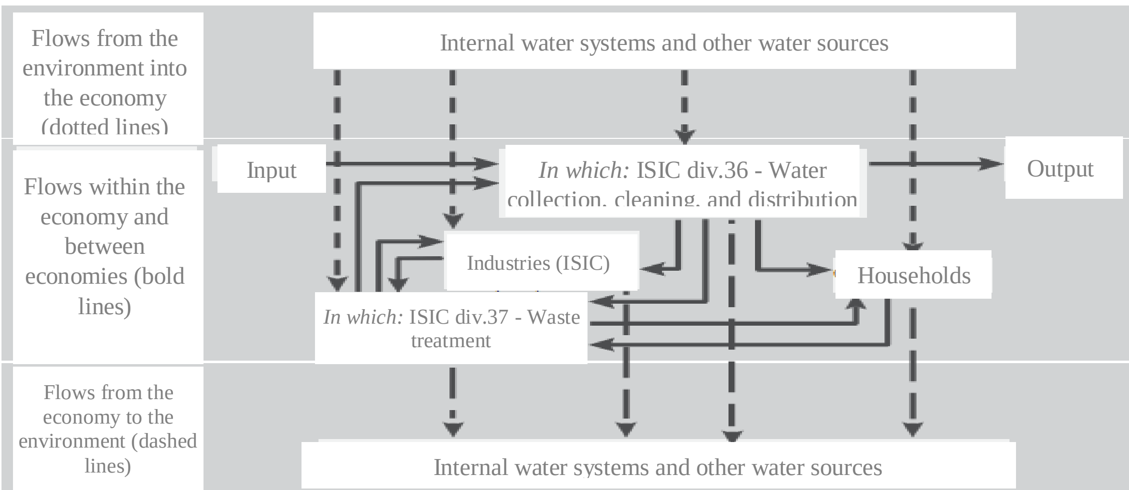


Figure 1.6. The flows of water in the economy

Source: ISPONRE, 2020

1.4. International experiences on the circular economy of water resources and water reuse circulation

1.4.1. Experiences of the EU

According to BIO by Deloitte (2015), the EU's water reuse policy is based on: (i) International standards: WHO Guidelines for Safe Wastewater Use (3rd ed. 2006); ISO standards (ISO 16075 – guidelines for the use of treated wastewater in irrigation projects); (ii) Policy evaluations in non-EU countries; and (iii) EU policy context in general.

Table 1.2. Examples of policy evaluations to promote water reuse in a number of non-EU countries

Policies	Examples
Price incentives	**Israel:** Agricultural water reuse is subsidized at high prices. The state pays the entire cost of transporting and storing water and also assumes the cost of high-level wastewater treatment system renovations. Farmers pay only for low-level wastewater treatment that is suitable for irrigation. This subsidy is smaller than wastewater treatment to meet discharge standards into surface water. **Australia:** A number of mechanisms are in place to avoid or reduce wastewater discharge into environmentally sensitive areas, in particular, not charging a fee for treated wastewater if it is reused.
Awareness raising	**Singapore:** The NEW ater project is associated with an impressive program of building national commitments on water reuse. The visitor's center was built to communicate about the project. **USA:** The United States has a national water reuse database (NWRD) that provides general utility/facility information and annual data on water flow, treatment, and reuse in the states that reuse the most water, which are California, Florida, and Texas. This database encourages, promotes, and disseminates information related to water reuse at the local, regional, state, and national levels.
Water reuse goals	**Australia:** In 2007, the government committed to achieving a national target of 30% wastewater reuse by 2015. Many large cities and some states also set specific targets. **USA/California:** Set a target to increase the amount of used water, compared to the 2002 level, to at least 1,233 m3/year by 2020 and about 2,467 m3/year by 2030. **Singapore:** For non-drinkable water reuse, the target by 2011 is 30%, according to the NEWater project (achieved). **Jordan:** The government intended to increase the reuse of treated domestic wastewater in agriculture to 220 m3/year by 2022, representing 13% of the country's available water.

Source: BIO by Deloitte, 2015

EU legislation focuses on the reuse of industrial wastewater. Essential documents include the Industrial Emissions Directive (2010/75/EU) and the Best Available Techniques Reference (BREFs). The applications mentioned in these documents are mainly related to water reuse and internal wastewater use for several purposes, such as cooling and cleaning. The EU does not yet have a framework standard for water reuse, but it is promoted by EU legislation. These policies either directly or indirectly address the benefits of water reuse or prescribe conditions to be followed in relation to the environment and health. The EU also issued many Action Plans for the circular economy. COM (2015)0614 emphasized, in addition to the efficient use of water, the reuse of treated wastewater through:

- Proposing legislation specifying minimum quality requirements for reused water as treated wastewater (used for irrigation and replenishment of groundwater);
- Guidelines for integrating water reuse in water planning and management;
- Giving good practices on water reuse implementation;
- Supporting innovation through the European Innovation Partnership;
- Investment support

The Water Framework Directive and relevant directives

The Water Framework Directive (WFD) No. (2000/60/EC) promulgated includes contents on water management in river basins; combining emission limits with environmental quality standards; ensuring adequate water supply; and encouraging the efficient use of water resources for greater citizen participation. The EU also issues many environmental directives and relevant standards.

Urban wastewater treatment

The EU promulgated many documents on urban and industrial wastewater treatment. These documents ***set limits*** on concentrations or percentages of pollutants in wastewater. The documents also stipulate that treated water can be reused. In addition, the EU has many documents regulating ***the safe use of fertilizers and food***, water reuse, and relevant water quality, as well as developing associated mechanisms and coordination activities to promote the practical implementation.

EU Innovative Partnership Mechanism on Water

The EU Innovative Partnership on Water (EIP Water) mechanism aims to remove barriers to innovation, connect supply and demand for stakeholders wishing to innovate, provide strategies and solutions, and promote experimentation. EIP Water's directing group invited action groups to develop and experiment solutions such as:

- Innovative solutions or treatment, production, water recycling and recovery experiments for urban residents, in agriculture and industry, ecosystem evaluation;

- Systems capable of determining the quality of water after recycling and recovery to make management decisions;
- Pilot projects of advanced separation and extraction technology in industrial zones to harvest resources from wastewater and reuse water.

Research projects

The EU sponsors research projects on community action on a wide range of issues: water reuse technologies, water quality assessment, and aspects of water resource management.

EU Structural and Investment Funds (ESIF)

This fund directly supports or links with agricultural and marine funds to provide financial support for projects that offer solutions to protect water resources, especially wastewater treatment or recycling plants.

1.4.1.1. Experiences of the Republic of Cyprus

Cyprus is a water-scarce country, heavily dependent on rainwater and prone to drought. In 2005, Cyprus defined criteria for wastewater quality, and water reuse has become one of the most integrated provisions in the regulations on urban wastewater management. Cyprus aims to replace 40% of freshwater needs in agriculture with circulating water. Currently, treated wastewater has been used for irrigation in agriculture, parks, and urban green areas. Cyprus issues Guidelines for Good Agricultural Practices providing how to use water to ensure the public health and compliance with regulations on use of wastewater after treatment. The use of wastewater for irrigation of leafy vegetables, tubers, export plants, and ornamental plants is prohibited. Cypriot legislation extends the standards and controls the use of treated wastewater for a variety of uses and types of circulating water.

1.4.1.2. Experiences of France

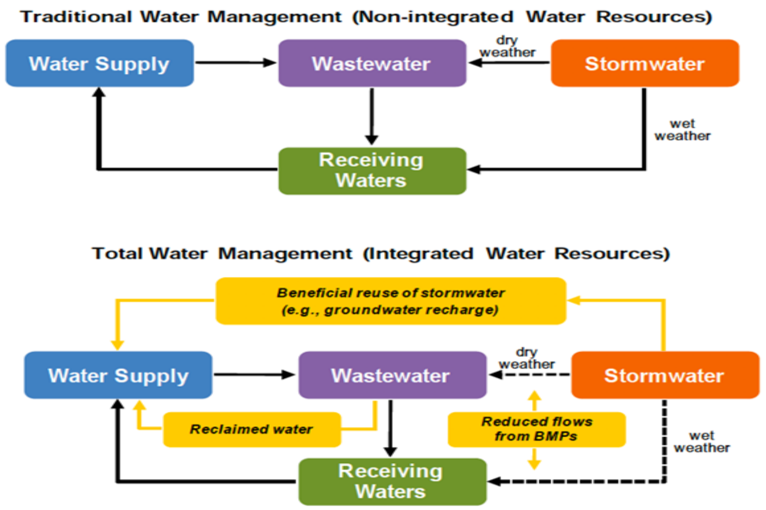
France is not under severe water pressure but is also gradually facing water scarcity. France issues water reuse standards in agriculture and irrigation for green areas, mainly related to horticultural crops, orchards, cereals, urban greenery, forests, grass fields, gardens, and golf courses. Recycled water quality standards in France are closely linked to national legislation on agricultural sludge. Monitoring is carried out with both wastewater and sludge. Legal standards for circulating water quality and minimum risk management measures for water treatment plants were introduced in 2010. In addition, wastewater treatment units need to establish programs to monitor treated wastewater and sludge quality. The data is passed on to the governor, the market, and the users of the land irrigated with the above water sources.

1.4.1.3. Experiences of Germany

Germany implements water reuse to restore aquifers in Berlin. For 120 years, the city of Berlin has used recycled water (treated wastewater) mixed with surface water. This water is put into water plants through filtration and storage systems, then can be used as drinking water. Berlin has established an integrated water management cycle related to water reuse circulation. Surface aquifers contain 14-28% recirculating water. Germany also applies many models of treated wastewater use for agricultural irrigation.

1.4.2. Experiences of the USA

In the US, about 7-8% of wastewater is reused for many different purposes, such as urban activities (landscape and golf course irrigation); agriculture (cultivation and livestock); isolation space creation; environment (water supply for wetlands and river and stream flow maintenance); industry (production, cooling, and equipment cleaning), in which, the reuse of wastewater for agricultural activities accounts for the highest proportion (Phan Mai Linh & Nguyen Dinh Tung, 2021).



…

Figure 1.7. The traditional water management model has been transformed into an integrated water resource management model in the US

Source: Rodrigo et al., 2012

Stemming from the transformation of management methods, the US identifies wastewater as a link in water resource management, not just an endpoint in management. Many studies on water reuse circulation have been carried out. Water reuse circulation is integrated into the integrated planning of water resources. The issues of water management and reuse are also addressed in federal and state legislations such as the National Environmental Policy Act (NEPA), legislations on the protection of biological resources, landscapes, and culture… On the basis of regulatory frameworks and federal guidelines, many states have issued detailed policies, regulations, and financial, technical, and management guidelines for wastewater reuse. Regulations and guidelines on water reuse have also been issued by many US states, specifying the requirements for water quality, the technology for the treatment, monitoring, and supervision of water quality, and the minimum distance to water supply wells corresponding to different reuse purposes. The water quality parameters required to be strictly controlled include pH, BOD, turbidity, Fecal Coliform, and Residual Chlorine. Some states provide separate licenses for wastewater reuse in the state licensing scheme system. Some other states incorporate permission for wastewater reuse in existing water resource licenses.

1.4.3. Experiences of some Asian countries

1.4.3.1. Experiences of Japan

According to UNESCO (2020), in order to manage wastewater reuse, in 2005, the Japanese Government issued technical standards on wastewater reuse with 7 pollution parameters that need to be controlled for different purposes of wastewater reuse (Table 1.3). The Ministry of Land, Transport, Technical Infrastructure and Tourism of Japan has also developed and issued technical guidelines related to wastewater reuse such as guidance on wastewater reuse systems using UF membrane filtration technology and UV sterilization. For technical requirements, Japan also has regulations on the level of wastewater treatment for the purposes of water reuse. Specifically, for water reused for sanitary washing, irrigation spraying, and landscaping, wastewater must be sand filtered or treated at an equivalent or higher grade; for water reused for recreational purposes, wastewater must be treated by flocculation combined with sand filtration or more advanced treatment.

Table 1.3. Water quality standards for water reuse in Japan

<table>
<tr><th></th><th>Standard applicable location</th><th>Sanitary washing</th><th>Irrigation spraying</th><th>Landscaping</th><th>Recreational areas</th></tr>
<tr><td>E-Coli</td><td rowspan="6">Wastewater treatment facility output for reuse</td><td colspan="2">Not detected</td><td>Total Coliform =1000 CFU/100ml</td><td>Not detected</td></tr>
<tr><td>Turbidity</td><td colspan="3">(Management goal) ≤ 2</td><td>≤ 2</td></tr>
<tr><td>pH</td><td colspan="4">5.8-8.6</td></tr>
<tr><td>Sensory assessment</td><td colspan="4">Good</td></tr>
<tr><td>Color*</td><td></td><td></td><td>≤ 40</td><td>≤ 10</td></tr>
<tr><td>Odor</td><td colspan="4">Odorless</td></tr>
<tr><td>Residual Chlorine</td><td>Responsible boundary location</td><td colspan="2">(Management goal)
Free residual Chlorine ≥ 0.1 mg/l
Synthetic residual Chlorine ≥ 0.4 mg/l</td><td>No regulations</td><td>(Management goal)
Free residual Chlorine ≥ 0.1 mg/l
Synthetic residual Chlorine ≥ 0.4 mg/l</td></tr>
</table>

1.4.3.2. Experiences of Singapore

Total water demand in Singapore is expected to double by 2060 compared to about 1.9 million m3/day of today's demand. To meet the expected demand, besides the water conservation strategy, water reuse and desalination were being increased to provide 85% of the water demand at that time. Singapore's long-term water security strategy began to take shape in 1965 (after independence) due to the scarcity of water resources. Throughout the years, Singapore has developed a comprehensive water resource management system, including basin management, infrastructure development, local treatment and storage, and imported water (from Johor, Malaysia), setting up pricing and non-pricing mechanisms for conservation purposes for domestic and foreign users, wastewater management and treatment to produce reused water from urban sources since 2003 (project NEWater), and desalination of water since 2005. Singapore is a leader in water innovation and saving. Thanks to timely action, the country significantly reduces water consumption, conserves natural resources, and makes the most of water recycling. In particular, water is not only recycled for agricultural and industrial use but also for drinking.

Water conservation in Singapore includes rainwater use, seawater desalination, standard rainwater harvesting systems, and treated wastewater reuse. Singapore collects rainwater from two-thirds of its land area through an 8,000-km network of sewers, which leads to 17 reservoirs, at the same time, collects used water from the drainage tunnel system located 60 meters below the ground. In 2003, the NEWater project was launched. This is a clean water source treated and purified by microfiltration, osmosis, and UV sterilization. NEWater is drinking water but is mainly used for industry and stored for the dry season and meets 30% of the country's demand. According to calculations by the National Water Agency of Singapore (PUB), by 2060, the NEWater program alone will meet 85% of Singapore's water consumption needs. Singapore is currently building a plant with a pilot program of electrochemical desalination, which uses an electric field to separate salt from seawater. In addition to the application of technological solutions, Singapore has increased the application of political institutions and raised awareness about water resource protection. The Public Utilities (Water Supply) Act and the Sewage and Drainage Act are the common legal basis for the water industry.

Figure 1.8 shows the water circulation in Singapore, including NEWater's contribution to the circular economy by closing the water cycle and extending the life of water resources through longer use, resulting in many economic, social, and environmental benefits.

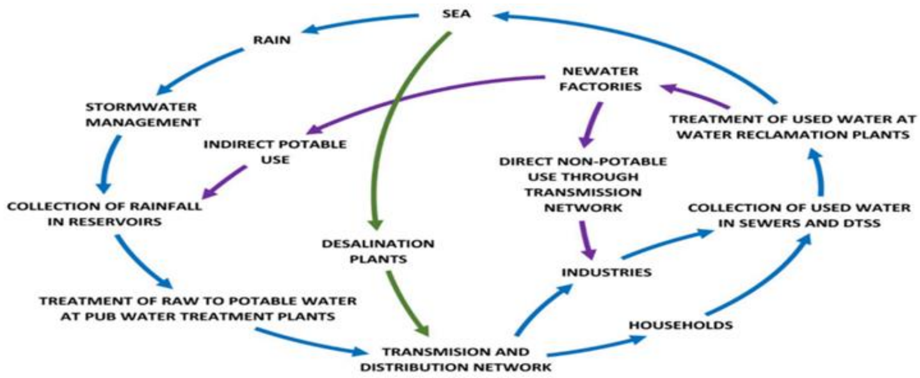


Figure 1.8. The water cycle in Singapore

1.4.3.3. Experiences of China

China is a rather special case when it has implemented the circular economy at all three levels: the macro level (cities, provinces, and regions), the medium level (symbiotic groups), and the micro level (enterprises) with a primary focus on industrial systems, the construction environment, urban infrastructure, and ecology. At the micro level, social production and ecological design in enterprises have been focused on since 2003, when the Law on Cleaner Production Promotion was enacted. The medium level is the model of EIZs, agroecological systems, and waste trading markets. The macro level is a model of ecological cities and ecology, which was started in 2005 in 10 localities, including Beijing, Shanghai, Chongqing, Guiyang, Ningbo, Hebei, Tongling, Liaoning, Shandong, and Jiangsu. The Circular Economy Promotion Law, which took effect in 2009, also further strengthens this approach. The Chinese government has also established many policies related to the recycling and reuse of water resources, including integrating them into the circular economy and urban water policies. China has issued the 12th National Five-Year Plan for Urban Wastewater Treatment and Construction of Wastewater Recycling and Treatment Facilities with an investment of about 30.4 billion yuan. The Plan sets out detailed targets for wastewater reuse rates in major cities and across the country over time. The main contents include:

- Detailed water quality standards (by sources and purposes of use after treatment) and guidelines for using recycled water;
- Support for the construction of a water treatment plant and encourage the expansion of the use of recycled water, primarily by local authorities using treated wastewater;
- Develop a detailed master plan for wastewater recovery for each city.

Table 1.4. Some of China's water reuse circulation policies

Government units	Policies	Policy contents
National Assembly	- The 12th Comprehensive Work Plan on Energy Conservation and Emission Reduction (2011); - The 12th National Five-Year Plan for Urban Wastewater Treatment and Construction of Wastewater Recycling and Treatment Facilities (2012)	- Apply a lower price for recycled water than for normal water; provide tax exemption and reduction policies for manufacturers using circulating water - Encourage the use of treated wastewater for industry, car washing, and urban irrigation; force certain subjects to use recycled water
MOHURD (Ministry of Housing and Urban-Rural Development) MOST (Ministry of Science and Technology)	- Procedures for the temporary management of water recovery facilities in urban areas (1995); - Regulations on water-saving management in urban areas (1998); - Policies on technology to improve and reuse wastewater in urban areas (2006); - Five-year national plan for science and technology development (2011)	- Actively use recycled water; promulgate policies to develop technology for wastewater recovery and reuse - Prioritize the use of circulating water in green parks; Use wastewater from water treatment plants in agricultural irrigation; - Have policies to encourage wastewater recovery and water reuse at central and local levels; financial support for recycling water from local sources - Step by step form a water supply system and rational water use structure
MEP (Ministry of Environmental Protection) GAQSIQ (General Agency of Quality Supervision, Inspection, and Quarantine)	- The 12th Five-Year National Plan for Environmental Protection Policy and Environmental Economic Policy Development (2011); - Water quality standards when using circulating water and treated wastewater according to different types and industries	Develop quality standards for wastewater treatment and use of treated wastewater, circulating water
MOF (Ministry of Finance) NDRC (National Development and Reform Commission)	- Announcement of non-collection of value-added tax on circulating water and relevant types (2008); - Announcement of Proposals for Investment policy and Financial support for the Development of the Circular economy (2011)	- Achieve wastewater reuse rates of 20-25% in major northern cities and 10-15% in southern coastal regions by 2015 - Encourage wastewater recovery and reuse to improve the efficiency of water resource use

Source: Lyu et al., 2016

However, the implementation of the above contents in China has many challenges, such as low demand for recycled water, very few public awareness and education programs promoting the use of circulating water, and low public acceptance limiting policy effectiveness. Policy implementation and enforcement are difficult to unify, as cities depend on water conversion in basins. Water resource management in China is divided into different levels, and sometimes the implementation is inconsistent. The proposed solutions emphasize technicality rather than overall management. The promotion of industry using circulating water has not been effective due to the cost of infrastructure investment, including pipelines and large treatment facilities. The resulting efficiency is not enough to cover the capital and investment costs.

CHAPTER 2

POLICY AND LEGAL SYSTEM ON THE CIRCULAR ECONOMY OF WATER RESOURCES AND WATER REUSE CIRCULATION IN VIETNAM

2.1. Policies on the management and protection of water resources in Vietnam

The first Law on Water Resources (Law No. 08/1998/QH10) was approved by the 10th National Assembly of the Socialist Republic of Vietnam, at its 3rd session, on May 10, 1998, and took effect on January 1, 1999. The LWR was amended for the first time in 2012 and continues to be amended from 2022. Along with the LWR, the Government has also issued sub-law documents detailing and guiding the implementation of the LWR. The Law affirms that water resources are owned by the entire people and are uniformly managed by the State. Water resources include surface water, rainwater, underground water, and seawater in the territory of the Socialist Republic of Vietnam. Seawater and underground water in the exclusive economic zone and continental shelf are prescribed in other legal documents. Mineral water and natural hot water are regulated by the Law on Minerals. The LWR stipulates the scope of regulations and the rights, obligations, and responsibilities of state agencies in the management of water resources; determines the responsibilities of state agencies, economic organizations, socio-political organizations, social organizations, armed units, and all individuals in the protection of water resources; determines the rights and obligations of the subjects when participating in relationships arising from the exploitation, use, and protection of water resources; stipulates standards on clean water, on that basis, to determine the level of pollution and degradation of the water environment and the responsibilities of individuals and organizations in compensation for damage and restoration of the current state of the environment.

Up to now, basically, legal documents in the field of water resources have been relatively complete, creating a legal corridor for the state management of water resources. Although the legal framework for water resource management in Vietnam is relatively comprehensive, there are still a number of policy challenges in this work, which are reflected in the following points:

- - According to the Ministry of Natural Resources and Environment, currently, 67 legal documents have been issued on water resource management, including 13 Decrees of the Government, 35 Circulars of the Minister, 445 documents guiding and implementing the LWR, and provisions of the provincial decree. In the period of 2016-2020 alone, 04 Decrees and 19 Circulars and Decisions were issued. However, up to the present time, the responsibilities among ministries, branches, and localities in state management of water resources, management and operation of water exploitation and use works, responsibility for protection and development of water resources, prevention of harmful impacts caused by water... still not clearly separated.

- Over the past years, with the attention of the Party and State, the investment in the field of water resource protection and development, irrigation, hydropower, forest protection and development, water supply for industry, and clean water for domestic use has been gradually concerned and focused on. However, the investment and allocation of resources are still unbalanced; the capital arrangement is inadequate, lack of synchronization, and ineffective in many unfinished projects. Funding for basic water resource surveys, planning, database building, and digital transformation is lacking and inconsistent.

- After nearly 10 years of implementation, the 2012 LWR has contributed to a positive change in the awareness and actions of the whole society on the protection, exploitation, and use of water resources more effectively and sustainably, bringing in revenue for the state budget. However, in the context of climate change (CC), 63% of the water is formed outside the territory, and the declining quality of water resources is posing significant challenges. Many new guidelines on resource management and practical requirements for protection and restoration to ensure national water resource security have emerged. That fact requires the law on water resources and a number of regulations related to the management and protection of water resources to be updated, amended, and supplemented soon, ensuring consistency and comprehensiveness.

2.2. Policies on circular economy development in Vietnam

Developing the circular economy has become a trend in countries, especially when the world's resources are increasingly depleted. In Vietnam, the Party and State have determined that the development of the circular economy is one of the important orientations of the country in the coming time. As early as 1998, Directive 36/CT-TW, dated June 25, 1998, of the Politburo on Strengthening environmental protection in the period of industrialization and modernization of the country clearly stated the need must “promulgate tax and credit policies to support the application of clean technologies” and “apply clean technologies with low waste and low consumption of materials and energy”. Resolution No. 41-NQ/TW, dated November 15, 2004, of the Politburo clearly stated: "Encouraging the recycling and use of recycled products" and "Step by step applying measures to force import and production facilities to must recover and treat used products”. Directives 29-CT/TW in 2009, Strategy for Socio-Economic Development 2011-2020, and Resolution 24-NQ/TW, dated June 3, 2013, on Proactively responding to climate change and strengthening resource management and environmental protection also continued to emphasize and detail the above tasks. The point of view of circular economy development is emphasized in the Resolution of the 13th Party Congress “Digital economy, circular economy, green growth are models chosen by many countries" and set orientation in the period of 2021-2030, Vietnam "building a green, circular, environment-friendly economy". The Resolution of the 13th Party Congress considers "encouraging the development of the circular economy model for integrated and effective use of the output of the production process" as one of the strategic solutions for the next 10 years. To develop the circular economy, the Politburo also issued Resolution No. 55-NQ/TW, dated February 11, 2020, "On orientations of Vietnam's national energy development strategy to 2030, with a vision to 2045", which affirms that priority must be given to the development of renewable energy, power plants using waste to protect the environment, and the circular economy. Most recently, the circular economy is regulated in Article 142 on the circular economy of the 2020 LEP (Law No. 72/2020/QH14). Accordingly, the circular economy is defined as "*an economic model in which the design, production, consumption, and service activities aim to reduce the exploitation of raw materials and materials, extend the life cycle of products, limit waste emissions, and minimize adverse impacts on the environment*". The regulation of the circular economy directly in the 2020 LEP shows the importance of the circular economy as well as the consistent and synchronous policies on building the circular economy in Vietnam. Within the framework of the 2020 LEP, the responsibilities of organizations and individuals producing, importing, and exporting products and packages in the collection, recycling, and treatment are specified in Article 54 and Article 55. Along with the recognition of the circular economy, the 2020 LEP has added a number of mechanisms, policies, and regulations to promote the circular economy, including economic tools and policies such as natural resources tax, environmental protection fee, and preferential policies of the state, and on resource mobilization for environmental protection.

In order to concretize the Party's policies, besides the LEP, over the years, Vietnam has had many policies and regulations related to the development of the circular economy, including the 2010 Law on Minerals, the 2012 LWR, the 2013 Law on Land, and many sub-law documents. The contents related to the circular economy are also reflected in the Strategy for the Sustainable Development of Vietnam 2011-2020, the Strategy for Environmental Protection to 2020, with a vision to 2030, the Strategy for Green Growth, and the National Strategy for Integrated Management of Solid Waste to 2025, with a vision to 2050.

Due to early orientation on legal policies related to the contents of the circular economy, since the 2000s, the Government has soon issued sub-law documents to concretize and gradually implement the contents of the circular economy.

Decree No. 38/2015/ND-CP, dated April 24, 2015, on Waste and Scrap Management. Several articles in this decree (Articles 4, 40, 51) state that wastewater must be collected, treated, reused, or transferred to an appropriate functional unit for reuse or treatment to meet environmental technical regulations before being discharged into the environment. The State encourages the socialization of waste collection, transportation, reuse, recycling, and treatment. Regarding waste management from agricultural activities, Article 51 of Decree 38 clearly states that livestock wastewater can be reused for watering crops or used in other agricultural production activities, according to the regulations of the Ministry of Agriculture and Rural Development and the Ministry of Natural Resources and Environment.

Decision No. 16/2015/QD-TTg, dated May 22, 2015, regulating the recovery and treatment of discharged products. Article 5 of this Decision clearly states the responsibilities of the manufacturer in reusing the discharged products that have been recovered in accordance with the regulations on waste management.

Decision No. 491/2018/QD-TTg, dated May 7, 2018, approving the adjustment of the national strategy on the integrated management of solid waste to 2025, with a vision to 2050. The main point of view is defined as the integrated management of solid waste is the management of the entire waste life cycle from generation to final treatment, including prevention, reduction, classification, collection, reuse, recycling, and final treatment for the purpose of protecting human health, protecting the environment, saving resources, and adapting to climate change towards the sustainable development of the country; Solid waste generated must be managed in the direction of being considered as a resource, classified and collected in accordance with the selected treatment technology. The views identified in Decision 491 are the most direct orientations for building a circular economy in Vietnam in the coming period. Along with that, the vision for 2050 is determined: "Striving to 2050, all types of solid waste generated will be collected, reused, recycled, and treated with advanced and environmentally friendly technologies, suitably to the actual conditions of each locality, limiting the volume of solid waste to be buried to the lowest level".

Decree No. 08/2022/ND-CP, dated January 10, 2022, detailing a number of articles of the Law on Environmental Protection. Article 138 of Decree 08 provides more detailed regulations for owners of investment projects in concentrated production, business, and service establishments and zones, industrial clusters, and owners of investment projects in urban and concentrated residential areas in the implementation to achieve the circular economic criteria. Accordingly, the three pillars represent three groups of common criteria for the circular economy, including:

- The first group: Reducing the exploitation and use of non-renewable resources and water resources; increasing efficiency in using resources, raw materials, and materials; and saving energy.
- The second group: Extending the use life of materials, equipment, products, goods, components, and elements.

- The third group: Limiting waste generation and minimizing adverse impacts on the environment, including reducing solid waste, wastewater, and emissions; reducing the use of hazardous chemicals; recycling waste; recovering energy; reducing single-use products; and green shopping.

Article 139 of Decree No. 08 stipulates the roadmap and responsibilities for the implementation of the circular economy.

Box 2.1. Responsibilities for the implementation of the circular economy

1. The Ministry of Natural Resources and Environment shall:

a) Preside over and cooperate with Ministries, ministerial agencies, and provincial People's Committee in formulating and submitting to the Prime Minister a national action plan on circular economy as prescribed in clause 5 of this Article before December 31, 2023;

b) Build and operate a platform for connecting information and sharing data on the application of the circular economic model;

c) Establish and introduce a methodological framework for the application and evaluation of the implementation of the circular economy;

d) Fulfill the responsibilities specified in Clause 2 of this Article in the industries and fields under its management.

2. Ministries and ministerial agencies, based on their assigned functions, tasks, and state management fields, shall:

a) Formulate and approve an action plan for the implementation of the circular economy applied to the industries, fields, and products in conformity with the national action plan mentioned in Clause 5 of this Article;

b) Organize propaganda and dissemination of legal knowledge, education, and training on circular economy contents;

c) Integrated specific criteria for the implementation of circular economy in the process of formulating development strategies, planning, plans, programs, and projects; management, reuse, and recycling of waste;

d) Manage and update information and data on the implementation of circular economy and integrate them with the MONRE's information system;

đ) Organize pilot application of the circular economy to the energy, fuel, and waste industries and fields according to the action plans specified in Clauses 4 and 5 of this Article;

e) Fulfill other responsibilities related to the circular economy according to the regulations of this Decree.

3. Provincial-level People's Committees shall:

a) Formulate and collect opinions of relevant Ministries and ministerial agencies and approve a provincial action plan for implementation in conformity with the national action plan mentioned in Clause 4 of this Article;

b) Fulfill the responsibilities specified in Points b, c, d, and e, Clause 2 of this Article within their provinces;

c) Organize pilot application of the circular economic model to the energy, fuel, and waste industries and fields according to the action plans specified in Point a of this Clause, Clauses 4 and 5 of this Article.

Source: Decree No. 08/2022/ND-CP (Article 139)

In addition, Decree No. 08 also clarifies the mechanism to encourage the implementation of the circular economy. Article 140 clearly states that the State gives priority to investment in the development of the circular economy for the following activities:

- Scientific research, application development, technology transfer and equipment production, and human resource training.
- Platform provision for sharing information and data about the circular economy.
- Organizations and individuals that have activities and projects applying the concept of the circular economic model that are eligible for incentives and support for environmental protection and projects granted green credits in accordance with the law and entitled to the incentives and supports prescribed in this Decree and other relevant laws and the incentive mechanism for green credits and green bonds according to the provisions of this Decree.

Also in this Decree, the State encourages:

- Researching and developing technologies and technical solutions, providing consulting services, and evaluating the implementation of the circular economy in accordance with the law.
- Developing linking and sharing models on the circular use of products and waste; establishing cooperative groups, cooperatives, unions of cooperatives, recycling alliances, regional and urban-rural linking models, and other models as prescribed by law to implement investment, production, business, and service activities meet the criteria of the circular economy.
- Developing the market for the reuse of discharged products and the recycling of waste.
- Mobilizing resources in society to implement the circular economy.
- International cooperation, exchange of experience, knowledge, and technology on the circular economy.

On June 7, 2022, the Prime Minister issued Decision No. 687/QD-TTg, approving the Master Plan for Economic Development in Vietnam. The specific objectives of the Master Plan are:

- Contributing to concretizing the goal of reducing greenhouse gas emission intensity per GDP by at least 15% by 2030 compared to 2014, towards the goal of net emissions to "0" by 2050.
- Increasing awareness and investment interest of domestic and foreign enterprises and investors to the circular economic model; enhancing the application of the circular economic model to promote the greening of economic sectors. By 2025,

economic projects will initially be put into practice and bring into play their economic, social, technological, and environmental efficiency; contribute to the recovery of renewable resources; reduce energy consumption; increase the share of renewable energy in the total primary energy supply, the rate of forest cover, the rate of waste recycling, and the localization rate of agricultural, forestry, fishery, and industrial export products. By 2030, renewable energy-based projects will become a major driver in reducing primary energy consumption, achieving self-sufficiency in most or all renewable energy-based energy needs, and increasing the forest cover rate.

- The circular economic model supports building a green lifestyle, encouraging waste separation, and promoting sustainable consumption. By 2025, it will reuse, recycle, and treat 85% of generated plastic waste; reduce 50% of plastic waste in the sea and ocean compared to the previous period; gradually reduce the production and use of non-degradable plastic bags and disposable plastic products in daily life; significantly increase the recycling capacity of organic waste in urban and rural areas; and raise awareness of agencies, organizations, enterprises, communities, and people in the production, consumption, and disposal of plastic waste, non-biodegradable plastic bags, and single-use plastic products in daily life. By 2030, the proportion of urban domestic solid waste collected and treated up to standards and regulations through the circular economic models will reach 50%; 100% of urban organic waste and 70% of rural organic waste will be recycled. It will not give rise to the direct burial of domestic solid waste from the circular economic models in urban areas and maximize the rate of urban wastewater collected and treated to meet standards and regulations as prescribed in urban areas.

- The circular economic model makes an important contribution to improving the quality of people's lives and resilience to climate change, ensuring equality in conditions and opportunities.

The circular economy has been and is becoming an inevitable trend, taking place strongly in many countries around the world, including Vietnam. Shifting from a traditional economy to a circular economy is an effective solution, helping to maintain economic development while minimizing adverse impacts on the environment.

2.3. Problems raised in perfecting the law on the circular economy of water resources and water reuse circulation in Vietnam

It can be affirmed that Vietnam has built a policy and legal foundation to promote the implementation of the circular economy. In particular, Vietnam is one of the first countries in ASEAN to institutionalize the regulation of the circular economy in the Law. Although there have been some achievements in policy development, the regulations on the circular economy in general, and the CEWR, in particular, have just stopped at the framework level and have not yet been concretized in detail and fully. References to previous relevant legal documents to create a synchronous legal corridor for the development of this economic model are as follows:

2.3.1. In the management of water resources

Some policy difficulties in the management of water resources can be mentioned as follows:

- The national water resource planning and General planning for basic surveys of water resources have not yet been issued;
- General planning of most inter-provincial river basins and inter-provincial water sources which belong to the planned subjects has not yet been developed;
- No national inventory of water resources has been carried out; The basic surveys and protection of water resources and the prevention of pollution, degradation, and depletion of water resources have not yet reached the set targets. The database on water resources is still small, scattered, and not synchronized;
- Several policies related to ensuring water security, water sources for drinking and living, landscape, and the circulation of rivers, ponds, and lakes are lacking and not specific;
- The capacity to organize law enforcement and water resource management is not commensurate with the requirements of the task, especially at the provincial-level;
- Water resources have not been given due attention in the formulation of strategies, master plans, and plans for the socio-economic development and development of various sectors;
- The establishment and implementation of activities of river basin organizations are slow; Coordination, monitoring, and integrated management activities by river basin are lacking and weak;
- The network of water resources monitoring and supervision stations is still lacking and inconsistent, not meeting the requirements for evaluating the quantity, quality, and forecasting of water resource developments;
- The awareness of enterprises and people about the protection, exploitation, and use of water resources is still limited;

- There are no appropriate mechanisms and policies to mobilize society's resources to participate in the protection and prevention of pollution, degradation, and depletion of water resources;
- There has not been close and synchronous coordination between the water resource management agency with relevant agencies, ministries, and branches and the People's Committees of the provinces in solving inter-sectoral, inter-provincial, and local issues, such as planning, development, and restoration of watershed forests, protection of aquatic resources; protection of water sources during the implementation of hydropower, irrigation, and aquaculture projects;
- The inspection of the enforcement of the law on water resources has not been regular. There is no specialized inspection organization for water resources.

2.3.2. In policies on water reuse in Vietnam

The reuse of treated wastewater plays an important role in each country's development strategy and is one of the contents of Goal 6 - ensuring the availability and sustainable management of water resources and improving sanitary conditions for all people (SDG6) of the Sustainable Development Goals set by the United Nations and committed by member states to 2030, including Vietnam. In order to achieve this goal, enterprises participating in the circulation/reuse of treated wastewater will enjoy preferential policies and incentives from the State through a number of regulations and decrees specifically as follows:

- ***Article 41*** The 2012 LWR clearly states that individuals and organizations investing in using recycled water and reusing water will be entitled to preferential loans and tax exemption and reduction in accordance with the law. ***Article 42*** also indicates that organizations and individuals conducting scientific research, application, and development of water reuse treatment technologies will be encouraged, created favorable conditions, and allocated funds and developed scientific and technological research programs from ministries, ministerial-level agencies, and provincial-level People's Committees.
- ***Article 7*** of Decree 54/2015/ND-CP states that organizations investing in building new or upgrading work items to collect and treat wastewater up to the national technical standards on water quality under the purpose of reusing and using circulating water for their activities will be entitled to preferential loans in accordance with the law on investment credits of the State; be exempted or reduced from corporate income tax in accordance with the tax law.
- ***Article 5*** of Decree No. 154/2016/ND-CP shows that enterprises with circulating water in production facilities that do not discharge into the environment in any way will be exempted from environmental protection fees.

- Decree No. 13/VBHN-BXD, dated April 27, 2020, regulating drainage and wastewater treatment, also mentions the reuse of wastewater and rainwater in Articles 20 and 24. ***Article 20*** states that the State encourages the reuse of rainwater to serve the needs contributing to reducing inundation, saving water resources, and minimizing the exploitation and use of groundwater and surface water. Organizations and individuals that invest in equipment and technology for rainwater treatment and reuse will be supported with preferential loans and other incentives as prescribed by law. The reuse of rainwater for different purposes must meet appropriate standards and technical regulations on water quality. ***Article 24*** regulates the use of wastewater after treatment. Using wastewater after treatment must satisfy the following requirements: (i) The quality of treated wastewater must comply with the standards and technical regulations prescribed for the use of water for different purposes without affecting people's health and ensuring environmental safety and hygiene; (ii) In case of using wastewater after treatment, wastewater must be distributed to the point of consumption according to a separate system, ensuring that it does not infiltrate and affect the clean water supply system in the same area or region, and (iii) the MONRE shall preside over and cooperate with relevant ministries and branches in promulgating standards and technical regulations on the use of wastewater after treatment.

Although the State has issued policies to encourage and give incentives to enterprises to participate in water circulation and reuse, these incentives are only meaningful in terms of policies and guidelines for state management without specific guidelines for implementation. Currently, the Government has issued Decree No. 80/2014/ND-CP on drainage and wastewater treatment and Decree No. 38/2015/ND-CP on waste and scrap management to manage the issue of the reuse of wastewater after treatment.

Article 24 of Decree No. 80/2014/ND-CP stipulates that the management and reuse of wastewater after treatment must ensure quality, and the treated wastewater must comply with the standards and technical regulations prescribed for the use of water for different purposes without affecting people's health and ensuring environmental safety and hygiene; Such wastewater must be distributed to the point of consumption according to a separate system, ensuring that it does not infiltrate and affect the clean water supply system in the same area or region. This Decree assigns the MONRE to preside over and cooperate with relevant ministries and branches in promulgating standards and technical regulations on the use of wastewater after treatment. However, up to now, there have been no documents promulgating standards and technical regulations on the use of wastewater after treatment.

Article 36 of Decree No. 38/2015/ND-CP on general principles of wastewater management states that wastewater must be managed through activities of reducing, reusing, collecting, and treating up to environmental technical regulations, and encourages activities to reduce and reuse wastewater. Article 40 of this Decree also indicates that the wastewater after treatment must be collected for discharge into the receiving sources or collected for reuse. If for reuse, it must comply with specific regulations for each use purpose.

To implement Articles 23 and 24 of Decree No. 80/2014/ND-CP and Articles 36 and 40 of Decree No. 38/2015/ND-CP, so far, only Circular No. 04/2015/TT-BXD on decentralized wastewater treatment management mentioned the possibility of water reuse. Article 4 of Circular No. 04/2015/TT-BXD indicates that the management and use of wastewater after treatment must aim at saving water resources, using it safely, and ensuring the requirements of public health and environmental sanitation. Wastewater after treatment is mainly used for the following purposes: agricultural irrigation, watering plants, washing roads, washing cars, industrial reuse, water replenishment for water reservoirs serving recreational landscapes, and using circularly or for other purposes. The quality of treated wastewater for reuse must ensure that it meets the national technical regulations on the quality of water used for the corresponding purposes and complies with current regulations. This also indicates the responsibilities of the owner of the drainage work in organizing, directing, developing plans, and implementing water reuse or water circulation; organizing and directing the review and evaluation of environmental impacts and influences on wastewater activities after treatment; organizing the supervision, monitoring, and periodically check and analysis of the quality of treated wastewater according to regulations. Provincial-level People's Committees shall promulgate mechanisms and policies for the implementation of incentives and support for activities using treated wastewater in their respective localities in accordance with local conditions; organize inspection and examination of the management and use of wastewater after treatment according to its competence.

In addition, the Ministry of Natural Resources and Environment has issued a document guiding the implementation of the reuse of treated wastewater for watering plants and washing roads as follows: The reduction and reuse of wastewater by individuals and organizations in the production process, business, and service activities are encouraged to comply with the provisions of the 2020 LEP and Decree No. 38/2015/ND-CP. However, in order to be reused for the purposes of watering plants and washing roads on the premises, the treated wastewater must meet the corresponding national technical regulations on wastewater identified in the approved environmental impact evaluation report or certified environmental protection plan or equivalent documents and records and must meet the following requirements:

- In case of treated wastewater reuse to irrigate green plants on the premises, the establishment owner is responsible for treating wastewater up to technical standards as prescribed in QCVN 08-MT:2015/BTNMT, column B1 before reusing;

- In case of treated wastewater reuse to flush toilets or washing streets on the premises, the establishment owner is responsible for treating wastewater up to technical standards as prescribed in QCVN 08-MT:2015/ BTNMT, column A1 before reusing;

- Owners of production, business, and service establishments must declare and pay environmental protection fees for the amount of wastewater used for the purposes of watering plants, flushing toilets, and washing streets according to the provisions of Decree No. 154/2016/NĐ-CP dated November 16, 2016, of the Government on Environmental protection fees for wastewater.

Although there have been many different documents on water reuse, Vietnam currently has no official document on national technical regulations on the reuse of treated wastewater. Decree No. 80/2014/ND-CP, stipulating that the Ministry of Natural Resources and Environment shall preside over and cooperate with relevant ministries and branches in promulgating standards and technical regulations on the use of wastewater after treatment suitable for each recycled wastewater use purpose (Article 24), has not been fully implemented so far. Currently, the Vietnamese national standard agency has accepted the first TCVN on water reuse and has been announced by the Ministry of Science and Technology (MOST) as the national standard in this field, including TCVN 12526: 2018 (ISO 20761:2018) on Guidelines for safety evaluation of water reuse - Evaluation parameters and methods; and the set of TCVN 12525:2018 (ISO 20760:2018) (2 parts) on Guidelines for centralized water reuse systems. The latest set of standards to be issued is QCVN 01-195:2022/BNNPTNT on Livestock wastewater used for crops, chaired by the Plant Protection Agency, jointly compiled by the Livestock Production Agency, submitted by the Department of Science, Technology, and Environment, appraised by the Ministry of Science and Technology and issued in December 2022. This regulation stipulates the allowable limit values for the parameters of livestock wastewater used to irrigate crops.

Article 7 of the 2020 LEP mentions that the result of the appraisal of the environmental impact evaluation report shall be approved for or an environmental license shall be issued to the new investment project that discharges wastewater directly into the surface water only for the case in which the investment project owner has adopted a scheme to treat wastewater in accordance with environmental technical regulations regarding the quality of surface water before discharging into a receiving environment or has adopted a circulation or reuse scheme in order not to generate more wastewater. However, the contents of the environmental impact evaluation report mentioned in Article 32 do not mention the recycling or reuse of wastewater after treatment. Regulations on legal procedures for the issuance of environmental permits when there is a system to reuse wastewater after treatment or water circulation, but there are no specific guidance circulars.

In addition, although the 2020 LEP has mentioned the issue of waste reuse in production, business, and service establishments in Article 53 and encourages the reuse of wastewater when meeting the requirements on environmental protection and water use purposes in Article 72, there are no specific guidelines for enterprises when reusing treated wastewater as well as technical standards for different use purposes. The commercialization of treated wastewater to become a water supply is also not mentioned in any documents.

CHAPTER 3

CURRENT SITUATION OF THE APPLICATION OF THE CIRCULAR ECONOMY OF WATER RESOURCES AND WATER REUSE CIRCULATION IN VIETNAM

3.1. Current situation of the application of the circular economy in industrial production facilities in Vietnam

As described in Section 1.2, a number of circular economic models have been applied in production and business in our country. In agriculture, the use of circular economic models, making use of agricultural wastes and by-products, is quite common. Typically, the model Garden-Pond-Cage (GPC) or Forest-Garden-Pond-Cage (GFPC) has been applied since the 1970s-1980s then, developed in popularity with many different livestock and plants, combining cultivation and livestock along the food chain and waste treatment with Biogas.

This is a closed circular economic model that is effective in agricultural production while making full use of and exploiting waste and by-products in production, ensuring economics and solving environmental problems in agriculture and in the countryside. In rural areas, the model of using post-harvest straws for cattle and buffaloes and producing straw mushrooms and construction materials is also popular. Some craft villages use agricultural by-products such as corn husks and rice straws to make handicrafts.

In the field of industry and handicrafts, circular economic models are also applied in many fields and enterprises. Specifically:

- In the field of renewable energy development, many enterprises have invested in the development of solar power and wind power. The number of registered solar energy projects increased sharply in the 2018-2020 period, mainly in the South Central provinces. Wind power also has great potential for development as Vietnam has more than 8% of the area rated as having good wind potential, which can generate 110 GW of electricity, concentrated mainly in the central and southern coastal areas and Highlands. Vietnam also has the potential to develop biomass electricity with the sources of wood waste, agricultural by-products, urban waste, livestock waste, and other organic matter. However, currently, the development of biomass energy is still limited.

- The model of making use of waste products and by-products in production is applied in many enterprises, such as waste products from the sugar industry to make alcohol and generate electricity, ash and slag from thermal power plants as construction materials... Some enterprises are conscious of recycling and reusing waste, such as the model of beer companies reusing bottles and recycling beer bottle caps, tobacco companies selling tobacco rolls for manure, and the packaging recycling model of a group of 9 Vietnamese companies, including Coca-Cola Vietnam.

- The model of EIZs was recently born in some localities such as Hai Phong, Ninh Binh, Can Tho, and Da Nang.
- Many Vietnamese craft villages have been recycling scrap, domestic and industrial waste for many years, such as recycling steel from scrap, recycling paper scraps, and recycling plastic... while creating livelihoods for people. people and contributing to waste treatment.

In consumption, many green consumption models were born in the direction of using renewable and energy-saving products. For example, many consumers tend to give up the habit of using plastic straws and plastic bags to use organic packaging products and green housing designs using wind and natural light.

It can be said that the circular economy was applied quite early in Vietnam and brought certain results. Although the idea of the concept of the circular economic model is very feasible and effective, the practical application in Vietnam is still not much. In nature, the transition to a circular economy model requires the participation of all stakeholders in the product value chain. The limited demonstration models have not yet created persuasion and spread in the communities and society. In the field of wastewater reuse, currently, in Vietnam, a number of enterprises have been reusing wastewater to clean and cool industrial equipment, such as Vedan, Nestle, Ajinomoto, and Formosa. To protect and save water resources, Ajinomoto company has built and put into operation two systems, including a cooling tower and wastewater treatment system applying bio-nitrogen technology. The production process of the Ajinomoto factory often consumes a large amount of water to cool down the machinery. This water source is taken from the Dong Nai River. In 2009, the amount of water used to cool down machinery taken from the Dong Nai River amounted to 864,268 m3. Therefore, the company applied a new technology by building a cooling tower system with its own water reservoir and using circulating water from these lakes for cooling. By 2017, the amount of water the company used to cool down machinery had decreased by 84.5% to 125,492 m3. Intel Products Vietnam company has put into operation a system that allows the reuse of 100% of industrial wastewater from a private factory in 2014 in Ho Chi Minh City, helping save nearly 200 m3 of clean water/day (nearly 74 million liters of water/year) and reduce about 40% of water consumption of the whole factory. Approaching the circular economy and water reuse is relatively popular at Vinamilk company with a water volume of 237309 m3/year (accounting for 5.15% of water supply) through the application of technical and management initiatives to serve for equipment cleaning and watering plants (Vinamilk, 2020).

Nestlé Vietnam Co., Ltd. and La Vie Co., Ltd. are two enterprises that are working to create a more positive impact on local water sources in Vietnam. Specifically, Nestlé Vietnam and LaVie strictly control water usage at factories. As a result, the water-saving rate is improved year by year. The amount of water used in production per unit of product in 2020 decreased by 30-35 % compared to 2010 thanks to initiatives and solutions to reduce water use and collect, treat, and reuse water. Wastewater in Nestlé's coffee factory in Vietnam is filtered and reused. In 2015, 7.7 million m3 of water in the entire production operation was reused. With the Nescafé Plan sustainable coffee development of Nestlé Vietnam, through easy-to-practice irrigation techniques, coffee farmers can now save more than 40% of water while still achieving crop yields as desired. LaVie company is supporting enterprises with professional and technical solutions and investing in some equipment to help enterprises reduce 80% of the water used for the cooling system of machinery and equipment, contributing to limiting the use of water from nature. LaVie is also studying the expansion of cooperation so that other enterprises can reuse Class A wastewater from LaVie's factories to serve some stages in industrial production where the enterprises are using groundwater. With the ambition of "No negative impact on the environment in production and business activities until 2030" of Nestlé Group and the goal of creating a positive impact on local water resources, Nestlé Vietnam and La Vie will continue to launch initiatives to contribute to the community contribution to the sustainability of natural water resources, both in terms of quality and quantity.

However, the number of enterprises participating in water reuse and water circulation is still very limited. Most enterprises today do not pay much attention to these issues.

According to a survey of 51 manufacturing and service enterprises in Da Nang, only 1 enterprise uses water reuse measures, and 9 enterprises want to reuse water in the future. Although the reuse of water can help enterprises save money on buying clean water and wastewater treatment costs, the licensing procedure is complicated, the investment is large, and enterprises are responsible for the quality of reused water. This leads to the fact that most enterprises are still hesitant to reuse wastewater.

At the macro level, the promotion of the circular economy in the reuse of wastewater after treatment is almost not specifically mentioned in the legal documents, so the integrated approach of the circular economy in the reuse of water resources, serving different economic sectors, has not been paid attention to.

Some initial practices that have approached the concept of the circular economy in water use in enterprises in Vietnam are as follows:

Reuse wastewater for plant watering

In order to reuse water for the purpose of watering trees on the premises, the establishment owner is responsible for treating wastewater up to technical standards as prescribed in QCVN 08-MT:2015/BTNMT, column B1 before reusing.

Reuse wastewater for toilets

The use of wastewater for toilet flushing reduces the need for clean water. The feasibility of reusing wastewater for toilet flushing depends primarily on the design and construction capabilities of the plumbing system and the associated infrastructure costs.

Reuse wastewater for road washing

Road care and maintenance uses a large amount of reused wastewater with specific quality requirements, such as odorless, non-corrosive, or colorless water. Water is also used in dust control (dust suppression) or street washing on factory premises.

Reusing wastewater for production

Depending on the production technology, it is possible to study the option of wastewater reuse applied in the process/stage. For example, recirculating condensate and wastewater for washing (in textile dyeing), exhaust gas treatment systems, and heat exchangers...

Reuse wastewater for fire prevention and control and landscaping

Rainwater and wastewater, after treatment up to standards, can be stored and used for fire prevention and control and created circulating lakes for air conditioning, landscape creation, and fish and aquaculture farming…

For each enterprise, the problem of approaching the concept of the circular economy in wastewater reuse is also receiving attention and response. Research and implementation in Da Nang in 2021-2022 within the framework of the project "Collective Actions for Water Conservation" with 50 enterprises have shown the potential of approaching the circular economy in water reuse.

3.2. Opportunities and potentials for transition to the CEWR model and water reuse circulation in industrial production facilities

According to many experts, the decade 2020-2030 is a decisive period for Vietnam to transform itself into an industrial country. This is an important milestone and opens up many opportunities for the development of the circular economy in water reuse in Vietnam, as shown in the following points:

First, the circular economy is a general development trend of the world in the context of increasing environmental pollution, climate change, and depletion of natural resources, especially water resources. Many countries around the world, like the Netherlands, Sweden, Japan, Singapore, etc., have applied the concept of the circular economy in water reuse and achieved great benefits. This is a testament to the correctness of the model and, at the same time, suggests many lessons for other countries, including Vietnam.

Second, sustainable consumption is becoming a new requirement as consumers begin to pay attention to environmental issues. According to a study by Circular Colab (2018), in the United States, 66% of consumers said that they are willing to pay more for environmentally friendly products, 88% of consumers would stick with enterprises that have active activities in environmental protection and sustainable social benefits, and 76% would leave suppliers and enterprises that operate contrary to consumer expectations, etc. In Vietnam, according to the Corporate Social Responsibility Report (Nielsen, 2017), consumers are paying more and more attention to “green” and “clean” issues, especially health and natural environmentally friendly organic product factors. The report also showed that up to 86% of Vietnamese consumers are willing to pay more to buy products with a commitment to positive environmental and social impacts. This causes manufacturers to find ways to change their production and business models to fulfill social responsibilities and meet the increasing requirements of consumers.

Third, Industry Revolution 4.0 creates technological breakthroughs, fundamentally changes production methods, and breaks down the material limitations of the development process. Many green, smart, environmentally friendly technologies, wastewater treatment, and recycling technologies were born, which is a golden opportunity to help Vietnamese enterprises shorten the time to access modern technology in the world, narrowing the gap in technology level with other countries.

Fourth, the development of the circular economy has been integrated into the guidelines, policies, and strategies for socio-economic development and legal documents of Vietnam and received the consensus and support of all classes of society because it has solved the problem of resource scarcity, protected the environment, responded to climate change, and improved economic efficiency. Many legal documents such as the LEP, the LWR, and the Law on Livestock have mentioned the encouragement of the reuse of water after treatment up to standards.

Fifth, Vietnam is in the process of perfecting the socialist-oriented market economy institution. Encouraging and creating a mechanism for the circular economy to develop in the context of a competitive market will create many opportunities for private sector investment in the development of circular economic models in water reuse in the coming time.

3.3. Barriers and challenges in the application of the circular economy of water resources and water reuse circulation in Vietnam

In addition to development opportunities, Vietnam also faces many challenges in the application of the CEWR and water reuse.

First, the pressure to implement the CEWR is not strong enough to make a change. Social pressure from the communities, suppliers, customers, and consumers is evaluated as a factor that has a close relationship with the enterprise's environmental status. The survey results of VCCI show that enterprises are not under much pressure from customers. Only about 20% of enterprises receive requests from customers on issues such as the rate of wastewater reuse, the percentage of recycled materials in products or packaging, and the percentage of renewable energy used in production and business activities (Pham Hong Chuong et al., 2022).

Second, the mechanism to encourage the application of circular economic models is still limited and inadequate. Enterprises that carry out water reuse and circular water resource economic activities are mainly based on their own experiences, initiatives, and financial and technical capabilities. 54% of surveyed enterprises believe that the transition to a circular economy model faces many difficulties in terms of policy, technology, or finance (Pham Hong Chuong et al., 2022). The activities of recovering and recycling materials, products, waste, water, and energy can only be carried out within the enterprise due to the costs of building a recovery and recycling system for the entire value chain. Although the reuse of wastewater has great potential, there is no incentive mechanism. In addition, Vietnam does not have a system to recognize the efforts as well as the results of enterprises' transformation to the circular economic model as a basis for proposing appropriate incentive mechanisms.

Third, there is a lack of information and demonstration models of the CEWR that are suitable for Vietnam's conditions. The limited demonstration models have not yet created persuasion and spread in the communities and enterprises.

Fourth, there is no legal framework for the development of circular economic models applied to water reuse, and there is a lack of technical standards to define the purposes of using recycled water.

Fifth, investment in the waste sector is still low. The level of wastewater treatment technology has improved but still reveals many limitations. Domestic enterprises face many difficulties in standard wastewater treatment technology to reuse wastewater for different purposes.

Sixth, the waste management system in general, and wastewater in particular, still has many shortcomings and lacks coordination and responsibilities in wastewater and water resources management under the management of many ministries, branches, and localities. The mechanism of sanctions and punishments for violations of the environmental law is not strong enough and has a deterrent effect.

Seventh, community awareness about reused water is still low due to concerns about safety and hygiene conditions in the reuse of treated water.

CHAPTER 4

EVALUATION OF THE POTENTIALS OF WASTEWATER TREATMENT TECHNOLOGY IN SUPPORTING THE WATER REUSE CIRCULATION TECHNIQUES IN VIETNAM

4.1. Treatment and management of urban and industrial wastewater

4.1.1. Domestic wastewater

Pollution level:

Domestic wastewater contains many pollutants, such as suspended solids, dissolved organic matter, inorganic salts, nutrients, and pathogenic bacteria in addition to some metals. Concentrations of these substances vary with the amount of water used by households. The amount of water reused depends on water supply capacity, income, usage habits, and weather. The harmful effects of these ingredients include oxygen depletion of water sources due to the decomposition of organic matter, eutrophication of water sources by nitrogen and phosphorus, and foaming due to jerky powders, detergents, and indole odors.

The direct discharge of household waste into the environment greatly affects the ecosystem in the area, especially the surface water environment, such as rivers, lakes, canals, and ditches. Domestic wastewater is also a cause of soil and water pollution if not treated properly. Dirty water flows into crop and livestock areas, causing adverse impacts on crops and livestock. Untreated domestic wastewater flows into ponds, streams, and rivers, killing organisms such as shrimp, fish,..., then seeps into the ground and pollutes groundwater. Some manifestations of health being affected by water pollution such as jaundice, gastrointestinal diseases,...

Treatment requirements

Article 86, Clause 4 of the 2020 LEP on Collection and treatment of wastewater stipulates: "*Wastewater generated from organizations and households in a low-density residential area must be collected and treated on the spot in accordance with environmental protection requirements before being discharged into receiving sources*".

4.1.2. Industrial wastewater

Pollution level:

Water source pollution due to industrial production is very heavy. For example, in the textile industry and the pulp and paper industry, wastewater usually has an average pH of 9-11 times; biochemical oxygen demand index (BOD) and chemical oxygen demand (COD) can be up to 700mg/1 and 2,500mg/1; suspended solids... much higher than the allowable limit. The wastewater content of these industries contains cyanide

(CN-) exceeding 84 times, H_2S exceeding 4.2 times, and NH_3 content exceeding 84 times the permissible standard, causing heavy pollution of surface water sources in residential areas. The level of water pollution in industrial zones, export processing zones, and industrial clusters is very large.

Treatment requirements

Article 86, Clauses 1, 2, 3 of the 2020 LEP on Collection and treatment of wastewater stipulates:

1. New urban areas, new concentrated residential areas; business, production, and service establishments; concentrated production, business, and service zones; and industrial clusters must have a wastewater collection and treatment system separated from the rainwater drainage system, except for special cases prescribed by the Government.

2. Wastewater in urban areas or concentrated residential areas shall be managed as follows:

a) Domestic wastewater generated from organizations and households must be collected and connected to the wastewater collection and treatment system;

b) Wastewater generated from production, business, and service activities in urban areas must be collected and undergo preliminary treatment before being connected to the urban wastewater collection and treatment system; preliminarily treated wastewater must comply with the regulations of the urban area or concentrated residential area or regulations of the local authority;

c) Wastewater generated from production, business, and service activities in urban areas that not-yet have a centralized wastewater treatment work must be collected and treated in accordance with environmental protection requirements before being discharged into receiving sources.

3. Wastewater generated from production, business, and service activities shall be managed as follows:

a) Wastewater in production, business, and service establishments; concentrated production, business, and service zones; and industrial clusters are collected and preliminarily treated before being connected to the industrial wastewater collection and treatment system at the request of the investor in the construction of concentrated production, business, and service zones or industrial clusters, ensuring that wastewater must be treated to meet environmental protection requirements;

b) Wastewater in production, business, and service establishments located outside urban areas and concentrated residential areas; concentrated production, business, and service zones; and industrial clusters cannot be connected to the wastewater collection and treatment system must be collected and treated to meet environmental protection requirements before being discharged into the receiving sources.

4.2. Research situation on water reuse in Vietnam and the world

4.2.1. In the world

In developed countries, due to the increasing awareness of the communities about environmental and resource issues, and stricter standards on the environment in general and wastewater in particular, enterprises tend to apply appropriate technologies for industrial wastewater treatment, starting with basic physicochemical technologies, gradually adding advanced biological and physicochemical technologies to meet the higher daily discharge standards. In addition, due to the increasing price of water supply for production, factories are looking for ways to reuse wastewater after treatment. Enterprises that invest in the reuse of wastewater after treatment not only achieve economic benefits but also improve their image in the eyes of the communities.

Nowadays, the reuse of industrial wastewater in developed countries has been widely deployed, especially in some industries that use a lot of water or can generate highly toxic wastewater, such as the Pulp and Paper manufacturing industry, Electric factories, Textile dyeing industry, and Food processing industry…

Today's trend is to move towards factories with an increasingly radical level of water reuse, to the point of being called "Zero Discharge" factories.

Industrial water reuse programs began in the United States in the 1940s when treated wastewater was disinfected and used in steel production lines. In Sweden, between 1930-1970, a total 5-6 time-increase flow of reused water has been recorded. During the last quarter of the 20th century, the benefits of promoting water reuse as a means of replenishing water resources were recognized by the United States and the European Union.

In European countries, the implementation of water reuse depends on current regulations or guidelines and is divided into 3 groups of countries:

- Countries that already have regulations and/or guidelines related to water reuse such as France, Italy, and Spain;
- Countries that plan to introduce regulations and/or guidelines related to water reuse such as Belgium, Greece, Portugal, Sweden, the Netherlands, and the UK;
- Countries that do not have regulations and/or guidelines related to water reuse such as Austria, Denmark, Finland, Germany, Ireland, and Luxembourg.

Although interest in water reuse is widespread in many other parts of the world to meet the demand for reliable and high-quality water supplies for agriculture, industry, and cities, water reuse technology was only discovered in Asia in the last years of the 20th century. The results of implementation in China showed that the average rate of water reuse in 82 major cities reached 56% in 1989 and the highest rate of water reuse was 93%.

In Singapore, water reuse technology also appeared very early. In 2003, the country produced and supplied reused water with high quality after treatment, meeting the standards of drinking water. This water is supplied directly to industries, commercial centers, and buildings. In addition, Singapore's Hyflux Water Treatment Co., Ltd. has developed a device that uses advanced membrane filtration technology to remove contaminants from wastewater in order to reuse water for production. Singapore is also a leader in the technology of treating wastewater into drinking water.

In Japan, the application of water reuse has been around since very early due to limited water resources in this country. Previously, only 40% of Japan's population (including rural residents) had access to a water supply. However, by 1995, 89.6% of the Japanese population in cities larger than 50,000 people had access to clean water. Initially, the water reuse program was applied in buildings, schools, and commercial centers to reuse water mainly for sanitary ware. After that, the centralized wastewater treatment and reuse works of the city were built and provided the water source for urban sanitation for the whole city.

4.2.2. In Vietnam

Research on water reuse in Vietnam is mainly related to cleaner production programs. Cleaner production has been popularized since the 90s of the last century through the support projects of many sponsors such as Switzerland, Sweden, Canada, and Denmark and efforts of all levels of government.

Many enterprises in the textile, paper, food processing, and metal processing industries in Hanoi and Ho Chi Minh City, Da Nang, Hai Phong, Nam Dinh, Ninh Binh, and Phu Tho have participated in the application of cleaner production within the framework of the UNIDO-SECO project (VIE/96/023) and the project "Reducing industrial pollution – cleaner production" funded by UNIDO and SIDA (Sweden). The VCEP project (phase 2) has also supported the Departments of Science and Technology, Natural Resources and Environment of Hanoi, Hai Phong, Da Nang, and Binh Duong to implement cleaner production solutions for the ceramic, rubber latex processing, recycled paper, seafood processing, steel, textile dyeing industries... Over a period of implementation, managers as well as manufacturers have acknowledged that cleaner production is an effective tool to reduce environmental pollution. The demonstration models at hundreds of production facilities and their benefits have been demonstrated in practice and communicated on the mass media but the extent of diffusion and effectiveness has not been as expected. Many enterprises, especially small and medium enterprises, have not yet applied this tool or have not applied it continuously. The vast majority of CP projects implemented in the past years are mainly internal management, energy saving, and material change. Deeper cleaner production solutions, such as the reuse of water in production, involve technological lines that require significant investment capital, so they are rarely applied in Vietnam. Therefore, at present, the research and application of water reuse in industrial production is still limited.

4.3. Analysis and selection of technology in water reuse circulation in Vietnam

4.3.1. Some guidelines for water reuse in urban areas

There are now some specific guidelines for water reuse in urban areas:

- TCVN 12525:2018 (ISO 20760-1:2018): Water reuse in urban areas - Guidelines for centralized water reuse systems.
- TCVN 12526:2018 (ISO 20761:2018): Water reuse in urban areas - Guidelines for safety evaluation of water reuse.

Safe reuse of water includes the elements shown in the following table:

Table 4.1. Elements showing "Safety for reuse of water"

Goals	Consideration factors
Health safety	Health risks to communities and renewable water treaters
Environmental safety	Effects on terrestrial and aquatic ecosystems Effects on receiving land, groundwater, surface water, and air.
Vehicle safety (such as equipment and piping)	Closure of deposits, dirt, and corrosion of vehicles Hazardous effects on the properties of the user's belongings, e.g. clothing and vehicles Operational adverse effects (excluding failures in manual operations) of processes and equipment
Community acceptance	Color and odor

- TCVN 13247:2020: Guidelines for water quality classification for water reuse

Table 4.2. Classification of water quality for non-drinking reuse purposes with regard to the levels of treatment

Quality level	Possibility of contact	Example minimum processing requirements
High	Direct body contact In a public place Children Unwanted risk of ingestion or inhalation	Level-2 treatment with filtration and sterilization
Medium	Accidental body contact (direct body contact is not recommended)	Level-2 treatment and sterilization
Low	Body contact prohibition	Level-2 treatment done at high speed with coagulation, flocculation, or stable lake

- TCVN 13246:2020 (ISO 20426:20180): Guidelines for the management and evaluation of health risks for the reuse of non-drinking water.

In Vietnam, sets of standards related to the reuse of water after treatment have been gradually formed and interested since 2017, with the first set of standards being TCVN 12180: 2017 (ISO 16075: 2015): Guidelines on the use of treated wastewater for irrigation projects. Since that time, many other sets of standards have been developed to guide the reuse of wastewater, helping to make the problem of wastewater reuse more accessible to a wide range of subjects.

However, at present, all the Vietnamese standards related to water reuse are only focusing on the goal of reusing non-drinking water, none guiding the reuse of water for domestic use. Therefore, it is necessary to develop more standards to guide the reuse of treated water for different purposes. These standards are also a good premise for the development of technical regulations to assess the quality of treated water for different purposes.

4.3.2. Wastewater objects

The object of assessment is domestic wastewater. Domestic wastewater is generated in all types of industrial, commercial, and service production. According to management requirements, the wastewater after treatment needs to control 11 parameters as follows:

Table 4.3. Parameters of untreated input water

No.	Parameter	Unit	QCVN 14:2008-BTNMT column A (1)	QCVN 08-MT/2015 column A (2)
1	pH		5-9	5,5 – 9
2	BOD_5	mg/l	30	15
3	Total suspended solids (TSS)	mg/l	50	50
4	Total dissolved solids	mg/l	500	500
5	Sulfur	mg/l	10	1
6	Ammonium	mg/l	5	0,9
7	Nitrate	mg/l	30	10
8	Animal and vegetable fats and oils	mg/l	10	1
9	Total surfactants	mg/l	5	0,4
10	Phosphate	mg/l	6	0,3
11	Total Coliforms	MPN/100ml	3000	

If domestic wastewater is treated to reach column A (QCVN 14), it is unlikely to be discharged into water sources used for domestic purposes (with technical quality equivalent to columns A_1 and A_2 of QCVN in terms of surface water quality in the table above), because A_1 and A_2 are values in the receiving source, not the values after the treatment source. Therefore, to ensure the purpose of using water for domestic use, the water quality level must be raised to column A_1 (QCVN 08 – MT: 2015/BTNMT), in which 3 parameters of ammonium, nitrate, and phosphate need to be further treated.

Table 4.4. Parameters of treated output water

No.	Parameter	Unit	QCVN 14:2008-BTNMT column A	QCVN 08-MT/2015 column A_1
1	Amoni	mg/l	5	0,3
2	Nitrat	mg/l	30	2
3	Photphat	mg/l	6	0,1

The new QCVN 01-195:2022/BNNPTNT, issued in December 2022, stipulates the allowable limit values for parameters of livestock wastewater used to irrigate crops, only specifying some parameters relevant to heavy metal and pathogenic micro-organisms contents.

Table 4.5. Limit values of parameters of livestock wastewater used for crops

No.	Parameters	Unit	Limit value	Types of crops
1	pH	-	5,5-9	All types of crops
2	Chloride (Cl-)	mg/L	≤ 600	
3	Arsenic (As)	mg/L	≤ 0,1	
4	Cadmium (Cd)	mg/L	≤ 0,01	
5	Total chromium (Cr)	mg/L	≤ 0,5	
6	Mercury (Hg)	mg/L	≤ 0,002	
7	Lead (Pb)	mg/L	≤ 0,05	
8	E.coli	MPN or CFU/100 mL	≤ 200	All types of crops
			> 200 - 1.000	All types of crops except for annual vegetables and medicinal plants
			> 1.000 - 5.000	Forest trees, long-term industrial plants not used as food or pet food
			> 5.000	Not used for crops

Currently, the circulation and reuse of wastewater after treatment is a matter of concern. The research and application of post-treated wastewater reuse technology both save water resources and two costs for enterprises, including input clean water costs and costs for a third party collects and treats them up to standards to discharge into the environment. Depending on the purpose after treatment, there will be corresponding output standards and the selection of appropriate technology. With the treatment of wastewater so that the water can be reused, there are a number of technologies used, such as ion exchange, adsorption, and membrane filtration technology... However, there has not been a complete evaluation of the effectiveness of the application of the above technologies in wastewater treatment for reuse, clearly realizing the potential of the ion exchange method in wastewater treatment to be able to reuse wastewater after treatment.

Today, strict regulations on environmental management and the impacts of water scarcity have caused the cost of freshwater consumption to have increased globally. In addition, the pressure on enterprises to maintain or increase profit margins for their stakeholders is another driver toward water reuse in production processes, making this the optimal solution to replace freshwater sources in nature and save costs. Advanced technologies for effective treatment towards water reuse include RO membrane filtration technology. Ion exchange and adsorption are methods that also achieve high wastewater treatment efficiency with the purpose that after treatment, the water is used for irrigation and other domestic activities.

4.4. Wastewater treatment technologies used for water reuse

4.4.1. Adsorption technology

Adsorption technology can be used to remove the remaining pollutants in the wastewater after treatment to improve the quality of the treated water for reuse. Table 4.6 synthesizes ammonium, nitrate, and phosphate removal processes by different adsorption processes.

Table 4.6. Removal of ammonium, nitrate, and phosphate by adsorption processes

No.	Adsorption process	Typical absorbent materials
1	Ammonium adsorption	Ammonium adsorption by CeO2 – Mn2O3
		Ammonium adsorption by activated carbon made from rice straws
		Ammonium adsorption by zeolite
2	Nitrate adsorption	Nitrate adsorption by polystyrene
		Nitrate adsorption by biochar from melaleuca
		Ammonium and nitrate adsorption by biochar made from rice husk
3	Phosphate adsorption	Phosphate adsorption by ZnO
		Phosphate adsorption by laterite

Adsorption process

Because NH_4^+ ions can be oxidized to NO_3^- through nitrification, it is necessary to place the NO_3^- adsorption tower behind the NH_4^+ adsorption tower. If the NO_3^- adsorption tower is placed in front of the NH_4^+ adsorption tower, part of the NH4+ ions, after passing through the NO_3^- adsorption tower, may be oxidized to NO_3^- and not treated in the rear adsorption towers.

The study on PO_4^{3-} adsorption capacity of laterite showed that this process is affected by NO_3^- ion present in water. Therefore, it is necessary to place the NO_3^- adsorption tower in front of the PO_4^{3-} adsorption tower to avoid reducing the efficiency of the laterite PO_4^{3-} adsorption process.

On the above basis, it can apply the adsorption process below:

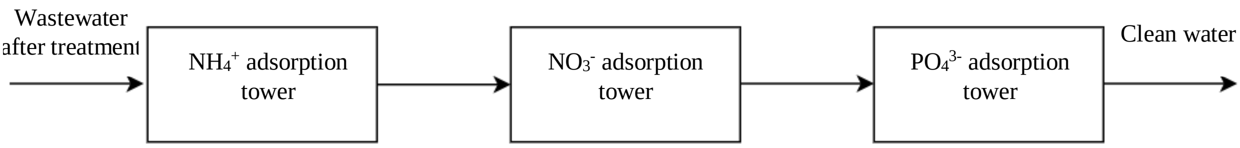


Figure 4.1. Schematic diagram of the adsorption process

Selection of adsorption equipment

Table 4.7. Characteristics of some types of adsorption equipment

Equipment	Advantages	Disadvantages
Powder material adsorption tank	Easy to disassemble, suitable for short-term use Fast adsorption rate due to large surface area	The treated water may contain adsorbent materials, which should be removed before using Adsorbent materials are difficult to regenerate Equipment works in batches and requires manpower to operate Need to install stirrer High-cost requirement
Static adsorption tower	Materials can be reused many times No need for rear-processing devices Can work continuously	Slow adsorption rate
Fluidized bed adsorption tower	Larger contact area than static adsorption tower Make the most of the surface area of the adsorption materials	Water flows at high speed, no guarantee of adsorption time Materials prone to abrasion Output water quality is not guaranteed

Choose a granular static adsorption tower due to higher economic benefits and ensure output water quality. The direction of water movement is from the top to avoid disturbing the materials. Water going to the top of the tower through the pump pipe is always easier than going through the adsorbent layer. Install support nets above and below the adsorbent to keep the water in place.

Feasibility of the method

Adsorption is a fairly common method today, used to treat water after treatment for the purpose of reuse. The adsorption method has the following advantages:

- Capable of treating some ions in water with high efficiency for reuse purposes;
- Diverse adsorbent materials can treat many types of ions in water;
- Some materials can be regenerated after adsorption, saving costs;

- Simple installation and operation process.

Specifically, in this research, the team recommends using three types of adsorbent materials for 3 different types of ions in water: acid laterite - PO_4^{3-} adsorption, biochar - CeO_2 - Mn_2O_3 - NH_4^+ adsorption, polystyrene attached trimethylamine group (TPM) - NO_3^- adsorption. These are the three materials with the highest adsorption capacity for each type of ion in the water, respectively, out of a total of more than 10 materials that the team has studied, achieving high adsorption efficiency. In addition, the adsorption saturation time of these three materials is very high (all over one month). Therefore, the use of this adsorption method to reuse the water after treatment is completely feasible.

Limitations that need to be overcome

However, the adsorption method still has some disadvantages to keep in mind:

- Some adsorbent materials can only absorb certain types of ions;
- Adsorbent materials have uneven sizes, causing errors in the calculation;
- Some materials in the adsorption process are affected by some other types of ions present in the water, leading to low adsorption efficiency;
- In addition to some cheap, easy-to-find, and easy-to-make adsorbent materials, there are also some materials with complicated processing and are hard to find, leading to high prices.

The adsorption system is effective only for granular materials. In order to improve the adsorption efficiency, for the powdered adsorbent materials that have better adsorption ability, higher capacity, and longer saturation adsorption time, it is necessary to improve and upgrade the system to meet the actual requirements.

4.4.2. Ion exchange technology

The ion exchange process is a chemical interaction process for liquid phase ions and solid phase ions (ion exchange resins). Swap chemical reactions (also known as substitution reactions) implement the mechanism that solid phase ions will absorb liquid phase ions, through which liquid phase ions will replace ions present on the membrane framework of solid phase ions (which is the exchange resin). Substances participating in ion exchange are usually inorganic and organic substances. Based on the nature of this ion exchange process, we can choose ion exchange materials to treat pollutants in wastewater. The efficiency of ion treatment depends on the properties of each resin, as outlined below. These ion exchange resins are of natural or artificial origin. The artificial ion exchange materials have higher exchange efficiency, while the natural ion exchange materials have lower exchange efficiency but are more environmentally friendly and regenerated.

Applicability evaluation

To evaluate and compare ion exchange materials, it is necessary to understand several parameters of resins: physical shape and processing performance. From these parameters, the advantages and disadvantages of various resins can be drawn, as well as the most suitable resin for the ion to be treated with the highest exchange efficiency and the most reasonable cost.

Table 4.8. Synthesis of usable ion exchange materials for water reuse

No.	Material	Category	Physical shape	Application
1	PLE (Polymeric Ligand Exchanger)	PO_4^{3-} exchange material	Large porous shape	PLE is used as PO_4^{3-} ion exchange material in secondary wastewater treatment, which can be applied to industrial wastewater containing a lot of phosphates.
2	KF zeolite resin	NH_4^+ exchange material	Fine grain and coarse grain	Performance affected by anion competition The efficiency depends on the ionic ratio in the material / the ion ratio in the wastewater
3	SIR-600 resin	NH_4^+ exchange material	Uneven shape, moss green color	Removes NH_4^+ in wastewater but requires a large amount and is costly
4	NaP1 zeolite resin	NH_4^+ exchange material	The shape depends on the grain size, 2 types are fine grain and coarse grain	Results of laboratory scales for ZM from fly ash to ammonium absorption, based on the cation exchange capacity of zeolites, show significant removal rates.
5	A490 relite resin	NO_3^- exchange material	slightly yellow, opaque grain, opaque yellow grain	This type of plastic only allows processing of NO_3^-
6	A520E purolite resin	NO_3^- exchange material	Spherical grain, color	Removes NO_3^- in wastewater with high efficiency

The ion exchange method is a potential method for water reuse because it allows the production of very high-quality water, the concentration of pollutants being almost completely removed through this technique. Various ion exchange materials. However, ion exchange technology has some limitations, as follows:

- The cost of construction, purchase of materials, and operation is high, so large projects rarely use this method;
- The cost to buy resin grain is very high because there are few types of exchangeable resins that have high exchange efficiency and meet the efficiency of the exchange process so that the output water quality meets the standards. To

solve the above problem, it is possible to regenerate the exchange material after the material has been saturated. Moreover, it is possible to find and replace artificial resins with natural exchange materials.

4.4.3. Modified membrane filtration technology

Modified membranes can be applied to remove residual pollutants in wastewater, specifically ammonium, nitrate, and phosphate.

Phosphate filtration membrane

a. Ceramic combined with activated carbons membrane

Membrane forming materials: A mixture of aluminum oxide powder (Al_2O_3) and activated carbon (AC) is mixed with a ratio of 9:1. Considering the structural characteristics of two types of membranes: (i) ordinary ceramic membranes and (ii) modified ceramic membranes, it shows that ceramic membranes often have pores (micropores) arranged quite seamlessly, so ions will easily pass through. For modified ceramic membranes, the pores are arranged alternately so ions will be blocked in many small membrane units in a large membrane, thereby increasing the filtration efficiency. The number of pores of the modified ceramic membrane increases significantly thanks to AC, so the water conductivity is enhanced.

Mechanism of membrane operation: Modified ceramic membranes treat phosphate ions in wastewater after treatment through an adsorption mechanism. The process occurs with three reactions: electrostatic interaction, ligand exchange, and surface complexation in the presence of two OH^- and amino groups. The three-component interaction of amino, OH^-, and phosphate eliminates the presence of phosphate in the water.

AC combination was found to increase the hydrophilicity of the membrane and facilitate the adhesion of the adhesive water layer near the membrane surface, preventing the adhesion of contaminants on the membrane surface. In addition, the increase in the negative surface charge of the modified membrane is thought to enhance the electrostatic repulsion of negatively charged contaminants from the membrane surface.

b. Combined membrane filtration/coagulation system

Membrane forming materials: The membrane system and adsorbent were supplemented with alum or a new aluminum-based adsorbent (heated aluminum oxide particles, HAOPs) in the MBR permeable membrane.

Membrane filtration mechanism: The addition of alum or HAOPs to an MBR permeable membrane or a synthetic solution containing only inorganic components removed the phosphate from the solution.

The removal of phosphate ions and the minimization of membrane clogging is the greatest advantage of MBR permeable membranes when combining alum and HAOPs (heated aluminum oxide particles). When both alum and HAOPs are applied (alum is applied directly to the membrane, and HAOPs are pre-deposited on the membrane), the system achieves good phosphate removal with a low clogging rate. In addition, the system can maintain a lower operating pressure, and the frequency of chemical cleaning can be reduced.

Nitrate filtration membrane

Membrane materials: PolyHIPE membrane is researched and fabricated through trimethylamine (TMA) and polypropylene (PP), which has shown to be effective to fabricate membranes with high nitrate (NO_3^-) treatment efficiency.

Material characteristics: Polypropylene is hydrophobic. According to research, only polypropylene MF membranes. The membrane is chemically and biologically stable, tolerates moderately high temperatures, and has a pH value range of 1-13.

Membrane filtration mechanism: Prepared anion-exchange polyHIPE membranes are used to remove nitrate ions from low concentrations of aqueous solutions. Mechanism of nitrate removal through ion exchange with a maximum ion exchange capacity of 1.76 meq/g.

The modified PES membrane has many outstanding advantages compared to the conventional PES membrane, from filtration efficiency to durability and adaptability in different environmental conditions. In addition to nitrate treatment, the membrane can also treat metals with very high treatment efficiency and is applied to treat different types of wastewater. The disadvantage of the membrane is that it is easy to clog the membrane if the concentration of nanoparticles is too large, so a backwash system is required.

Ammonium filtration membrane

Adsorbent materials: Clinoptilolite is the most abundant natural source of zeolites, which effectively remove ammonium from water. However, the use of Clinoptilolite powder has many disadvantages. Therefore, the application of Clinoptilolite with membrane filtration is a novel and innovative method.

The removal efficiency of HFCM for ammonium at different adsorbent dosages. The removal of ammonium increased to 96% as the number of adsorbent membrane fibers increased.

The HFCM ceramic membrane has many advantages, with its ammonia removal efficiency of 96%. The largest disadvantage of the membrane can be etched through the regeneration process.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The CEWR and water reuse have become an inevitable trend, taking place strongly in many countries around the world, including Vietnam. Shifting from a traditional economy to a circular economy is an effective solution, helping to maintain economic development while minimizing adverse impacts on the environment and protecting water resources.

Ensuring water security, water reuse circulation through the CEA, efficient and economical management and use of water is an important content defined in the LEP and the LWR. Circulating water management requires the integration of all possible initiatives to implement circular economic principles in the water and wastewater sectors, including technological, organizational, and societal changes. The selection and application of a systematic range of circular solution groups vary depending on the requirements and context of each specific country and region.

The experiences of developing frameworks and policies on the CEWR and water reuse circulation by countries around the world show that this problem is not only necessary for countries with water scarcity. Some lessons learned for Vietnam, in particular, are: (i) Concretizing the CEWR and water reuse in policies in different stages; (ii) Water reuse circulation should be considered on micro, medium, and macro levels; (iii) Promulgating and publishing information on specific standards on wastewater after treatment, circulating water for different use purposes; and (iv) Developing incentive mechanisms to promote the CEWR and water reuse.

The application of the CEWR and water reuse is a new issue in Vietnam and has achieved certain results in the following aspects: (i) Initially forming a legal and policy foundation to promote the implementation of the CEWR and water reuse; (ii) A number of models on the CEWR and water reuse have appeared; and (iii) Evidence of the potentials of wastewater treatment technology in supporting wastewater circulation and reuse techniques. However, the circulation and reuse of wastewater in Vietnam have many limitations, including The pressure to implement the CEWR is not strong enough to make a change; Mechanisms to encourage the application of circular economic models are lacking and weak; Lack of information, demonstration model on the CEWR suitable to Vietnam's conditions; No legal corridor for the development of circular economic models applied in water reuse, lack of technical standards to define the purposes of using recycled water; Investment in the waste sector is still low, the level of wastewater treatment technology is still limited; The wastewater management system has many shortcomings, lack of coordination and responsibilities in wastewater management; Community awareness about using reused water is low due to concerns about safety and hygiene conditions in the reuse of treated water.

Solutions

From policy and implementation experiences in a number of countries, the main solutions to enhance the efficiency of circular water economic practices in the industry can be grouped as follows:

Evaluating water availability and water balance at the basin level to support evidence-based decision-making: A comprehensive water resource evaluation to determine the quality and quantity of available water; Technical studies prepare scenarios for future water supply ability based on existing water consumption trends; Water security evaluation takes into account risks and uncertainties.

Reducing water use and diversifying supply: When a factory exceeds a certain threshold of water consumption from the public water supply system, a surcharge will be charged to the factory; Establish support funds: Promote industries to pursue water-efficient projects; Set out policy objectives to reduce water consumption per unit of value-added industrial output, as well as fees for non-compliance; Through regulations and tax incentives, increase the use of alternative water sources (rainwater, stormwater, and desalination).

Wastewater treatment: Regulations/rules that determine the level of pollution for wastewater; Environmental policy measures to ensure compliance with environmental regulations, such as fines for illegal discharge of wastewater and periodic/random inspections of industrial facilities.

Water reuse/circulation: Policies mandate the reuse of recycled water/wastewater for non-drinking uses, including the use of water in industrial processes; Financial incentives such as tax breaks or exemptions can encourage companies and IZ operators to adopt water reuse/recycling technologies.

Realizing the value of water (total cost and other non-economic values) to set out higher water prices and demonstrate the economic potentials of water conservation, reuse, and recycling technologies/solutions.

Promoting policy dialogues and building interactive platforms between water policy-makers and enterprises as well as between enterprises to enhance stakeholder engagement.

Recommendations

Recommendations for the draft Law on Water Resources

- Adding concepts related to water circulation, water reuse, and the circular economy of water resources to ***Article 3. Explanation of terms*** is as follows:

- ***Water circulation*** is the existence and movement of water flow according to a cycle (production, living).
- ***Water reuse*** is the proactive process of capturing wastewater, stormwater, saltwater, or greywater and purifying it. The water, after cleaning, can serve many necessary purposes, such as drinking water, water for industrial use, replenishment of surface water or groundwater, and restoration of river basins.
- ***Circular economy of water resources*** is an economic framework for reducing, conserving, and optimizing the use of water through waste avoidance, efficient use and maintenance, and assurance of water quality as well as environmental protection.

- Emphasizing the state's policy on the circulation and reuse of wastewater in **Article 6. Specific policies of the state on water resources** is as follows:
  - Having mechanisms to encourage organizations and individuals to participate in the implementation of water circulation solutions and wastewater recycling technologies for different use purposes
- Combining the contents of promoting water circulation in Chapter IV: Water regulation, distribution, and exploitation. Section 3 should be adjusted to ***Economical, efficient, and <u>circular</u> use of water***. Specifically:
  - Article 58. Measures for economical, efficient, and **circular** use of water
  - Article 59. Incentives for economical, efficient, and **circular** use of water
  - Article 60. Development of science and technology for economical, efficient, and **circular** use of water

Recommendations on points to keep in mind during implementation

- Developing mechanisms and methods to encourage water reuse in enterprises and communities.
- Developing new and reviewing guidelines related to the reuse of wastewater after treatment.
- Developing and reviewing existing regulations/standards in Vietnam on water reuse so that enterprises, as well as users, can easily access and implement them.

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OUR VISION

The VIWACON network is a pioneer in initiatives and solutions to ensure clean and clear water for everyone

OUR MISSION

Join hands to connect communities, social organizations, scientists, businesses and the State to preserve water secources

OUR CORE VALUE

Respect - Dedication - Unity - Creativity - Efficiency

VIWACON

Vietnam Water Conservation Network

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