STRATEGIC FORESIGHT OF INDUSTRIAL WATER MANAGEMENT IN THAILAND

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ABSTRACT

This research study the current and future situation of industrial water management in Thailand. Compared with the most four productive countries through bibliometric analysis with the VOS viewer program, the publications in Thailand mainly focus on water use efficiency and water and energy integration. Unlike, the other countries tend to balance the research on water use, water quality, and water-energy nexus. Indeed, the current significant challenge of industrial water is the water quality improvement with six components based on semi-structured interview. These include the manufacturing process, wastewater treatment technologies, awareness, knowledge management, law and regulation, and government support. For the future situation in the next five years relying on interview, the water technologies will be improved, particularly in value-added waste and cost-saving efficiency; however, the critical driving forces of future water management that are the law, leaders' mindset, staff knowledge, community acceptance as well. Therefore, the appropriate strategies to cope with this future challenge are suggested to the five guidelines: fit-for-purpose technologies and law, monitoring water quality and reward, active top management support, project recovery integration, and stakeholder engagement.

KEY WORDS: Strategy / Foresight / Thailand /Industrial water management

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CHAPTER I
INTRODUCTION

1.1 Background and rationale

The massive growth in global water demand accelerates owing to the combination of population growth, changing in consumption patterns, urbanization, industrial development, global warming, and economic globalization worldwide. Discovering and preserving the water resources as well as brainstorming to fabricate wastewater management are driven by these chaos factors affecting each other, resulting in the competing interests over time. (Graedel and Allenby, 2004; Koehler, 2008). The water demand on a global scale is expected to continue increasing with corresponding to the rate of 20 to 30% by 2050 above the current level of water use. (Burek et al., 2016) Globally, the water use comprises agriculture (i.e., irrigation, livestock, and aquaculture), which is the most substantial part, accounting for 69% of annual water withdrawals in 2010, the industry accounting for 19% and the municipal for 12%. (UNESCO, 2019) The 2050 projection of the agricultural water use increases by 60% globally and domestic water demand has a high increment, especially by 300% in Africa and Asia. Besides, the water demand for the industry by 2050 increases, particularly 250% in Asia, which includes a 400% increase in manufacturing and 85% for energy. (Alexandratos and Brunisma, 2012; IEA – International Energy Agency, 2019; Wada et.la, 2016; Alberto and Lorenzo, 2019) The United Nations claimed that "two-thirds of the population will have to manage the water stress condition if the consumption pattern of the business-as-usual will continue as nowadays." (UNESCO and Un-Water, 2015) This attribute to water quality deterioration and lack of access to a sufficient amount of fresh water.

According to the Department of Industrial Works (DIW), the statistic on the number of factories where register and permit to operate for industrial process in Thailand trends to increase over the period of 2008-2019 as can be seen in Figure 1.1 and integrated with the report relevant to the source of environmental pollution issue from Pollution Control Department (PCD). It found that 45% of problematic social and environmental concerns belong to industrial activities. Since the water effluent from the industry contaminates the considerable inorganic and organic level, it causes the poor quality of water surrounding. Therefore, the water quality becomes a perpetual problem threatening seriously to sustainable development in both developed and developing countries. One of the reasons for intensifying water pollution comes from releasing untreated industrial water. With these problematic concerns, the increase in attention is developing in wastewater management, including monitoring, controlling, innovated technologies development for efficient treatment of water and wastewater, and prevention programs of water pollution, water recycling and reuse applications, institutional development, as well as public participation. (Alberto and Lorenzo, 2019; Teodosiu and Ene, 2011)

Figure 1.1 Statistic on number of factories registered between 2008 and 2019
Source: Department of industrial works, 2019

According to the global recycling report, the global industrial wastewater treatment market represented $4,950 million in 2018. It continues to reach $6,530 million by 2025, growing at a CAGR of 3.5 percent during 2019-2025, whereas the global equipment market for wastewater treatment is valued at $30.01 billion in 2018, estimating at CAGR of 3.67 percent by 2025. The researcher from Wiseguyreports states that growing issues of industrial activities and contamination not only have strongly demanded water treatment and a boost in water reclamation requirements but also have the critical driver of water and wastewater treatment, which is people's awareness toward the water pollution. (Kürth, 2019)

Referring to the Office of the National Water Resources (ONWR) in Thailand, the government sector concerns current water situation, resulting in delivering a new water management mechanism under the water resource management strategic plan during 2015-2026, accordance with the Sufficiency Economy Philosophy of King Bhumibol Adulyadej integrated with the Sustainable Development Goal 6. Strategic planning comprises six strategies. Briefly, *the management of water for consumption* refers to improving the water supply among existing systems and expanding the new networks in the village, school, and urban areas by considering the water quality and affordable consumption toward the country. (as Strategic I) *Water security for the production sector* accounts for ensuring sufficient water budget for the sustainability and security of agricultural, industrial, and other economic sectors. (as Strategic II) *Flood and inundation management* is about enhancing the water drainage capacity, developing the construction of water containment areas. (as Strategy III) *Water quality management* refers to water quality level, developing wastewater management systems as well as enhancing the capacity of existing wastewater management systems. (as Strategy IV) *Rehabilitation of forest watersheds and degraded areas* refer to the balancing ecosystem toward rehabilitation and conservation of forest watersheds and the prevention of soil erosion in steep slopes areas. (as Strategy V) *Management and administration* refer to the organization, law, database, and publicity relevant to systematizing water, evaluating operational performances, and developing technologies as well as promoting public participation and awareness. (Strategy VI) Thus, the strategies directly related to industrial wastewater management are second, fourth, and sixth strategies. (Open Development Thailand, 2018; Ait-Kadi, 2016; Office of the National Water Resources, 2018)

As a consequence, in 2019, the ranking of Thailand toward SDG index monitoring has been in orange (SDG 6), which means significant challenges remain. The main challenge is that the anthropogenic wastewater received treatment. That is the percentage of collected and produced wastewater treated, normalized by the population connected to wastewater treatment facilities. It valued 12.1 % of SDG or is on the red scale, as illustrated in Figure 1.2 (Un-Water and United Nations, 2018; SDSN and Bertelsmann Stiftung, 2019)

Even though the awareness and implementation of wastewater treatment are raised, the industrial disposal into water is projected to increase due to the high cost of wastewater treatment and the advanced technologies. This minimizes the number of treatment plants in developing countries since the industries cannot be affordable to operate and maintain in the process. (Alberto and Lorenzo, 2019)

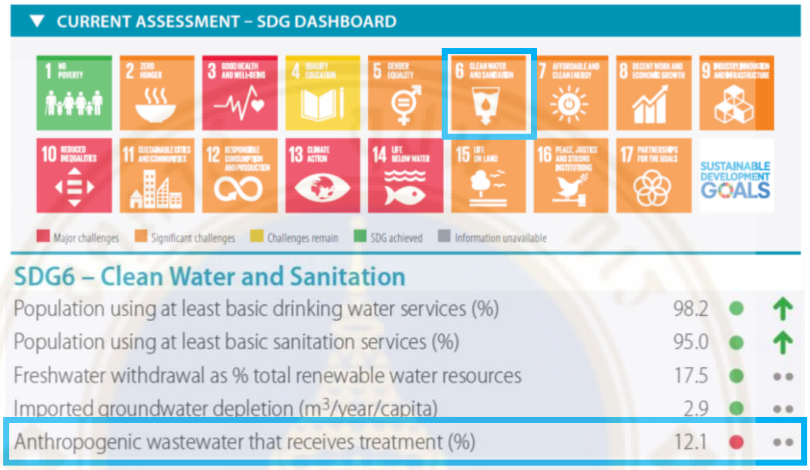

Figure 1.2 Sustainable development goal assessment

Source: Un-Water and United Nations, 2018

While industrial wastewater treatment remains a significant challenge, its information and research are not pervasive and up-to-dated in the Thailand industries. Therefore, this study will firstly focus on the wastewater treatment employing in the industry to understand the current situation and detect the problems facing. Besides, in order to realize the importance and opportunity of industrial wastewater treatment in Thailand, the foresight study, as a growing research interest among researchers, will be applied toward the observing and capturing the various factors that tend to affect the future changes, and assist the decision-makers to cope with the uncertainty toward the forward-looking approaches and strategic decision making, leading to recognize the uncertainty and accept the complexity as well as identifying the innovation. Therefore, the study will not only understand the current situation but also analyze the possible impacts of industrial wastewater treatment in the future and generate the strategy to deal with uncertainty.

1.2 Research objectives and research questions

First objective (OBJ1): To identify the current situations of water management using in industry in Thailand and compare the situation between Thailand and foreign countries.

- Research questions (RQ)

RQ1: What are the differences between the situation in Thailand and foreign countries?

RQ2: What are the current situations of water management using in industries in Thailand?

Secondary objective (OBJ2): To foresight the future of water management in industry in the next five years.

- Research questions (RQ)

RQ3: What are the possible driving forces of industrial water management in the next five years?

RQ4: What are the strategies to cope with the future challenges of industrial water management in the next five years?

1.3 Scope of the study

This study will focus on the Thai industry, where addresses the wastewater treatment process in the plant. The data collection contains, firstly, qualitative data toward interviewing at least ten participants, including three experts in the wastewater treatment field, and seven people relevant to the management level of well-known industry in Thailand. Second, quantitative data is relevant to the bibliometric analysis, which extracts the data from the Scopus database under the term of industrial water management along with sustainable development to see the current situation and trend in the industrial water management sector. The framework of the study uses the generic foresight framework because the final outcome offers the strategy to deal with future challenges in the next five years (2020-2025).

1.4 Analysis framework

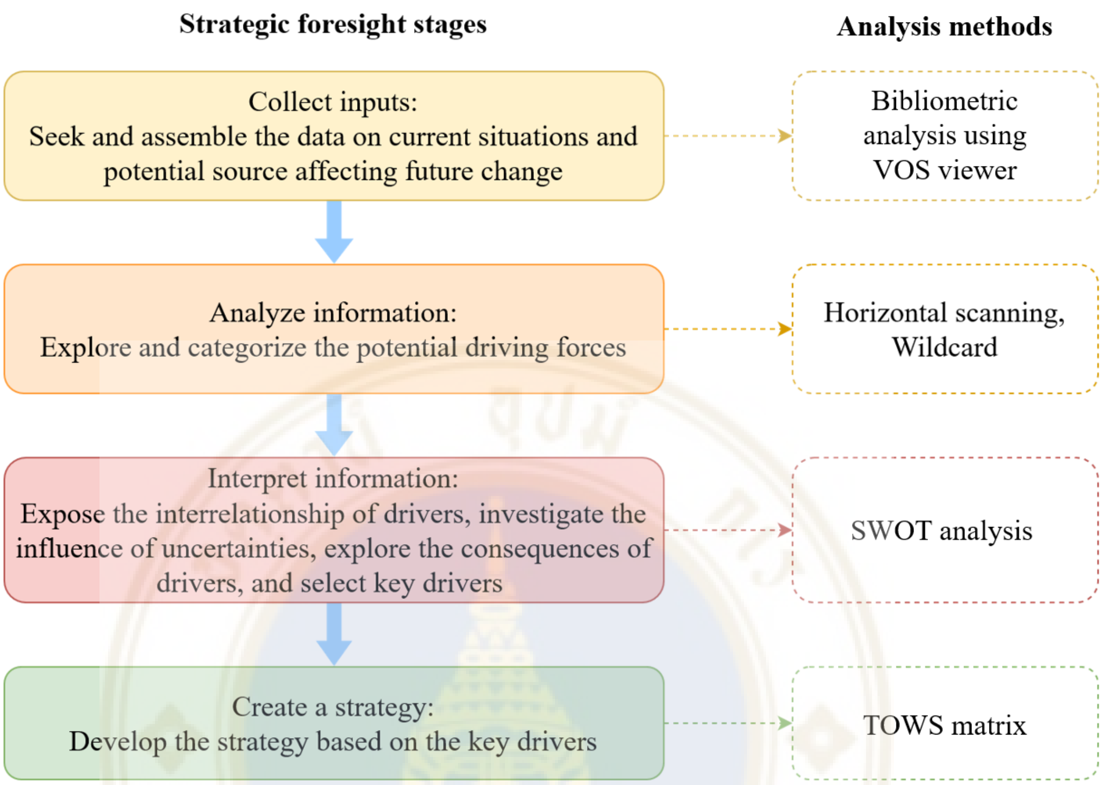

Figure 1.3 Analysis framework

1.5 The expected outcome of the study

This study will benefit the business owners in the industry already equipping the wastewater treatment in the process but intend to replace the existing one as well as the amateur factories that initially realize the importance of wastewater treatment while lacking knowledge. Thus, the study represents the possible future of the industrial wastewater treatment, which could be the way to help them encourage against the uncertainty and decide on planning the strategic management of the wastewater treatment in their industries.

1.6 Research structure

Chapter 1: An introduction provides a brief background on industrial water management in global and Thailand, followed by the current strategic planning of water resource management by ONWR according with the Sufficiency Economy Philosophy and the adoption of SDG 6 measurement to realize the water challenge in Thailand as compared with the worldwide. The further discussion provides the research objective and research questions, scope of the study, analysis of framework based on strategic foresight, and the expected outcome of the study.

Chapter 2: A literature review presents the background of water management, which includes the conceptual framework of sustainable water management and detailed scheme of water flow cycling from the input, process, and output under the industrial activities. Then, the review of the strategic foresight concept and theory is provided to explore an appropriate framework and technical methodology. Additional reviews discuss the related literature of foresight frameworks and foresight methods from existing papers to decide the suitable approach in this research.

Chapter 3: A research methodology covers the population and sampling method of this research, followed by the analysis tools comprising the assistance of the VOS viewer program and foresight methods aligning with the discussing framework and tools in the previous chapter. Next is data collection from data mining through the program and supporting evidence by an interview with Thai experienced participants. Accordingly, the data analysis is deployed in both the current situation and the next five years of industrial water management in Thailand.

Chapter 4: A result and discussion describe the result derived from content analysis which contains the current situations in foreign countries and Thailand as well as the future trends in foreign countries and Thailand in order to see the driving force shaping the future industrial water management in Thailand and generate the strategies coping with future five years' challenge.

Chapter 5: A conclusion of research provides the main results, the recommendations, and the limitation of the study and future research.

CHAPTER II
LITERATURE REVIEW

This chapter contains three sections including Section 2.1 provides a background of water management, Section 2.2 reviews the concept of foresight as well as theoretical approaches to implement the foresight in the industrial water management, and finally, Section 2.3 contains the previous research papers relevant to the topic and discuss the different perspectives compared with this study, as outlined each section and sub-section below:

Table 2.1 Guideline of literature review

Section 2.1	**Background of water management**
	2.1.1 Concept of Sustainable water management (SWM) 2.1.2 Water use cycle in the industry
Section 2.2	**The concept and theory relevant to strategic foresight**
	2.2.1 The definition and concept of strategic foresight
	2.2.2 Foresight frameworks 2.2.2.1 Generic foresight framework in detail
	2.2.3 Selection of foresight methodology
	2.2.4 The theory of technical methodology used in strategic foresight 2.2.4.1 Horizontal scanning (HS) 2.2.4.2 Wildcard (WC) 2.2.4.3 Cross-impact analysis (CIA) 2.2.4.4 SWOT analysis
Section 2.3	**The relevant research paper**
	2.3.1 Review of foresight frameworks
	2.3.2 Review of foresight methods
	2.3.3 Review of case studies relevant to the challenge of water management

2.1 Background of water management

2.1.1 Concept of Sustainable water management (SWM)

Sustainable water management is a significant component of sustainable development and has been defined by Global Water Partnership (GWP) as an Integrated Water Resources Management (IRWM), stated that "a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems." (Ait-Kadi, 2016) The International Water Association (IWA), a non-profit organization covering the whole water knowledge with globally connecting water professionals under the aim of seeking the solution to deal with the global water challenges, indicates that this sustainability issues cover all facet of water supply, water quality, transmission, use and reuse, resource recovery and energy use, which are essential to the water future related to all area concerns with the long-term protection of people, economic and environment in order to improve a healthy planet. (International Water Association, 2015) Collaborating GWP and Organization for Economic Co-operation and Development (OECD), the research clearly revealed that the water is a heart of the development process since there is a symbiotic relationship between water and development; the water is important for sustainable socio-economic development, on the other hand, this development can support the resource by means of investing in water security, water infrastructure, and water institutions. (Jeroen et al., 2015)

This becomes more multiple challenges to manage the water because it is a scalable and complexed concept where effects on various stakeholders as well as staying in the dynamic environment age in a growing population, climate, the development, and globalization; as a result, occurring more sophisticated understanding of interrelationship about water-related activities. If we still run the same business-as-usual approach, the serious consequences will rise unquestionably. (Ait-Kadi, 2016) Others have raised the word as "a perfect storm" in the 2030s due to the population growth, food production, and energy crisis. (Beddington and FRS, 2009)

With the statement of "Water connects us all," achieving SDG 6 addressed "the Water Goal" recognizes that water affects the entire development sectors that embed in other SDG. It means that the water goal will be achieved if another goal is attained; in turn, other SDGs will be attained if the water goal is achieved. The detail of SDG 6 will illustrate in Figure 2.1 and Table 2.2.

Figure 2.1 Sustainable development goal 6

Source: Paul, 2018

Table 2.2 Water goal

SDG6	Ensure availability and sustainable management of water and sanitation for all
6.1	By 2030, achieve universal and equitable access to safe and affordable drinking water for all
6.2	By 2030, achieve access to adequate and equitable sanitation and hygiene for all, and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations
6.3	dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally
6.4	and ensure sustainable withdrawals and supply of freshwater to address water scarcity, and substantially reduce the number of people suffering from water scarcity
6.5	By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate
6.6	By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes
6.6a	By 2030, expand international cooperation and capacity-building support to developing countries in water and sanitation related activities and programs, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies
6.6b	Support and strengthen the participation of local communities in improving water and sanitation management

Source: Ait-Kadi, 2016

It is suggested that sustainable water management can group into four domains following the sustainability concept, containing an explanation below (Figure 2.2). To clearly understand each sub-sustainability, the United Nations water (UN-water) provides the definition of the word associated with water concern, which is summarized in Table 2.3.

Figure 2.2 Sustainable Water Management (SWM)
Source: SHANMUGAM IAS ACADEMY, 2018

a. Social sustainability refers to "everyone can equitably access to adequate and affordable water services aiming to meet their health and livelihood requirements, and where citizens and communities play a meaningful role in water governance and decision making."

b. Environmental sustainability relevant to "water use and management does not compromise biodiversity, the functioning of habitats, or ecological or hydrological processes that are essential to society."

c. Economic sustainability is about "water management is affordable and cost-effective; in addition, economic costs and financial risks are understood, minimized, and balanced in a transparent, socially acceptable way."

d. Institutional sustainability relates to institutions received the task for managing and monitoring the water management that suffices water resources as consistent with social legitimacy.

Table 2.3 Definition of words by UN-water

Words	Its meaning
Sufficient	The water supply for each person must be sufficient and continuous for personal and domestic uses. These uses ordinarily include drinking, personal sanitation, washing of clothes, food preparation, personal and household hygiene.
Acceptable	Water should be of an acceptable color, odor and taste for each personal or domestic use. All water facilities and services must be culturally appropriate and sensitive to gender, lifecycle and privacy requirements.
Safe	The water required for each personal or domestic use must be safe, therefore free from micro-organisms, chemical substances and radiological hazards that constitute a threat to a person's health. Measures of drinking-water safety are usually defined by national and/or local standards for drinking-water quality.
Physically accessible	Everyone has the right to a water and sanitation service that is physically accessible within, or in the immediate vicinity of the household, educational institution, workplace or health institution.
Affordable	Water, and water facilities and services, must be affordable for all.

Source: United Nation Water, 2010

Numerous industries attempt to achieve this sustainable development by means of participating in the exploration and implementation of the competitive solution and products in the short term, meanwhile conducting the prevention of natural and human resources in the long run. (Artiachet et al., 2010). Thus, sustainability requires industry to develop the strategy with a holistic approach and understand their role and responsibility toward societal and cultural aspects together with the environment at the regional and global levels. (Labuschagneet et al., 2005)

2.1.2 Water use cycle in industry

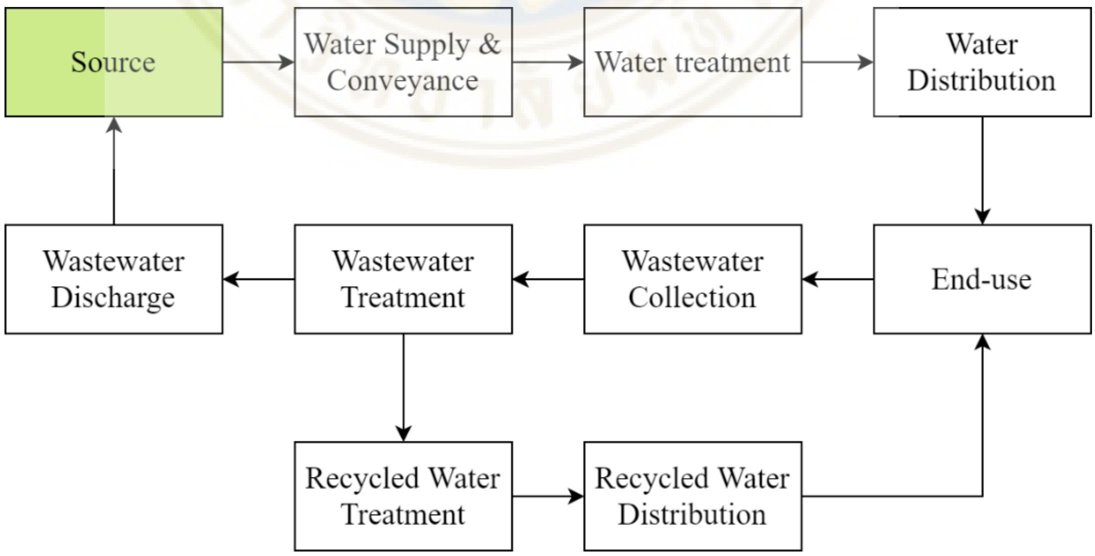

Figure 2.3 Water use cycle scheme

Source: Adapted from Schwarzenegger, 2005

As illustrated in Figure 2.3 above, the water utilized in the industry mostly is received from the water industry where typically pumps water from different natural resources, consisting of the groundwater; beneath the earth's surface that requires cracking the bed of sand and rock and the surface water; includes streams, rivers, lakes, reservoirs, and wetlands. Then distributed the water through conveyance, which its length depends on the distance and elevation of the destination. (Yoon, 2018)

Among the various water sources, "Desalination" has developed to allow the use of seawater and brackish water where is an important reservoir in the world. The desalination technology aims to remove the salts and minerals from saline water, and more than one hundred countries implemented due to water scarcity and poor geographies like arid areas in the Middle East, Mediterranean, and the Caribbean. Thus, this inequity of accessible and geographical sources has driven the potential of desalination technology increasingly from 1990 to 2020. There is no single technology of desalination provided each technology and its explanation in Table 2.4. Nowadays, many plants have integrated renewable energy on-site to increase energy efficiency and be a self-producer using energy by itself. (Abdel-Fatah and Bazedi, 2020; Yoon, 2018)

Table 2.4 Summary of different desalination technologies

Type	Technology	Explanation	Water type
Thermal process	Multistage flash distillation (MSF)	After heating water, pressure is diminished so that the water ‘’flashes’’ into steam. It is the most widely used thermal process.	Seawater, Brackish water
	Multiple effect distillation (MED)	A number of evaporators are installed in series so that the water passes through and vapour from one series is used to evaporate water in the next series. It is the oldest modern desalination technique and is efficient in thermodynamic terms.	Seawater, Brackish water
	Vapor compression (VC)	Water is evaporated to vapour to be compressed. The heated compressed vapour is used for the next feed of water.	Seawater, Brackish water
Mechanical process	Reverse osmosis (RO)	Membrane screens molecular size to about 1 Angstrom (10-4 microns) and removes salinity from salty water (or brackish water) when it is introduced with high pressure. Recovery rate of the process is usually higher than 60% (ratio of desalinated water over	Seawater, Brackish water
	Electro-dialysis (ED)	Electrical field is applied across a set of cationic/anionic membrane pairs which excite the ions to transfer through the membranes, leaving a stream of desalinated water.	Brackish water
	Forward osmosis (FO)	Relatively new process that uses injection of ammonia, carbon dioxide or other ingredients in the draw solution (salt) to increase the osmotic potential. Uses relatively little energy.	Seawater, Brackish water
	Pressure retarded osmosis (PRO)	Osmotic pressure is used to generate power where two solutes with different salt concentration are available. Newer	Seawater, Brackish water

Source: Adapted from Olsson, 2015; Plappally and Lienhard, 2012; March, 2015

When the water enters to "Water treatment process" or "Water purification" in the water industry, this procedure eliminates the unfavorable chemicals, natural contaminants, and suspended solids from the water inlet, which rely on the specific purpose of industrial water treatment, as summarized in Figure 2.4. Generally, the method involves the physical methods, such as sedimentation, distillation, and filtration; biological methods, such as slow sand filters and biologically activated carbon; chemical methods, such as coagulation, flocculation, and chlorination; lastly, electromagnetic methods by deploying ultraviolet light. The selection of technique depends on the removal of impurities, water properties, and capital costs. The membrane technologies play an important role in eliminating the wide range of particles in water, becoming more purified water. Then, the treated water or called industrial water supply because it is distributed through a pipe to the end-user, in this case, which is the manufacturing industry. (Abdel-Fatah and Bazedi, 2020; Yoon, 2018)

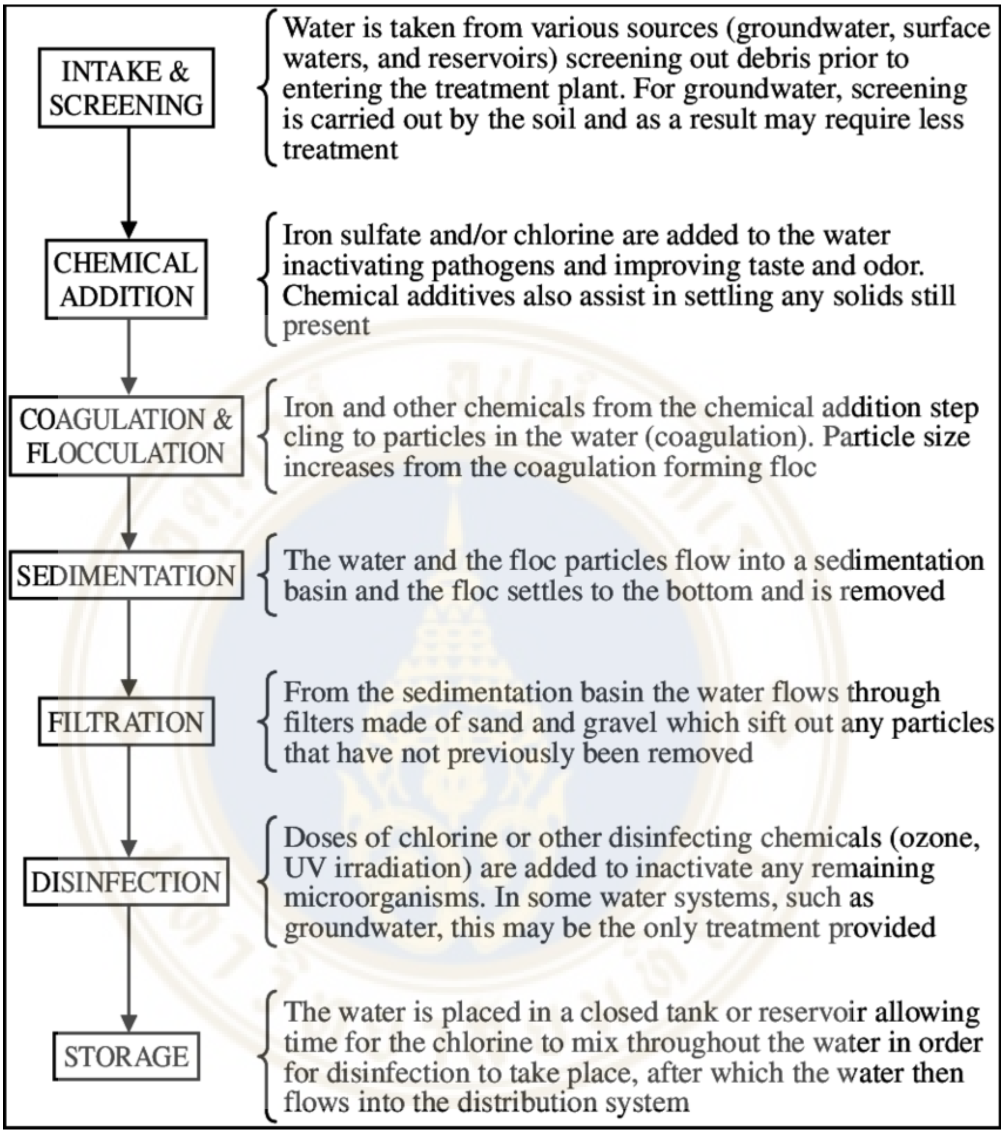

Figure 2.4 Summary of the basic water treatment process

Source: Gomes and Lester, 2002

During the industrial activities, the water used will be polluted with liquid and solid wastes. Due to increased disposal of untreated or partially treated industrial water, the government launched the environment regulation to force the industries per standard water discharge. (Alayu and Yirgu, 2017) So, the industries use wastewater treatment technologies to achieve regulation. Generally, the "Wastewater treatment process" provided in Figure 2.5 comprises, firstly, *pre-treatment or preliminary* *treatment* related to physical and mechanical methods removes the large materials (i.e., solid waste: plastic or tree leaves); *primary treatment* aimed to removes smaller materials by gravity (physicochemical and chemical methods). The technique contains the physical process of screening and sedimentation; *secondary treatment or purification* relevant to chemical and biological methods removes soluble organic that escapes from the primary stage to protect dissolved oxygen balance in the stream. The removal is eliminated by biological treatment methods (i.e., trickling filter, activated sludge process, and oxidation pond), consisting of microbes that consume their food called organic impurities and convert into CO_2, water, and energy for their reproduction; *tertiary treatment* for removing nitrogen and phosphorus via nitrification-denitrification method, forming N_2 into the air. This process requires the construction of aeration and setting tanks, which increase the cost of treatment. (Nathanson and Archis Ambulkar, 2018)

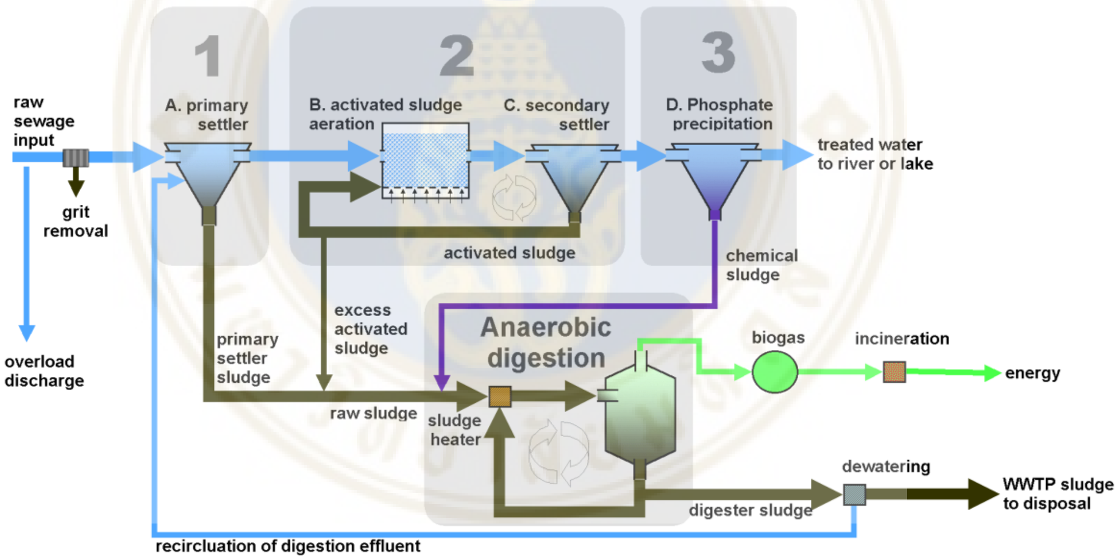

Figure 2.5 Wastewater treatment plant modeled

Source: Ivan et al., 2007

There various techniques to implement, which depend on the wastewater characteristics. Each technique has its own strengths in the technological and economic aspects and is classified into three categories; conventional method, established recovery processes, and emerging removal methods, as described in Figure 2.6.

Furthermore, Alayu and Yirgu (2017) suggest that anaerobic biotechnologies become the critical role for industrial wastewater treatment because it can degrade the organic contaminant by the anaerobic microbes and convert this organic compound into the light gas, including CO_2 and CH_4, as the biogas, one of the bioenergy. This technology can treat the sludge effluent from primary, secondary, and tertiary levels. Thus, the industrial wastewater treatment is not only useful to reduce the negative environmental effluent impact but also internal electricity and heat from the biogas, resulting in cost-effectiveness and economic benefit.

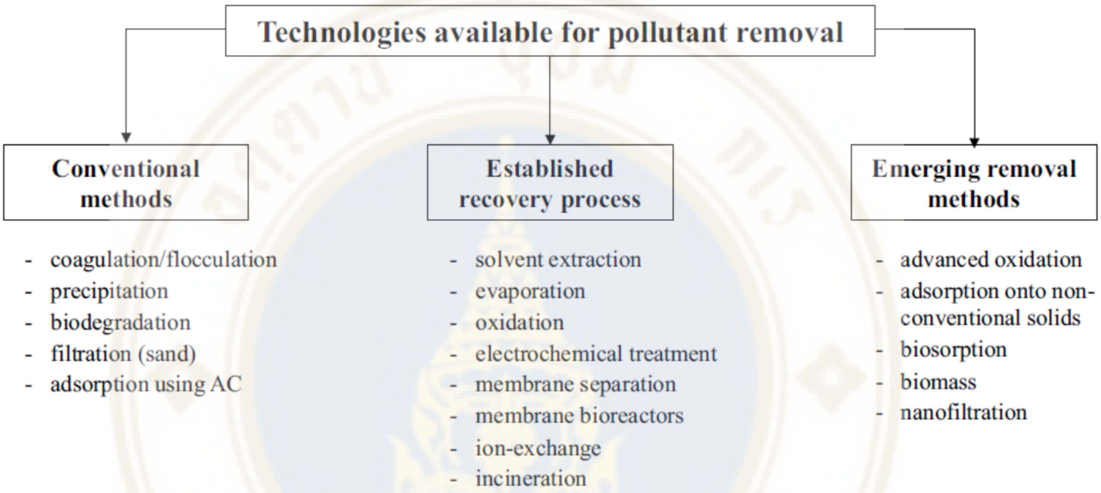

Figure 2.6 Classification of technologies available for pollutant removal and examples of techniques

Source: Crini and Lichtfouse, 2018

2.2 The concept and theory relevant to strategic foresight

2.2.1 The definition and concept of strategic foresight

Increasing rapid change, the uncertainty about future outcomes, and the complexity among multiple drivers of change affecting each other raise government attention for preparing the unexpected future. Strategic foresight is required to implement and help these situations. (OECD, 2018) "Foresight is the process of developing a range of views of possible ways in which the future could develop, and understanding these sufficiently well to be able to decide what decisions can be taken today to create the best possible tomorrow," stated the definition by Horton (Horton, 1999). To be clear, the foresight does not confirm to be predictive or not about the forecasting and predicting. Instead, the foresight focuses on exploring the multiple factors and encourage plausible and possible alternatives, which help to shape the uncertain futures. (Saritas and Burmaoglu, 2015) In order to achieve in the volatile market and unexpected future, the business needs the compass to give the direction and prepares the actions by using foresight as a part of strategy planning, called Strategy foresight. Richard A. Slaughter defined that "Strategic foresight is the ability to create and sustain a variety of high-quality forward views and to apply the emerging insights in organizationally useful ways; for example, to detect adverse conditions, guide policy, shape strategy; to explore new markets, products and services." Again, strategic foresight is not about better predictions, but it is a better preparedness confronting the different futures, which can be possible and plausible. (Slaughter, 2012; Munck and McConnell, 2010; Van and Janson Yap, 2016)

In conclusion, with this perspective, strategic foresight studies the future in a systematic way through the multiple factors that have a relationship in a particular situation. These factors or data are gathered as a trend to analyze and seek opportunities in order to generate the alternatives shaping the desired futures. Thus, the concept of strategic foresight has two purpose tasks including firstly, the observation factors inducing future changes, and second, the decision of appropriate responses regarding the changes, as can be seen, the process diagram in Figure 2.7. (Iden et al., 2017)

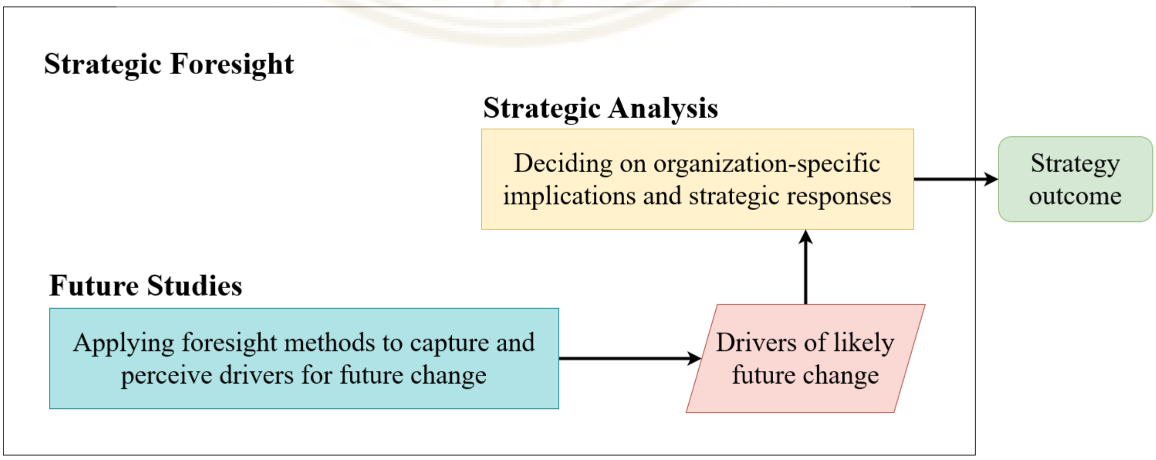

Figure 2.7 Strategic foresight- the conceptualization

Source: Iden et al., 2017

2.2.2 Foresight frameworks

Many experts have been considered the theoretical and conceptual framework of foresight in order to capture the transition. The frameworks play an important role in developing its terminology. Consequently, the following will provide extensively acceptable foresight frameworks and be summarized in Table 2.5. (Yuksel et al., 2017)

Table 2.5 Foresight framework in the literature

	Yüksel& Çifci (2017)	Martin (1995)	Miles (2002)	Voros (2003)	Bishop&Hines (2005)	Schultz (2006)	Saritas (2011)
	Foresight Functions	**Foresight Process**	**The Foresight Cycle**	**A Generic Foresight**	**Framework Foresight**	**Key Activities of Integrated Foresight**	**Systemic Foresight**
F	Framing	Pre-Foresight (Decision, Preparation)	Pre-Foresight	Inputs	Framing		
O	Obtaining		Recruitment		Scanning	Identify and monitor change	Intelligence
R	Reviewing	Foresight (Process Design, Strategic Analysis, Agreeing, Disseminating)	Generation	Analysis of Interpretation		Assess and Critique Impacts	Imagination
E	Establishing			Prospection	Forecasting	Envision Preferred Futures	Integration Interpretation
S	Synthesizing						
I	Illustrating			Outputs	Visioning Planning		
G	Guiding			Strategy		Plan and Implement change	Intervention
H	Handling	Post-Foresight (Implementation, Allocation)	Action		Action		
T	Tracking		Renewal				Impact

Source: Yuksel et al., 2017

First, Martin's foresight framework stands for three phases, which are the *pre-foresight* as a preparation process, and then the *foresight* being the next phase consisting of inclusive design, strategic analysis of utilities according to with the best promising options as well as ascertaining the scientific priorities of output. The last phase, called *post-foresight*, refers to the implementation in policy-making and resource allocation. (Martin, 1995)

Next, the well-known framework by Voros is called "generic foresight framework," modified from the combination of Horton's process with Slaughter's strategic foresight and Mintzberg's strategic view. The beginning step accounts for gathering information and strategic intelligence, namely the *inputs*, which is related to the question of "what seems to be happening?" The *foresight works*, including the three broad steps, which are analysis (to seek what seems to occur), interpretation (look for the deeper structure to find what really happening), and prospection related to the "what might happen?" The question of "what might need to do?" is handled in the *outputs* phase and the last step called *strategy*, which is the decision-making actions in strategy development and planning. (Voros, 2003)

The framing, scanning, forecasting, visioning, planning, and action are handled in the framework of Hines & Bishop. While identifying the problem and finding out its solution are assessed as *framing*, *scanning* is the detecting step for determining the trend and relevant information. *Forecasting* is about generating the possible futures, and the *visioning* refers to the selection of the desired future and defining the future position of an organization. Lastly, creating the direction to the desired future by bringing into an action plan, namely *planning*. (Hines and Bishop, 2015)

Schultz described the foresight as an integrated process and characterized it into five key elements, specifically "identify and monitor change," "assess and critique impacts," "imagine alternative outcomes," "envision preferred vision," and "plan and implement change." By putting the change to the center of the foresight process, the first activity can start catching the changing pattern toward the trend analysis. The next activity is to define the impacts of change and arrange them indicated by their importance. They imagine alternative outcomes is a crucial component by determining and envisioning alternative futures. The fourth element refers to choosing the desired future, and the final action is involved in determining the stakeholders, setting the resources, and developing the strategies. (Schultz, 2006)

While Saritas developed a Systemic Foresight Methodology (SFM) involved "Intelligence, Imagination, Integration, Interpretation, Invention, and Impact, combined within Interaction" to produce and direct the foresight operation, performed in a dynamic, repetitive and evolutionary way. This method is understanding the external context, such as social, technological, economic, environmental, political, and value (STEEPV system) in order to investigate the internal context (i.e., management, process, motivation, politics, culture, power, skills). Inside this framework, the intelligence phase refers to collecting data, analyzing trends, and changes to identify the scope and content of the study. Then, imagination contains generating and interconnecting new ideas. The following phase called integration to identify the priorities and making the agreed model of the future, and this model will transform into strategies, which are carried out in the interpretation phase. The plan and policies are required in a practical approach belonging in the intervention phase as well as the review and lessons learned are taken into impact phase. Finally, all of the SFM phases are led by the stakeholders in the interaction forms. (Saritas, 2013)

Yüksel and Çifci proposed a functional framework, namely FORESIGHT, which has nine blocks, being interrelated and interdependent. *Framing* refers to identify foresight scope, purpose, and time horizon. Gathering data and participants is in the *obtaining* phase, whereas sharing and analyzing the ideas and opinions along with the past and present data collected are handled in the *reviewing* phase. *Establishing* accounts for thinking and imaging the future of the alternative and then interpreting and discussing all the picturing alternatives, namely *synthesizing*. *Illustrating* is to point out the possible futures toward reports, multimedia, or social media. Defining the actions and develop the strategy are referred to in the *guiding* phase. *Handling* and *Tracking* relate to taking action and evaluating outcomes toward impact analysis. (Yuksel et al., 2017)

With the various foresight frameworks, many researchers attempt to develop to be suitable for the purpose and desired outcome. Thereby, this research focuses on Voros's foresight framework, which is also as known as the generic foresight framework since it is a simple framework that can apply in a wide range of fields. Also, the terminal stage offers the strategy shaping the future, which is the only framework meeting the objective of this research. As a consequence, the detail of the generic foresight framework is explained in the following part.

2.2.2.1 Generic foresight framework in detail

According to the previous short description of Voros's framework, the process contains the four key components: "Input, Foresight work, Outputs, and Strategy," as illustrated in the conceptually simple diagram in Figure 2.8.

(Voros, 2003) On the right-hand side of the figure, it represents the typical questions to delineate each step of the process, which is useful to understand the differentiation from each step, suggested by participants.

1) Inputs

This step is collecting information and scanning for strategic intelligence, basically called strategic scanning at the organizational level. There are many foresight methods to use in the first step, and the following are well-known methods (Voros, 2003):

a. Delphi technique and environmental scanning are the best known.
b. Competitive intelligence could be a relevant tool.
c. Brainstorming ideas toward the workshop pattern, namely "constructing the near future context" by asking the key questions, which are designed as open-end thoughts about the near future.

2) Foresight work

It is the second step, comprising the three consecutive sub-steps. First, *Analysis*: after getting the numerous data from the inputs step, this analysis sub-stage along with the question of "what seems to be happening?", which is similar to the translation step of Horton's framework, aims to find "first cut" to order the variety of data via the typical method including: "trend analysis, cross-impact matrix, and other analytical techniques." Second, *Interpretation* by asking the question of "what is really happening?" can determine the deeper structure toward the causal layered analysis and systems thinking. Finally, Prospection refers to creating and examining the future of the alternative. The foresight method are scenarios, visioning, backcasting, modeling method under the question of "what might happen?"

3) Outputs

It refers to "what might need to do?" There are a variety of methodologies employed to present the outputs, such as workshops, reports, role play, film, multimedia, presentation, and events.

4) Strategy

The final part of the framework with the question of "what will we do?" and "how will we do?" will consider by decision-makers to conduct the strategic actions for implementation toward strategic development and strategic planning.

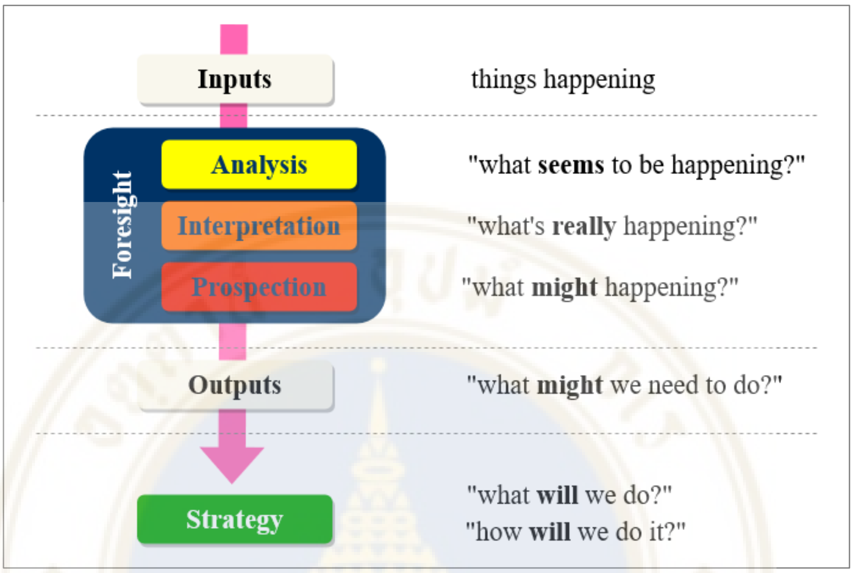

Figure 2.8 Generic foresight process

Source: Voros, 2003

2.2.3 Selection of foresight methodology

To classify the foresight method, there is the two-fundamental attribute, which is nature and capability. Beginning with nature, as appeared the comparison of foresight method in Table 2.6, it comprises three sub-categories (Popper, 2008):

a. The qualitative method involves subjective or creative thinking toward the participant experience, which could be challenging to evaluate and receive the direct answer based on the open questions, their opinions, judgments, beliefs, and attribute.

b. The quantitative method utilizes statistical analyses, using reliable and accurate data to measure the variables related to the context.

c. The semi-quantitative method is the combination of applying the mathematical approach, such as weighting opinions and probabilities, in order to quantify the subjectivity and the experts' points of view.

Table 2.6 Classifying methods by their nature

Qualitative	Quantitative	Semi-quantitative
Methods are providing meaning to events and perceptions. Such interpretations tend to be based on subjectivity or creativity, which are often challenging to be corroborated (i.e., brainstorming, interviews	Methods measuring variables and applying statistical analyses, using or generating (hopefully) reliable and valid data (i.e., economic indicators)	Methods which apply mathematical principles to quantify subjectivity, rational judgments, and viewpoints of experts and commentators (i.e., weighting opinions)
1. Backcasting 2. Brainstorming 3. Panels of citizens 4.Conferences/workshops 5. Essays/Scenario writing 6. Expert panels 7. Genius forecasting 8. Interviews 9. Literature review 10. Morphological analysis 11. Relevance trees/logic charts 12. Role-playing/Acting 13. Scanning 14. Scenario/Scenario workshops 15. Science fiction (SF) 16. Simulation gaming 17. Surveys 18. SWOT analysis 19. Weak signals/Wildcards	1. Benchmarking 2. Bibliometrics 3. Indicators/time series analysis 4. Modeling 5. Patent analysis 6. Trend extrapolation/ impact analysis	1. Cross-impact/structural analysis 2. Delphi 3. Key/Critical technologies 4. Multi-criteria analysis 5. Polling/Voting 6. Quantitative scenarios/SMIC 7. Road-mapping 8. Stakeholder analysis

Source: Popper, 2008

The latter attribute is relevant to the capabilities, which means the ability to gain information and implement the foresight process, according to creativity, expertise, interaction, and evidence. (Popper, 2008)

a. Creativity accounts for generating imaginative ideas based on rational knowledge and individual creative skills or the ingenuousness of brainstorming among various perspectives, which can be provided by the artists or experts in a particular area.

b. Expertise is generally regarded as the personal capability, accumulating pieces of knowledge and relevant information from working experience on a particular domain area in order to be assistance for decision making and suggestions by applying theoretical approaches, hypothesis, and research observation.

c. Interaction refers to the discussion among expertise and non-expert stakeholders to exchange opinions and thoughts and to gain more essential items, which not only depend on theory and evidence.

d. Evidence is considered as a reliable document presented in support of the analysis path to explain the situation or the process, and it is useful to understand the actual issues in the way of statistic and measurable indicators relevant to the topic concerned.

In summary, the entire of previous attributes, including by nature and by capabilities, are conglomerated around 25 methods and represented in Foresight diamond as the decision for selecting the foresight method, depicted in Figure 2.9. Thus, the Popper's foresight diamond is a guideline to consider and select the suitable foresight methodology under each stage of the chosen foresight framework. It helps to understand which methods are appropriate for the context of the research and in this paper realizing the industrial water management that is not pervasive among the researchers; as a result, the method needs to have both quantitative methods consisting bibliometric approach through the technical program and qualitative method to support the bibliometric analysis such as interviews, scanning, wildcards, and SWOT in order to cover the possible aspects and create the strategy.

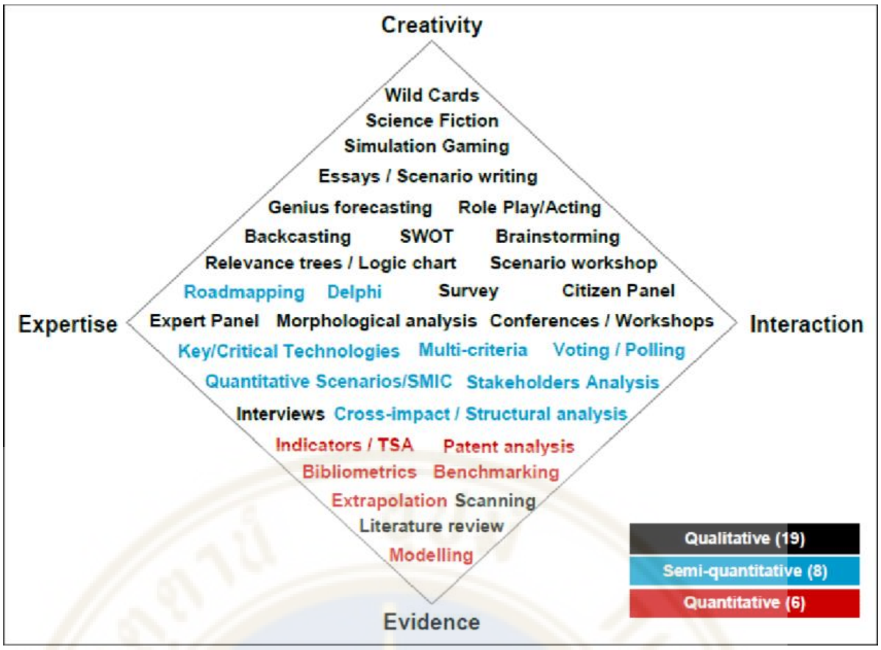

Figure 2.9 The foresight diamond

Source: Popper, 2008

2.2.4 The theory of technical methodology used in strategic foresight

2.2.4.1 Horizontal scanning (HS)

Since the environment is an unpredictable and changeable event, affecting various factors, the scanning process was introduced by Aguilar as "horizontal scanning," which is sometimes called "environmental scanning" or "identification of emerging risks." The concept of this method is concluded as the gathering and analyzing information associated with the external environment of an organization and generally uses STEEP analysis (Social, Technological, Environmental, Economic, and Political) as a tool to assist future action. (FAO, 2014) With scanning the environment, it helps to diminish the invisible and unexpected chance in the marketplace, eliminate some possible surprises, identify the trend, potential opportunities, and threats as early warning before becoming a significant trend, and develop the planning in the range from long to short term. Horizontal scanning is one of the foresight methods that usually apply in business, health technology, and the environmental sector. (FAO, 2014) HS's objective is to assist the decision-makers in creating the strategy and plan, but not predict the future and also to encourage the awareness of trend and signal to be the guideline of the action plan.

Typically, the weak signals or early warning signals are identified in horizontal scanning to aid strategic foresight activities. Ansoff defined the *weak signals* as "warnings (external or internal), events and developments, which are still too incomplete to permit an accurate estimation of their impact and/or to determine their full-fledged response." (Cuhls, 2019; Amanatidou et al., 2012) To scan the weak signals, it comprises two phases. The first phase refers to seeking strong signals from research and resources, which could be a benchmark for the next phase. The second phase identifies the weak signals, which is a small surprise and better to know earlier. (Duijne and Bishop, 2018)

The use of the HS method contains four steps. First, the detecting step is to seek the essential political, economic, social, technological, and environmental trends/situations/events. Then, the identifying step is to find the potential opportunities and threats for organization and industry based on the previous trends, situations, and events. The third step, namely determining, refers to understand the strengths and limitations of an organization clearly. Finally, providing a step, which is the fundamental analysis for future actions. (Jackson, 2013)

Therefore, the horizontal scanning method is a basic step of future research and may not need the technical tools; however, it requires the third parties, such as interviewees who experience in the particular field, to identify more source of information and facilitate the certain data that researcher is unfamiliar with in order to make the received information more reliable.

2.2.4.2 Wildcard (WC)

Many experts defined Wildcards in a similar meaning, which is the low probability event creating sudden and unfamiliar changes in the organization, as a consequence, occurrence of the massive potential impact, leading to threatening significant profit or opportunity ultimately. With the radical change, there are no historical records to compare the events coming, and the most stakeholder is not able to respond and prepare it adequately. Thus, this damaging event can turn the direction of the trend. (Cuhls, 2019; Duijne and Bishop, 2018; Saritas and Smith, 2011)

Wildcard method aims to learn and adapt the events to increase the strengthen in organization performance and be able to handle this shock with creative thinking. Therefore, the main reason for this method is to help and encourage thinking innovation and scratch the obsolete vision in order to realize the unbelievable event and open the new future. (Mehrabanfar, 2014) The most important term is a low probability. For instance, nuclear war and pandemic that make a negative impact on many countries and, for positive wildcards, it might refer to discover the new technology or medical treatment, such as the use of mobile phones with various features and the penicillium to treat the viral infections, as can be seen, more example in Table 2.7. (Saritas and Smith, 2011; Duijne and Bishop, 2018)

Table 2.7 The example of wildcards linking to trends

Trends	Wild cards
Globalization of markets: finance, goods and services, labor	Crash of global financial markets Globalization "with a human face." Clash of civilizations
Demography: aging and shrinking of populations	A new baby boom "Breakdown of the sperm count." Clash of generations
European Union: enlargement and institution building	Europe orients to the East "Fraglargement" Fortress Europe
Lifestyles: an erosion of traditional family	Return of family Spiritual revolution
Technology: rapid progress of ICT and biotech	End of Moore's Law 100 years life expectancy
Environment: global warming, resources depletion	The collapse of the Gulf Stream Cold fusion energy

Source: (Hauptman and Steinmüller, 2018)

Furthermore, the wild card concept is introduced as the Black Swan. That is a phenomenon containing the three traits. First, "it is an outlier, as it lies outside the realm of regular expectations because nothing in the past can convincingly point to its possibility. Second, it carries an extreme impact. Third, despite its outlier status, human nature makes us concoct explanations for its occurrence after the fact, making it explainable and predictable." (Pavlova et al., 2018)

There is a different type of wildcards by using probability, possibility, and plausibility in futurology terms to distinguish the wildcard. First, probability refers to the probable future, which is more likely to happen involving in the current trend. Next, possibility or possible future, which might happen by requiring future knowledge. Lastly, plausibility could happen based on the current knowledge holding a right and credibility to descried the future, as clearly illustrated in Figure 2.10 and the type of wildcards classified in Table 2.8. (Van Der Helm, 2006)

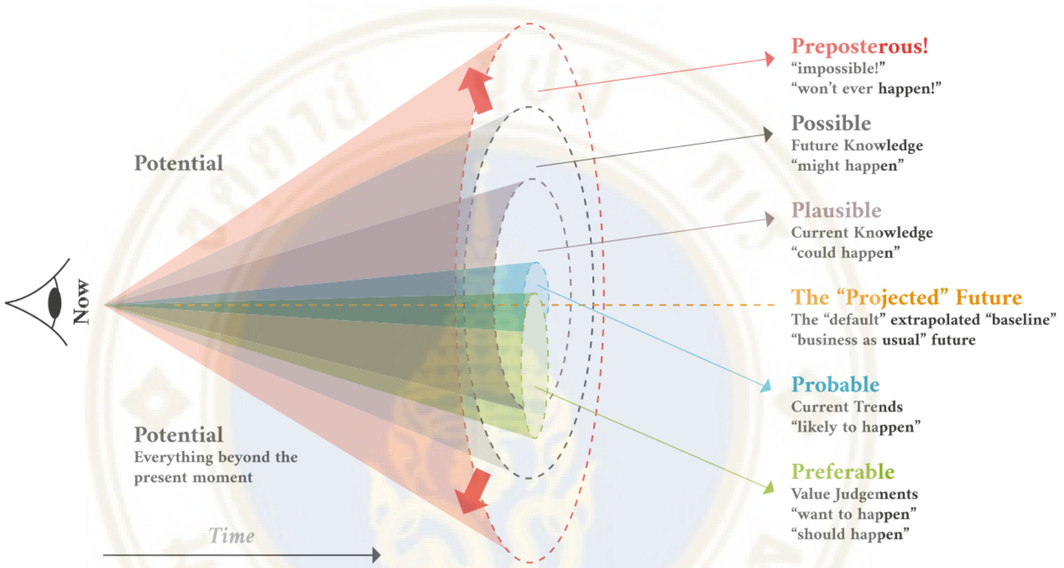

Figure 2.10 Future thinking

Source: UNDP, 2018

Table 2.8 Wildcard typology

Degree Probable↑ Improbable↓	**Yes or No Possible↑ Impossible↓**	**Truth Value Plausible↑ Implausible↓**	**Disruptive- ness High↑ Low↓**	**Wild Typolog y Or Popular Name**
PROBABILITY	**POSSIBILITY**	**PLAUSIBILITY**	**IMPACT**	**TYPE**
↓	↑	↑	↑	I
↑	↑	↓	↑	II
↑	↑	↓	↑	III
↑	↑	↑	↑	IV

Source: Van Der Helm, 2006

To achieve the wildcard method, it has roughly five approaches: Identify, which surprise and a sudden event can happen, generating extreme outcomes in an organization. The second approach called Determine to seek the most significant and high potential wildcards, affecting an organization based on the previous list. Then, Classify the wildcards into four types, as shown in Table 2.8 and Monitor is the most important signals that can grow to strength, so that they can determine the plans for preparing or avoiding the unexpected outcome. (Jackson, 2013) Wildcard application can apply with another foresight method, for example, Wildcard and environment scanning due to the restriction relevant to the quality of the scanning method, which cannot cover another potential. Thus, WS can support the missing part of the consideration for better preparation in the organization. (Barber, 2004)

In conclusion, a wildcard is an unexpected event with great potential. No matter what kind of wild card occurs, it will happen suddenly and affect the whole organization or society continuously, causing the variation in existing trends and societies. The information from this method is not revealed in horizontal scanning, which means the wildcard is one of the foresight methodologies of this research to explain and expand the knowledge and new aspects provided by the experience from the interviewees' perspective.

2.2.4.3 Cross-impact analysis (CIA)

Cross impact analysis is the analytical methodology, which determines the correlation between future events or variables toward the collection of quantitative estimation from the expert judgment to identify and evaluate the impact of event upon each other, placed in the probability matrix. In order to start the procedure, Gordan introduced the concept of defining the character and number of events based on the literature review and expert opinion. Mostly event occurring in the range of 10-40 events with the number of pair interaction equaled to $n^2 - n$. ($E_1, E_2, E_3, \dots, E_n$, where E is the event, and n is the number of events analyzed) (Gordon, 1994)

The second step is to estimate the initial probability (P) of each event under the assumption that the resulting event does not happen, conducting from the questionnaire, interview, and group meeting to collect all these expert judgments. The third step is to estimate the conditional probabilities of events, which concerns the combination of an event occurring and its impact applied in the cross-impact matrix, along with the question of "If the event m happens, what is the new probability of event n?" For example, when the original probability of event n is judged to be 0.50, the new probability of event n would be 0.75 if the event m happened. The probability of event x occurring (E_x) resulting in the occurrence of event y (E_y) is called $P(y/x)$. (Gordon, 1994)

Events	**Initial probability**	**Conditional probability**				
	$P(E)$	E_1	E_2	E_3	$E_{...}$	E_n
E_1	$P(y/x)$		$P(2/1)$	$P(3/1)$	$\dots$	$P(n/1)$
E_2	$P(2)$	$P(1/2)$		$P(3/2)$	$\dots$	$P(n/2)$
E_3	$P(3)$	$P(1/3)$	$P(2/3)$		$\dots$	$P(n/3)$
$\dots$	$\dots$	$P(1/...)$	$P(2/4)$	$P(3/4)$		$P(n/4)$
E_n	$P(n)$	$P(1/n)$	$P(2/n)$	$P(3/n)$	$\dots$	

The equation below expresses the initial probability:

$$P(1) = P(2) * P(1/2) + P(2c) * P(1/2c) \quad (1)$$

where,
$P(1)$ is probability that event 1 will occur
$P(2)$ is probability that event 2 will occur
$P(1/2)$ is probability of event 1 given the occurrence of event 2
$P(2c)$ is probability that event 2 will not occur
$P(1/2c)$ is probability of event 1 given the nonoccurrence of event 2

To find the limit range of $P(1/2)$, as already known $P(2c)$ is equaled to $1 - P(2)$ Moreover, equation 1 can be rearranged to the following equation 2. The minimum of $P(1/2)$ can be solved by substituting $P(1/2c)$ with zero and the maximum of $P(1/2)$ can be replaced $P(1/2c)$ with one. Therefore, the range of probability of event 1 given the occurrence of event 2 is expressed in equation 3, which aims to examine the probability of the event not lower or higher this limit of the range. (Gordon, 1994)

$$P(1/2) = [P(1) - P(2c) * P(1/2c)]/P(2) \quad (2)$$

$$[P(1) - 1 + P(2)]/P(2) \leq P(1/2) \leq P(1)/P(2) \quad (3)$$

The next step refers to the odds ratio technique. Applying this technique, the probabilities of the event will convert to odds, as following equation 4 and then find the index of the odds in equation 5 in order to determine the interaction between events, which means when the event 1 occurs, how it impacts on the occurrence of event 2. (Gordon, 1994)

$$Odds = \frac{Probability}{1-Probability} \quad (4)$$

$$Index = \frac{Odds\ P(1/2)}{Odds\ P(2)} \quad (5)$$

The relationship of events represents three characteristics (Gordon, 1994):

1) Unrelated, which means when the event 1 occurred, it will not impact on the event 2. (Index in the cross-impact matrix represents zero)
2) Enhancing is the probability of the second event, improved by the occurrence of the first event. When the event 1 occurred, it directly brings about the event 2, called enabling. However, event 1 affects some part of event 2 called provoking. (Index in the cross-impact matrix represents the positive number)
3) Inhibiting or the happening of the first event diminishes the second event. When event 1 happens, there is a nonoccurrence of event 2, called denigrated, but if event 1 inhibits some part of event 2, called antagonistically. (Index in the cross-impact matrix represents the negative number)

2.2.4.4 SWOT-TOWS analysis

Henry Mintberg claimed that "SWOT as underlying all attempts to formalize the strategy-making process." (Mintberg, 1994) SWOT analysis is an analytical framework for strategy research that commonly uses in foresight works as a tool for categorizing important internal and external factors to identify and improve the organization, region, nation, or city. (Kotler et.al, 2010; Nazarko, 2017) This framework stands for Strengths, Weaknesses, Opportunities, and Threats. The strengths represent areas that a company gains a competitive advantage, while the weakness is characteristic that needs to be improved. For external analysis, the characteristic of opportunities supports organizations to build up the strengths, but the threats involve the factors that have to avoid these potential problems and risks. The list of Strengths and Weaknesses indicates the internal factors involving the industry, company, region, or sector. In contrast, external factors represent Opportunities and Threats, such as political, environmental, social, technological, economic, and legal, based on the different background knowledge from the suitably prepared group of experts and participants. (Nazarko, 2017) The generic diagram of the SWOT profile is illustrated in Table 2.9 below. In foresight work, the characteristics of the SWOT analysis are a good beginning stage for identification and discussion on the present and future challenges. Also, it sorts out the horizontal scanning into internal and external topics as well as assists in framing the critical success factors and weakness of the study. (Kuosa, 2016; Nazarko, 2017)

Table 2.9 **SWOT profile**

SWOT Profile		
Internal characteristics	Strengths (S)	Weaknesses (W)
External factors	Opportunities (O)	Threats (T)

Source: Adapted from Nikolaou and Evangelinos, 2010

The study applies the SWOT approach through the internal factor evaluation matrix (IFEM) and external factor evaluation matrix (EFEM) to evaluate the driving forces by classifying into two majors. First, the analysis of the internal factors, including strengths(S) and weaknesses(W), demonstrates in the internal environment of the organization. It shows the competitive advantages and issues inside the company. Second, the analysis of the external factors contains opportunities (O) and threats (T) considered as the outside environments that support and obstruct the system, respectively. (Wasike et al., 2010)

The calculation requires the weighted scores that are from multiplying weight and rating scores from the participants' perspective. For the weight, each internal strength and weakness are assigned a weight ranging from 0.00, defined as low important to 1.00 (the most important factor). So, the more important factor, the higher weight. It is noted that the total of all internal factor weight should equal 1. Then, the rating scores are assigned between 1 and 4 by identifying the major weakness (rating =1), minor weakness (rating =2), minor strength (rating =3), and major strength (rating =4) based on each participant thought. Both the weighted rate of each factor and its rating score is multiplied, and finally, each weighted score is calculated by summing to result in the total weighted rate of IFEM. All of the calculation steps are reiterated to identify the total weighted rate of EFEM as well. It needs to remind that the meaning of rating factors defines the rating 1 as a major threat, rating 2 as a minor threat, rating 3 as a minor opportunity, and rating 4 as a major opportunity. When calculating completely, the result is brought to create a suitable strategy through the TOWS analysis.

Weihrich developed the TOWS matrix as the next step of SWOT to creating alternative strategies. The concept is based on combinations of internal factors, including strengths and weaknesses, with the factors associated with external opportunities and threats. So, there are the four conceptual group of strategies: Strengths - Opportunity (SO), Strengths - Threats (S), Weaknesses - Opportunities (WO), and Weaknesses - Threats (WT), as seen in Table 2.10. The SO strategies are related to using the strengths to take advantage of the opportunities, while WO strategies are to reduce the internal weakness by considering external opportunities. The ST strategies use the internal strengths for preventing or avoiding external threats, whereas WT strategies create a defensive plan to prevent weaknesses and threats. (Kapoor and Kaur, 2017; Weihrich, 1982)

In conclusion, the SWOT and TOWS analysis is an important method through logical analysis and systematic approach to determine and understand the critical factors in order to construct the strategy coping with the challenge of industrial water management in Thailand.

Table 2.10 TOWS strategic alternatives matrix

TOWS	Internal Strengths (S)	Internal Weaknesses (W)
External Opportunities (O)	**SO**: "Maxi-Maxi" Strategy Strategies that use strengths to maximize opportunities	**WO**: "Mini-Mini" Strategy Strategies that minimize weaknesses by taking advantage of opportunities
External Threats (T)	**ST**: "Maxi-Mini" Strategy Strategies that use strengths to minimize threats	**WT**: "Mini-Mini" Strategy Strategies that minimize weaknesses and avoid threats

Source: Weihrich, 1982

2.3 The relevant research paper

2.3.1 Review of foresight framework

According to reviewing the literature, many researchers applied various foresight frameworks to represent their strategy thinking toward accumulated experiences in a particular field. Proskuryakova, Saritas, and Sivaev (2018) studied "Global water trends and future scenarios for sustainable development: the case of Russia." They used the Forstar model and systematic foresight model (SFM), which covers the 7Is stage in order to create the scenarios for the Russian water section. For instance, the sustainability of water systems, water use by domestic and industry, and new water products and services by 2030. This results in identifying the factors relevant to water issues and generating the four alternative futures, one of them, namely, "Problem conservation and Losses and accident scenario" as possible options to occur. However, the study still has a limitation of resources and capabilities to capture the full range of existing trends and uncertainties. To compare with Çifci, 2019, under the title of "Technology foresight and modeling: Turkish cybersecurity Foresight," this study employed the FORESIGHT framework and foresight periscope model (FPM), developed in 2017, and the result demonstrates in the form of four scenarios. The framework can cover entire stages for strategic foresight with the simply recognized nine alphabets, while the SFM may not mention the framing, which refers to the scope, goal, and time of study as well as the illustrating stage to present the result via report, presentation, or social media. However, the Çifci framework does not specify the foresight method, which is necessary to research in the future study, leading to one of its drawbacks in terms of time-consuming to explore the suitable technique in each stage and fulfill nine stages of the framework.

Taking a step back to see the generic foresight framework by Voros in 2003, in Thailand, this framework is well known in various business areas, for example, "The scenarios of innovative competitiveness in medium-sized garment export business management in Thailand" (Niampradit and Mitrchob, 2012). With the generic foresight framework, there are four main phases, which capture all elements, excluding the final stage if compared with the Çifci study. That is tracking stage, referring to evaluate the impact of the outcomes after implementing the scenario or strategies, is also the critical stage of taking action; on the other hand, it is appropriate for the long-term projects as well as depends on the engagement level of experts and participants among the research studies. When comparing the framework between studies written by Proskuryakova et al., 2018 and Niampradit and Mitrchob, 2012, it found that the Saritas' framework and Voros framework have similar phases. The different part is the outcome: Saritas' outcome represents the scenarios to compare each situation, whereas Voros' points out the strategy after analyzing 39 scenarios and categorizing into the five most probable themes, such as product innovation, process innovation, position innovation, paradigm innovation, and others.

In conclusion, based on the current evidence, the three frameworks: (1) systematic foresight model (SFM), (2) FORESIGHT framework, and (3) generic foresight framework point out the same purpose, aiming to foresight the various industries systematically in order to prevent getting lost direction or ignorance some phases of the framework, however, it is essential that applying the framework needs to realize own resources, capabilities of researchers, experts, and participants as well as the project duration. Even though the literature presents various themes of foresight framework in different industries, this study will primarily focus on the generic foresight framework under the scope of the industry utilizing wastewater treatment because the outcome of this framework delivers the strategy and still lacks pervasive foresight research in Thailand.

2.3.2 Review of foresight methodology

Although many literatures relevant future studies provide a variety of using foresight methods to succeed in their objectives, this paper will review the five foresight techniques used in foresight work. These methods are literature review (LR) or bibliometrics, horizontal scanning (HS), wildcard (WC), cross-impact analysis (CIA), and SWOT analysis. The average of foresight methods used in previous studies is approximately 5-6 methods, and it found that 54% of these researches use literature review as a fundamental qualitative method to conglomerate all possible data related to the study, while the HS and SWOT used 14% and 11%, respectively. Wildcard and cross-impact analysis are less frequently used. (Popper, 2008)

According to the horizontal scanning, Alizadeh et al. (2016) studied in the foresight and strategic management of the energy industry by employing the HS at phase 2 in order to explore the driving forces toward expert judgment and literature review. The result represents the variables, classified into the four categories based on PEST analysis (political, economic, social, and technology) to prepare in the next step, namely cross-impact analysis. Furthermore, the study, titled "Environmental scanning and futures wheels as tools to analyze the possible future themes of the commercial real estate market" by Toivonen and Viitanen (2016) uses HS as a tool to isolate the driving force along with future wheel methods and categorize the 32 forces in nine groups under the economic, environmental, and social areas by collaborating with external experts and 400 literary sources. Similarly, in Thailand, the study by Sukumal et al. (2018) of future university aims at determining the current trend and event as well as considering the factor affecting the scenarios by 2023 via literature review and interview the expert under STEP analysis and the wildcard technique, which is the distinctive tool, compared with the previous two studies. Combining the HS and WC can enhance the exploration of possible variables relevant the future change since the scanning can capture the present situation and uncertainty factors; besides, the wild card fulfills observation of the unexpected event, which is less possibility to happen, but have a considerable impact if occur.

To conclude, horizontal scanning is applied in the nearly first phase of the framework, which assists gathering and categorizing data relied on PEST analysis as the macro environment by literature review and expert opinion. Moreover, a wild card can be a useful technique for exploring the unpredictable event, but referring to Popper's foresight diamond, it is qualitative with the highest creativity, which means the creative idea originates by the rational knowledge and experience in a particular field. Thus, using the WC tool needs a variety of perspectives from the group of expert discussion. The variables performing in horizontal scanning will be data preparedness for the latter phase, such as cross-impact analysis, based on these three literatures.

It found that Sukumal et al. (2018) and Alizadeh et al. (2016) applied the cross-impact analysis (CIA) tool after the HS method. In Thailand, Sukumal et al. (2018) demonstrated the CIA tool after the HS and future wheel in order to create a cross-impact matrix and calculate the impact index of each variable interaction and receive the result called scenarios planning, leading develop the strategy toward SWOT analysis as the final phase of framework. The study by Alizadeh et al. (2016) of the third phase applied the CIA tool and visualized the result from the MICMAC program. The study shows that the program can help to determine the level of influences and show the indirect variable to protect the delusion among analysts. With this MICMAC application, the expert judgment is significant to define the impact score of each variable and generate the graph based on influence and dependence criteria, leading to the discover three critical uncertainties for the Iranian energy industry that contain foreign investment in the energy industry, energy consumption growth, and economic sanctions and bring about the scenarios. The strengthened part of Alizadeh et al. (2016) study is utilizing the Delphi method, supported by many experts to discuss every round to increase its credibility. However, it also suggests that the CIA tool, analyzing the interrelated binary factors in a complicated situation, can handle the pitfall of using the Delphi method, being less efficient in dealing with sophisticated forecasts when the factor has a relationship with each other. Medina et al. (2015) claimed that even though the CIA technique, obtained by interviewing the experts about the future occurrences, is developed to deal with the limitation of the Delphi method, its function has two drawbacks: firstly, the consistency of data scoring can come from the subjective expert judgment. Secondly, the number of events required is quite low, usually not more than six events. Medina et al. (2015) suggest to use CIA together with factor analysis, one of the multi-criteria decisions making (MCDM) method, to cope with the high number of events and calibrate the subjective opinion toward SMIC technique as a mathematical programming tool to measure the consistency level in analysis and if the value is higher than 0.2, considered as a weak consistency.

Summarizing, the cross-impact analysis can stand alone to analyze the scenario and can apply with other foresight methods, such as HS, future wheel, and Delphi. However, there are limitations to the CIA as a semi-qualitative approach. So, the combination of CIA and MCDM can be a helpful technique to deal with the problems. Mostly the last output of this literature is the scenarios, but rarely to create the strategy to implement the possible scenarios created. It found only the study by Sukumal et al. (2018) that allow the SWOT analysis to generate the strategy. Thus, based on the current literature, this study will use a literature review or bibliometric to explore more on the current situation or tend of industrial wastewater treatment in Thailand. Besides, apply the horizontal analysis and wildcards are to identify the driving force affecting the future of industrial wastewater treatment in order to develop the strategy toward the SWOT analysis to extend the opportunities and cope with the future challenges. For cross-impact analysis or decision-making tools, these methods will apply in future research since the time constraints and uncertainty pandemic situation during implementing this study.

2.3.3 Review of application relevant to the water management

In this part, the researcher studied the past research papers for reference and supporting the strategic recommendations of industrial water management and sustainable management. The following explains the result of case studies both in foreign countries and Thailand to be the guideline for developing the appropriate alternative strategies.

2.3.3.1 Water management application toward social influence strategy

Numerous psychological researchers integrating with water application demonstrate the social norms can influence people's behavior, particularly those who have anxiety and ambiguity to behave and conform to the social situation. The unpredictive both current and future direction encourage public adaptation under the mindset that "If everyone is doing it, it must be a sensible thing to do." Together with the social comparison as one of social influence, the technique provides feedback about individual behavior and the comparison to others. Generally, when individuals receive feedback, they want to know more by comparing themselves to others in order to evaluate how much better or worse they are. Thereby, if lower than the norm, they will be motivated to change the behavior to be the same as society.

The study shows that the WaterSmart Software partner with water utility in the United States to deliver the report to the customer each month via mail or email. They provide the personalized water usage data and the average water consumption in the surrounding households, and the lower water use average by using the emoticon, such as a smiley, neutral, and a frowny face. The people measure their behavior to see how far from the average or norm. The result of the testing in twelve months is found that average water reduction is 4.6-6.6% after two months of sending the report. (Lede and Meleady, 2018) Importantly, it needs to ensure that the criteria set will not cause the undesirable behavior of the boomerang effect. When customers have water usage below the norm, socially comparative feedback encourages adversely to increase consumption. So, considering the social behavior is essential to create the measurement along with preventing the unwanted result.

Similarly, this technique has been adjusted and applied through a partnership with water utilities in the United Kingdom by Advizzo. The home water reports are delivered to the mail. The interesting is the volume of water consumption data shown in three characteristics comprising of efficient neighbor (those have 20% beyond the average), your home, and the average household in that area. To prevent the boomerang effect, individual water usage receives positive emoticon, such as "Great" and "Good," along with advice on how to save the water appropriately. The measurement over the six months is found that water demand reduces by 2.2%. (Lede and Meleady, 2018)

Hence, these shreds of evidence demonstrate the part of success in water-saving, and the lesson learns to use the social influence in the water management with concern the emoticon criteria. This can apply to other purposes, including the energy-saving or water quality; however, it needs to consider the users relevant to the project and appropriate criteria in a particular area.

2.3.3.2 Managerial support in sustainability management

Since the trend of sustainable water management is implementing in the global industries, the integration of sustainability issues is brought in all activities and processes to develop a sustainable enterprise. The study collected data on sustainable management in large companies and small-medium enterprises in Austria. It is revealed that the top factors promoting the sustainability implementation are corporate philosophy, the individual interest of employees, organizational culture, and the top management support. Conversely, the lack of personnel capacities, finance, top management support, and know-how are the strongly inhibiting factor for sustainability implementation. (Kiesnere and Baumgartner, 2019) It is noticed that the support from top management is located in both promoting and inhibiting factors from acting sustainability plan. To be more empathetic, Rauter et al. explained that the leadership perspective in companies, along with leader knowledge, have a strong influence on strategic goal. Thus, leaders or founder needs to open mind and understand the sustainability work. Besides, the research provides recommendation for the executive team who realize themselves have a bias toward the stability of the company; however, needs to transform as a sustainable enterprise. Then, consulting and hiring another team member with a different mindset is an appropriate method to gather the new aspect of sustainability. (Kiesnere and Baumgartner, 2019; Rauter et al., 2017)

Furthermore, the research in Thailand advised applying sufficiency economic philosophy (SEP) in the organizational culture for top management to conduct and enhance the industry as a guideline of industrial sufficiency economy. It is shown that the trend of sustainability changed business management, especially the new generation pay attention to sustainable practices. Consequently, the SEP becomes an interesting corporate philosophy introducing in Thai businesses and be more applicable to the industry sector. (Fakfare and Dechthaisong, 2019) The fundamental industrial guideline is widespread in various research containing the three pillars (moderation, reasonableness, and self-immunity) and the other two conditions (knowledge and morality). (Mongsawad, 2012) Indeed, in 2012, the Management system certification institute (MASCI) and the institute of sufficiency economy (ISE), together with the Ministry of the industry in Thailand (MOI), developed and launched the managerial SEP guideline to encourage the entrepreneurs to utilize the philosophy in manufacturing company to balance society, environment, economic, and individual's development. To be more effective action, the top management needs to play a critical role in clearly understanding and leading from planning, implementing, monitoring, evaluating and reviewing, and lastly, improving stage. (Yipyintum, 2014; Ministry of Industry of Thailand, 2013)

The research results after adopting SEP in the Thailand industry, for example, can run business with low cost and maintain product and service quality. In the typical mindset of many entrepreneurs, if the industry hires laborers with lower wages and low efficient machines, the cost of operation activities will be lower and serve the low price to satisfy the customers. This misunderstanding will be able to preserve the profit but in the short term. (Khunthongjan and Wiboonpongse, 2010) With the philosophy, the leader understands the current situation and lead the idea that quality is the crucial successful business and employee create the new planning that it needs low capital with still the quality under the moderation pillar. Subsequently, the new campaign generates to select suitable machines with considering lifetime and maintenance to increase both the quality and quantity of products and lessen cost per unit in the long term. This meets reasonableness and self-immunity. To maintenance the equipment, the staff skill development through training becomes the option instead of lower-wage, meaning that the company can bring each staff capability and their knowledge to solve the problem by linking to the knowledge element in SEP. Aside from the knowledge, it reaches morality since the awareness of the quality can provide products according to the laws and ethics, leading to offer credible service and create trust and satisfaction among customers in the long term. (Khunthongjan & Wiboonpongse, 2010)

In conclusion, the top management or founder is the critical success factor to deliver the message and lead the staff in the industry. Those who have sustainable leadership encourage and support to balance the social, environmental, and economic dimensions with long term profitability. To be a sustainable enterprise, the researches recommend in two ways, which and the consulting the third party who experience sustainability and applying the sufficiency economy philosophy into the organizational culture.

2.3.3.3 Circular water management

According to International Water Association (IWA), their business guide is recommended to adopt the 5Rs approach to circular water management, meaning that industries need to consider the approach as standard practice in entire water activities in industries from the source to consumers' hands. They define the five elements and its definition in Figure 2.11 following:

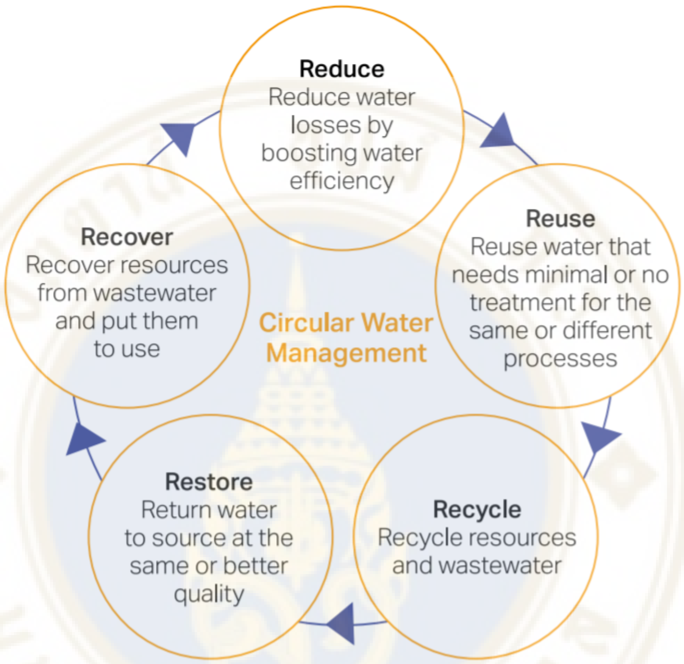

Figure 2.11 5Rs approach to circular water management

Source: World Business Council for Sustainable Development (WBCSD), 2017

The suggestion emphasizes the point of view about developing an innovative solution for water management. The adoption of 5Rs is not only considering the water, energy, waste, and nutrient system independently and attempting to improve just one-side of water resource scarcity for their industry. Rather than that, it has to integrate the water issue with others, such as the resource recovery from wastewater that can combine the nutrient and water problem within a project together with realizing the border stakeholders, including agriculture, community nearby, and collaboration with government. The integration of issues is an important aspect of the circular economy method. Therefore, the study has prospected that many kinds of research and businesses need to increase the project about expanding resource recovery systems and revise the policies to correspond with the recovery researches with consideration of incentive schemes to develop staff motivation and engagement. Significantly, the support of research and development promotes innovation within the manufacturing process and across departments. (World Business Council for Sustainable Development (WBCSD), 2017; EU Commission, 2018)

The case studies show that Agua Inc., an innovative water and wastewater treatment technology company and facility developer, provides the novel solution that combines between plants, bio hardware, and biofilter materials to naturally treat water and industrial wastewater effluent to serve more effectively, sustainably, and affordably to business owners. They optimize the conventional biological treatment process with their biotechnology, including macrophytes accumulating heavy metal, bio-engineering absorbent, and hardware. This method, called ABIS (Aquatic biological integrated systems), increases the performance of the process and reduce the cost and maintenance for industry and modern city. Another example is an Indian waste management enterprise, namely Bridgedots. The company developed technology for waste treatment to dewater the sludge and remove the hazardous component from the waste along with the extraction of the useful components that help increase the waste utilization. (Elaine & Natalia, 2017; Agua Inc, 2015; Bridgedots, 2011)

Summarized, apart from the reduction, reuse, recycle, and restoration, the recovery is the interesting practice of integrating components including waste, water, energy, and nutrients in industries to overcome the barrier, such as operation cost and generate the value from separating the unwanted output.

2.3.3.4 Community engagement

The spectrum from the International association for public participation (IAP2) describes the five elements of community engagement level, as shown in Figure 2.12. (IAP2 Australasia, 2019) It is found that there is no single pathway to apply the activities in the community, meaning that it can use either the fundamental elements to create an effective engagement or select one of these approaches depending on the expected outcome of the company, characteristics of the community relevant to the openness level and budget and duration of the proposed project. (Dean et al., 2016)

Inform	Consult	Involve	Collaborate	Empower
To provide the public with balanced and objective information to assist them in understanding the problem, alternatives, opportunities and/or solutions.	To obtain public feedback on analysis, alternatives and/or decisions.	To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered.	To partner with the public in each aspect of the decision including the development of alternatives and the identification of the preferred solution.	To place final decision making in the hands of the public.

Figure 2.12 IAP2 Public participation spectrum

Source: IAP2 Australasia, 2019

The initiative relevant to the inform part has the purpose of building awareness, knowledge, and concern. The study reveals that face to face education programs, such as seminars, workshops, community events, and site tours is a successful approach to build awareness and knowledge as well as enhance the attitude to be more sustainable water practices among attendees. The effective evidence shows that the company provides a one community education program through a one-hour presentation and question session by an emphasis on the water cycle. (Cockerill, 2010) After completing the evaluation of 145 people, 97 percent had similar opinions that "they have a clearer understanding of how water works than I did before this presentation," and then a half attendee indicated that they gain the new information providing in the presentation, which is different from their previous knowledge of how waterworks. (Dean et al., 2016)

To maintain the improvement of knowledge and attitudes over time, the next initiatives are the alternative options, including consult, involve, collaborate, and empower to enhance the community engagement. This can implement toward social feedback gathering the new ideas and learning opportunities from communities as well as the community participate, naturally creating social learning practice. (Dean et al., 2016)

Another interesting case study is about government information to show that this spectrum can use in a wide range of attendees. In the case of the government sector, the aim is to build public support to the new policies, adaptation of new technology, new infrastructure, and new regulations. The persuasive communication technique is essential to cultivate and engage the public interest, and then the social diffusion drives individual by sending a signal to others in their social network, as a result, increase the similar attitude and likelihood of adopting support the new policy. (McKenzie-Mohr & Schultz, 2014) For example, the introduction of drinking recycled water in Singapore from growing pressure on water security prompt the government to bring the water reclamation technologies from industry. The communication campaign with a careful message is essential to overcome the public psychological barrier toward the recycled water by avoiding the negative word, such as wastewater or sewage. Instead, the Public Utilities Board suggests the novel term, namely NEWater for recycled water, deriving from the "new and improved" term. Also, renamed the sewage treatment plants to the water reclamation plant. The successful campaign gradually accepts among citizens with the assistance of media coverage, the NEWater ambassadors, public displays and exhibitions, public sampling of bottle NEWater, and public education. The result indicated that there is a very high public acceptance of the NEWater. (Howe & Mitchell, 2012; Leong et al., 2011)

In conclusion, the spectrum of community engagement is the guideline for entrepreneurs who experience the community confliction about the water and wastewater treatment plant to create the knowledge and awareness first to ensure that the community understands the industry and shows what we are implementing to generate the social acceptance. The suggestion in each type of initiative can either do step by step or choose one of them relying on the scale and characteristic of the community, the expected outcome of the proposed project, along with considering budget and time supporting by the company.

CHAPTER III
RESEARCH METHODOLOGY

This chapter introduces how the study conducts the strategic foresight of industrial water management in Thailand in the next five years (2020-2025). The study relies on reliable information and perspectives from many participants who experience in the wastewater treatment field to deliver their future aspects. According to the conceptual framework in Figure 1.3, the strategic foresight stages include four stages: collecting input data, analyzing the information, interpreting the information, and creating strategy. Therefore, the following explains the research method, as concluded in the overview of data collection and data analysis of this framework in Table 3.1 below.

Table 3.1 Summary of qualitative and quantitative data collection and data analysis

Research questions (RQ)	Objectives (OBJ)	Data collection		Data analysis and tools
		Data sources	Data collection methods	
RQ1 RQ2	OBJ1	Journal articles, conference papers, books, and book chapters related to industrial water management in Thailand	Systematic literature review based on the Scopus database	Bibliometric analysis and Data visualization via VOS viewer program
		10 participants relevant industrial wastewater treatment toward snowball sampling under non-probability sampling	3 experts in the wastewater treatment field and 7 people at the management level in the well-known industry in Thailand by semi-structured interview	Content analysis of current situations and trend
RQ3 RQ4	OBJ2	10 participants relevant industrial wastewater treatment toward snowball sampling under non-probability sampling	3 experts in the wastewater treatment field and 7 people at the management level in the well-known industry in Thailand by semi-structured interview	Content analysis and foresight tools: HS, WC, and SWOT analysis

3.1 Research methodology

This study uses the mixed-method research to gain a better understanding of the connection between qualitative and quantitative research. First, the research analysis is analyzed by exploring the secondary data from published works in Scopus via the assistance of the VOS viewer program to understand the current situation and the trend of industrial wastewater treatment in global and to compare between Thailand and foreign industry. Next, the semi-structured interview is from ten participants' perspectives involving the industrial wastewater treatment area. After completely collecting information from data mining and visualizing with the VOS viewer as well as the interview, the foresight methods will be applied by the SWOT tool in order to the foresight and develop the strategy to implement in the next five years.

3.2 Population and sampling method

3.2.1 Population

This research selects at least ten interviewees relevant to wastewater treatment in medium-sized to large companies considered as well-known and experienced the industries. First, at least seven people who have experienced in the industrial wastewater treatment process at least three years of the management level to middle management level. Also, the other three experts include a minimum of 3 years' experience in environmentalists at a professional level and specialists who have at least 3-year experience in industrial water and wastewater technologies in those industries.

3.2.2 Sampling method

The sampling method for a semi-structured interview among ten people mentioned above is snowball sampling under non-probability sampling due to the uncertainty in the number of company acceptance for interviews and the time constraint of the project.

However, this research could bring some potential risks to participants in terms of psychological risk, which is mental discomfort during the interview of their internal business, such as tiredness, serious depression resulting from the COVID-19 crisis, and economic slowdown. To minimize the risk participants, the researcher collects data from standard-of-care procedures to avoid unnecessary risk, especially the invasion of privacy information, and will not reveal information of participants or interviewees in person. These documents and files will be destroyed after the research is completed.

3.3 Analysis tools

There are five analysis tools to measure the factor affecting the future change of industrial wastewater treatment, as follows:

3.3.1 VOS viewer program

Due to rarely research doing area of industrial water management in Thailand, this study reviews literature based on the Scopus database by using VOS viewer to extract the data, analyze the bibliometric network and display a visual map to interpret under the current situation and see the trend of water management in the industry.

3.3.2 Horizontal scanning

In order to gather information from all participants' perspectives covering internal factors and external factors such as political, economic, social, environmental, and technological topics in both current and future situations, this study uses a semi-structured interview through the management team associated with the wastewater treatment process and experts in wastewater treatment technology from different industry.

3.3.3 Wildcard

After the use of the HS technique, this study requires the utility of the wildcard tool to fulfill unpredictable events as possible that generate a tremendous impact in industrial wastewater treatment by interviewing the possible aspect from the management team and experts.

3.3.4 SWOT analysis

Analysis of the previously driving forces is accomplished in a SWOT matrix. This study applies the SWOT approach integrated with the internal factor evaluation matrix (IFEM) as well as external factor evaluation matrix (EFEM) to facilitate and assess the previous driving forces via Microsoft Excel. There are two major categories of SWOT analysis:

a. Internal factors analysis: Strengths(S) and weaknesses(W) represent in the internal environment of an organization that illustrates the completive advantage and hind challenges from achieving company goals, respectively. (Wasike et al., 2010)

b. External factors analysis: Opportunities(O) and threats(T) consider as external environments that support and obstruct the system, respectively. (Wasike et al., 2010)

When computerizing completely, the result is brought to create a suitable strategy for future water management in the industry via TOWS analysis.

3.4 Data collection and data analysis

According to the conceptual framework in Figure 1.3, there are four strategic foresight stages in this study, as explained following:

3.4.1 Current data collection

The bibliometric review approaches have utilized the quantitative analysis to describe the pattern of publication and accumulate knowledge over the period in particular, willingly educated field by mining data and applying citation analysis. Currently, this advanced approach of bibliometric analysis has employed science mapping to visualize and analyze bibliometric researches on the database. The following is the method guided for implementing this review. (Hallinger and Suriyankietkaew, 2018)

3.4.1.1 Search criteria and identification of sources

Many scholars have recently revealed that even though the Web of Science (WoS) was more accessible than Scopus, the Scopus database still a better alternative since it has full coverage in management fields. (Mongeon and Paul-Hus, 2015; Falagas et al., 2008) Thus, the first stage of this study involved a review of published work accessing the Scopus database, where it is broadly used to create systematic reviews of research. This review explores and assembles the data dealing with industrial water management globally to represent further the global trend and the comparison of analyzed results between Thailand and foreign countries. This method has acquired the sources, including journal articles, conference papers, reviews, books, and book chapters, with the timeframe covering from 1990 through 2020.

To identify the database of studies for the industrial water management review, the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method, being a guideline for systematic review, comprises of four steps: Identification, Screening, Eligibility, and Included, as can be seen in Figure 3.1, in order to assist authors to minimize the set of an item for reporting of systematic reviews and meta-analyses. (Moher, 2009) When accomplishing through this method, the set of appropriate database delivers into the next step. Initially, the author explored the broadest perspective by searching the keyword, TITLE-ABS-KEY ("water management" OR "wastewater management"), which contains all aspects including residential, agricultural, and industrial water areas. This yielded 139,270 documents providing in the Scopus database, which has been numerous interesting issues for a long time. Then, the author specified in industrial water field covering economic, environmental, and social elements. So, it is scoped only relevant and appropriate keywords, which were TITLE-ABS-KEY ("industrial" OR "industry" OR manufactur*) AND TITLE-ABS-KEY ("sustainable" OR "sustainability"). These keywords generated the first result of 2,409 documents.

Next, in the initial screening of documents, eliminated were the editorials, book reviews, notes, comments, and letters. Then, the author reviewed titles and abstracts to identify their topical relevance with two reasons for considering the documents of this study. First, the documents focused only on water utility through development and improvement in the industrial sector. Second, the studies had the primary focus on industrial water and show the impacts of each industrial activity to other related sectors, including the environment, society, and economics. Therefore, these exclusion criteria of documents were eliminated 56 % of documents in the initial Scopus database. Consequently, the process remained 1,066 final eligible documents.

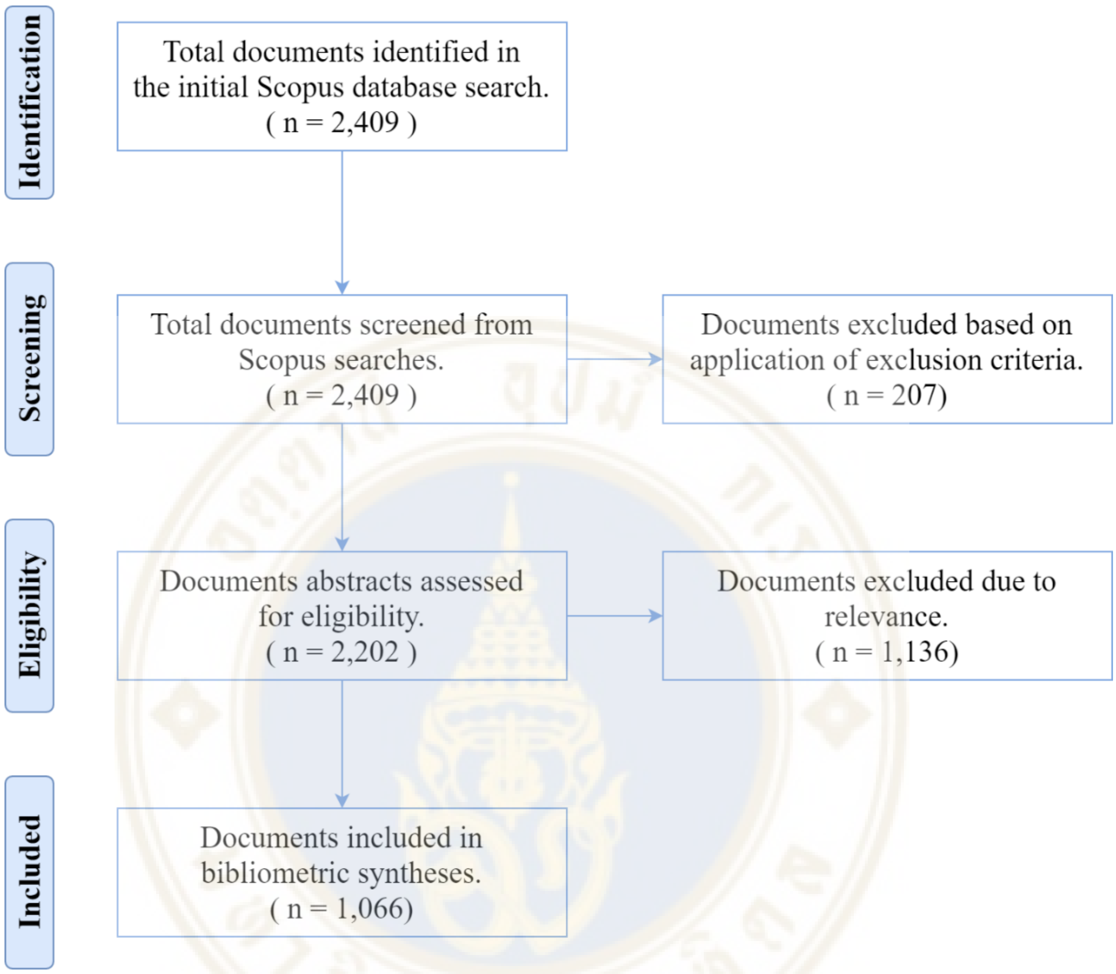

Figure 3.1 PRISMA diagram presenting the database number of literatures in industrial water management

3.4.1.2 Data extraction and analysis

Since preparing the Scopus database relevant to the scope of industrial water management, the database from Scopus in a common-separated values file (.csv), is stored and uploaded in the VOS viewer program, which helps to integrate relied on descriptive statistic and bibliometric analysis. The data extraction through bibliometric analysis comprises a citation and co-citation analysis, aiming to determine the impact of authors, journals, publications in the literature. Citation analysis computes the number of times that documents were cited by another document located in Scopus, and the results are interpreted to represents the measurement of scholarly influence, such as total citation and citation per document (CPD). (Hallinger and Suriyankietkaew, 2018)

Besides, "co-citation is defined as the frequency with which two units (authors, journals, documents) are cited together" as given by Zupic and Cater. (Zupic and Čater, 2014) Thus, co-citation analysis is the way to establish the similarity between two documents. If the first and second documents are co-cited, both of them will appear in the reference list of the third document, which could imply that they are related to one another although they do not directly cite each other. Also, the more first and second documents are cited by many other documents, the stronger relationship between them. (Ganesh et al., 2011) In this review, the author co-citation analysis (ACA) has been used to generate and cluster under the intellectual structure and then focused on keyword co-occurrence analysis in order to determine frequently co-occurrence of keyword via deep extraction and also highlight the topic trend of industrial water management in the most recent year with temporal keyword analysis generated by VOS viewer software.

3.4.2 Data categorization and analysis

This stage is to explore the driving forces affecting future wastewater treatment in the industry with the interview. To collect this interview data, the research creates the letter requesting permission certificated and signed by the university and form the fillable file in docx. format for the convenience of the interviewee answering. Then, sending the letter to the selected company or industry or person relevant to wastewater treatment via e-mail. After approving permission from the company, the attached fillable file will be delivered to the company, and the research will receive the replies via the researcher's e-mail, which is the direction the responsibility of the researcher in order to prevent the information from distributing in public as well as keep the information confidentially. If the interviewee has any questions, they can send the question back via this email or contacting the researcher's telephone number provided in the e-mail context.

The interview separates into two parts: firstly, horizontal scanning aims at gathering the data toward interviewing ten people including the management team associated with the wastewater treatment process and experts in wastewater treatment technology from the different industry under the question of what the current situation of water management in their industry and what the wastewater treatment going to be in the next five, in particular five dimensions: political, economic, social, technology, environment and legal.

Secondly, the wildcard technique applies for covering other unpredictable events or driving forces that have less likely occurrences, but a high positive or negative impact for future changes, and this study also uses a semi-structured interview with the same group of participants for identifying less probably happening but very effective if occur. After they provide the driving forces in each dimension, the next question will ask to weight and rate the score of these driving forces with an explanation of the reason based on their experience and perspective of their position. Since these factors are utilized in the next stage, called SWOT analysis, the score will follow the criteria of IFEM and EFEM. The explanation below is the step of the scoring process of both internal (strengths and weaknesses) and external (opportunities and threats) factors:

Step 1: Relevant to weight ranging

Each internal factor consisting of strength and weakness was assigned a weight ranging from 0.0 (low important) to 1.0 (most important). Thus, the more effective factor, the higher the assigned weight. It is noted that the summation of all weights of all internal factors should equal 1.0. In addition, each weight of external factors including opportunity and threat, can follow these criteria and need to be careful that the total weight of external factors should be 1.0 as well. (Monavari, et al., 2007; Reihanian et al., 2012)

Step 2: Rating score

Each factor is rated between 1 and 4 under the question of how much it impacts on the company, and the table below summarizes the rating score of both internal and external factors. (Monavari, et al., 2007; Reihanian et al., 2012)

Internal factors		External factors	
Rating = 1	Major weakness	Rating = 1	Major threat
Rating = 2	Minor weakness	Rating = 2	Minor threat
Rating = 3	Minor strength	Rating = 3	Minor opportunity
Rating = 4	Major strength	Rating = 4	Major opportunity

Then, the collected data from the bibliometric method and these driving forces shaping the future change from the ten interviewees are gathered and categorized into a SWOT matrix toward content analysis for preparing data into the next stage.

3.4.3 Interpretation

This stage is about SWOT analysis by using the prior data preparation of both bibliometric approach and interview. After completely gathering data, the scores evaluated by ten interviewees are brought into the Excel file for calculation, as illustrated the Table 3.2 below. First, to calculate the weighted rate of each internal factor, its assigned weight is multiplied by its rate. Then, the total weighted rate of IFEM is calculated by summing the weighted rate of each factor. If this score is less than 2.5, it means that the strengths are lower than weakness. Conversely, if the score is more than 2.5, the strengths are more than the weaknesses. (Reihanian et al., 2012) Again, the calculation of the score can iterate in EFEM. Thus, the interpretation of score when it below 2.5, the opportunities are less than threats; however, if it is more than 2.5, opportunities are more than threats. (Monavari, et al., 2007; Reihanian et al., 2012)

Table 3.2 Internal and external factors evaluation matrix (IFEM and EFEM)

IFE Matrix				
Strengths	**Weight**	**Rating**	**Weighted score**	
S1				
S2				
…				
Sn				
Weaknesses	**Weight**	**Rating**	**Weighted score**	
W1				
W2				
…				
Wn				
Total	1.0			**=Total IFE weighted score**

Table 3.2 Internal and External Factors Evaluation Matrix (IFEM and EFEM) (cont.)

EFE Matrix			
Opportunities	**Weight**	**Rating**	**Weighted score**
O1			
O2			
…			
On			
Threats	**Weight**	**Rating**	**Weighted score**
T1			
T2			
…			
Tn			
Total	1.0		

= Total EFE weighted score

Source: Özözen et al., 2012

3.4.4 Strategy creation

When already assess the driving forces in both internal and external dimensions, this final stage uses the result to analyze the strategy toward TOWS analysis based on the SWOT matrix.

3.5 Summary

Research questions (RQ)	**Objectives (OBJ)**	**Data collection method**
RQ1 RQ2	OBJ1	Data collected via the literature review and interview the people associated with the water management field in industry and experts in the wastewater treatment area
RQ3 RQ4	OBJ2	Data collected via interview the people relevant to the water management field in industry and experts in the wastewater treatment area

CHAPTER IV
RESULTS AND DISCUSSION

This chapter includes demographic interviewee data, current situations in foreign countries and Thailand, future trends in foreign countries and Thailand, and strategies coping with future five years' challenge, respectively, in order to answer the research questions, as summarized below.

Table 4.1 Guideline of results and discussion

Section 4.1	Current situations in foreign countries and Thailand	Research Questions
	4.1.1 Descriptive analysis of literature 4.1.1.1 Basic growth trend 4.1.1.2 Country analysis	RQ1
	4.1.2 Analysis of Influential Journals, Authors and Documents 4.1.2.1 Analysis of Influential Journals 4.1.2.2 Analysis of Influential Authors 4.1.2.3 Analysis of Influential Documents	RQ1
	4.1.3 Intellectual Structure of the water management in industry	RQ1
	4.1.4 Topical Foci of the industrial water management knowledge base	RQ1
	4.1.5 Conclusion of comparison between four foreign countries and Thailand	RQ1
	4.1.6 Current situation of industrial water management in Thailand through supporting from an interview	RQ2

Table 4.1 Guideline of results and discussion (cont.)

Section 4.2	**Future trend in industrial water management**	
	4.2.1 The overview of future water management in Thailand manufacturing industry	RQ3
	4.2.2 Potential driving force of future 4.2.2.1 Horizontal scanning 4.2.2.2 Wildcard analysis 4.2.2.3 Internal factors	RQ3
	4.2.3 SWOT analysis	RQ3
Section 4.3	**Strategies coping with future five years challenge**	
	4.3.1 TOWS matrix	RQ4
	4.3.2 Industrial water management strategy in Thailand	RQ4

4.1 Current situations in foreign countries and Thailand

This section uses bibliometric analysis through VOS viewer generating the past until the present situation in industrial water management and comparing between top-four most productive foreign countries and Thailand with the supporting evidence from interviews and literature review relevant.

4.1.1 Descriptive analysis of literature

4.1.1.1 The underlying global growth trend

The number of sustainable industrial water management publications per year is shown in Figure 4.1. As the number of documents increases slightly since 1991, it is evidence that the researchers began interested in the study of sustainable industrial water management before the 20th century. Until 2003, the publications generated started going down below twenty publications per year. After a few years, it turned back in 2006 and then continued to proliferate through the present. This revealed that numerous researchers had gained many attracted attentions of these industrial water management in the last fifteen years. The growth trend illustrates four critical phases; modest increase (1991-2003), a significant decrease (2003-2006), continuous growth (2006-2014), and accelerated increase (2014 until the present).

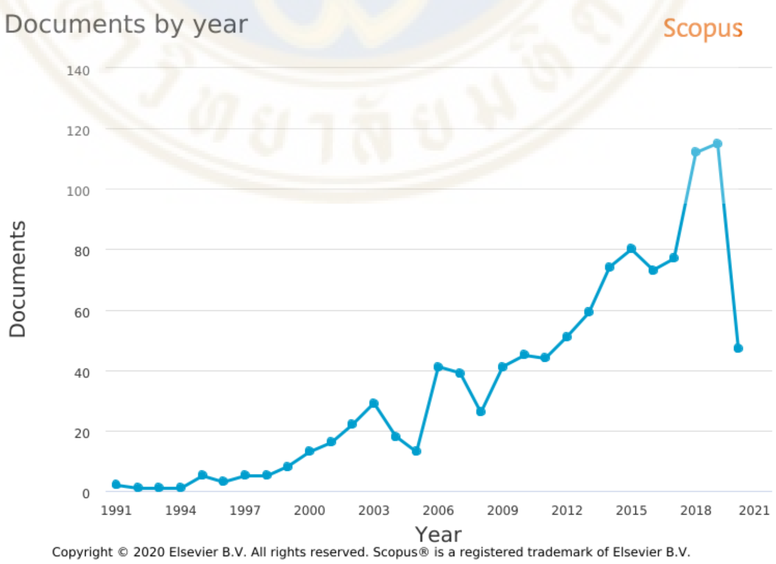

Figure 4.1 Global growth of industrial water management literature, 1990-2020 (n=1,066)

From reading the titles and abstracts, during 1991 and 2003, it was found that the majority of researches was on the scope of environmental protection from industrial disposal and a little concern about water shortage in developing countries. Then, the lower number of publications shown between 2003 and 2006 could be the effect of the subprime mortgage crisis. That occurs the mass destruction in finance and investment in the business as well as the loss of trust in banks; as a result, the phenomenon transformed the attention of the water research to individual financial priority surviving in the business world. After relieving the past suffers, many studies tried to suggest the sustainability tool for evaluating the industrial performance along with intensively finding industrial water quality assessment releasing in the natural resources. Besides, in 2009, social sustainability in the industrial water sector is raised under considering stakeholder engagement near the manufacturing industry and connecting to the environmental issue. After 2012, the publications increased significantly and mostly focused on wastewater treatment technologies for untreated water disposal from the industry by improving the membrane filtration. In contrast, some studies developed the concept of water and energy relationship to perform suitable water use efficiency and energy efficiency in the industry. Subsequently, the publications numbers after 2014 doubled as compared to 2006, and the topic was related to advanced treatment technologies and innovative water system employing in the industry. From 2018 until the present, publication numbers were jumped around one hundred and ten documents and tended to increase in the future. The studies mostly focused on green technologies and tried to implement the framework or suggestion for closing the industrial water system by considering the sustainability elements.

4.1.1.2 Country analysis

From the Scopus database, 95 different countries are generating the publication relevant to sustainable industrial water management. The top 20 countries producing represents in Table 4.2, and it is found that the top 4 countries were United States (219), China (139), and India and the United Kingdom being the same place with producing 91 documents while Thailand was the 33rd ranking which had a total of eleven documents.

Table 4.2 Top 20 countries producing industrial water management, 1990-2020

Rank	Country	Documents	Citations	Total link strength
1	United States	219	4563	68
2	China	139	2487	78
3	India	91	1294	27
4	United Kingdom	91	2497	23
5	Australia	87	4274	72
6	Canada	50	1194	42
7	Spain	48	1616	12
8	Germany	43	802	14
9	Italy	41	885	25
10	Netherlands	37	1319	20
11	South Africa	33	166	27
12	Belgium	27	1681	16
13	Malaysia	27	648	17
14	Turkey	27	467	14
15	Brazil	26	259	5
16	South Korea	23	768	10
17	Mexico	19	237	5
18	Greece	17	657	10
19	Sweden	17	450	11
20	Finland	16	129	21
…	…	…	…	…
33	Thailand	11	116	14

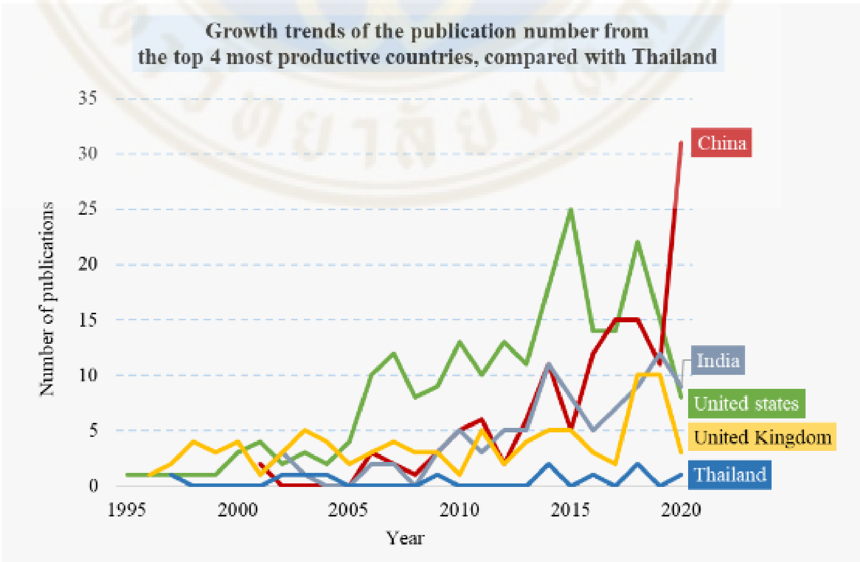

Figure 4.2 Growth trends of the publication number from the top 4 most productive countries, compared with Thailand

Figure 4.2 presents the growth trends of the top 4 most productive countries as compared with Thailand. It is revealed that the USA was the pioneer in industrial water management research in 1995. After one year, the researchers in the United Kingdom began to publish this research. Interestingly is that Thai researchers also started the industrial water research area in 1997, while the publications of China and India were initiated in 2001. Then, the five countries, including Thailand, minimally generated the documents, and it was below five publication numbers.

After 2006, the publication numbers of the USA increased rapidly, which doubled as compared to the other countries. The critical concern of their research was water utilities. According to the signed agreement of the US Environmental Protection Agency (USEPA) and American Water Work Association (AWWA), the suggestion of a holistic approach, namely sustainable water infrastructure, is released with the aim at better utility management, water efficiency, operational efficiency, source water protection, and full-cost pricing. This agreement was motivated to effort many industry groups to promote utility management across the entire water sector. This could be the supporting evidence of a notable increase in the US and then trended to grow significantly over the period. A sudden rise in numbers of publications to twenty-five documents appeared in the year after 2014, primarily focusing on the membrane technologies for wastewater treatment in manufacturing industries. However, the momentum was not staying long, where the publication numbers decreased after 2018. From 2018 to present, the topical area focused on the integration of renewable energies and existing water infrastructure, particularly in the water industry. (Heare, 2007; Mann & Runge, 2007)

The publication of China, India, and the United Kingdom increased gradually between 2006 and 2014. In China, the effect of severe drought, flood, and water pollution events drive the series of water resource management, water conservation measures, and water supply during this period whereas China was the forefront of green technology, which means they also focused on the environmental technology innovation including membrane filtration and solar energy under the environmental policy. At the same duration, the researchers in India attempt to develop an article related to the advance membrane technologies applying in various industries with the purpose of water quality improvement (Ranade & Bhandari, 2014; Bhuta,

2014) while UK articles intended the sustainable water infrastructure and integrated water resource management for the water industry. Also, the development of methods termed advanced oxidation processes of water in industry. (Comninellis et al., 2008)

From 2015 to the present, the trend of publication numbers in India and the United Kingdom moderately increased. The current topic in India still improves the treatment technologies by merging biotechnology for lower energy consumption and environmental safety, also known as the bioremediation approach in the manufacturing industry. (Chakraborty, Sikder, Mukherjee, Kanti Mandal, & Arockiasamy, 2013) For UK concerns, at present, there are integrated water resource management and water network supporting the digital utility to enhance the business. (Department for International Trade, 2016; Lawson, Farmani, Woodley, & Butler, 2020) Apparently, the researches in China increased abruptly from 5 (2015) to 32 (2020), where it was more magnificent than US publications. It is revealed that due to the rapid change worldwide, the Chinese government is implementing to promote the industrial capability in the focal area of innovation-driven manufacturing, optimization in the industrial system, quality improvements, and green industry development. Consequently, many documents mainly public about advanced membrane filtration and water resource management since the significant issue, namely water scarcity, remain across the country, associated with the relationship between water use efficiency and industrial transformation. Until the present, Chinese researchers generate the framework relevant to water and energy nexus and attempt to demonstrate the closing loop in the industrial process.

In Thailand, the average publication number is a lower rate than in other countries. Starting in 1997, the studied publication facilitated the zero liquid discharge system, which is an alternative way to be a water source of industry. In other words, applying the zero discharge is self-reliance since it does not depend on only groundwater as water supply in industry-leading to a more cost-effective approach than a traditional single pathway. So, it is interesting that Thai researchers paid attention to the zero-discharge concept before the 20th century. In 2004 and 2009, the concept of water conservation and wastewater reuse continuously developed to reduce the raw water consumption and improve the wastewater discharge quality to the surrounding. It is questionable that even though the researchers suggested the practical approach to enhance the industrial capability, the water scarcity and severe water pollution still were available in the top issues. According to DIW, it is found that the reason behind is associated with the end-user, including entrepreneur and industrial staffs that unprepared industrial plans and implementation for upcoming threats along with the budget constraints and the lack of preventive maintenance management. These barriers caused the reduced efficiency of water and environmental management in the industry. (Department of Industrial Works, 2014)

From 2014 until 2016, the philosophy of sustainable industrial water management grew due to government promotion. The Ministry of Industry policies promoted the development of Eco-industry to encourage the awareness of industrial sectors relevant to efficient use of resources consisting of the utilization and reduction of wastewater disposal and support the consistent development in terms of economy, society, and environment to reach the sustainable goal. Thus, the sustainable direction in the Thailand industry primarily focused on the 3Rs; Reduce water resource and water use; Reuse water-related to industrial activities; Recycle, which transforms the industrial water to water using for other activities. (Ministry of Industry, 2016) It could be the outcome that many studies attempted to redesign the system design for water and wastewater management. Subsequently, since 2018, the publication expressed concern about the development the clean technologies or environmental management systems (EMS), which in conjunction with the 3Rs concept to increase the industrial operation efficiently.

4.1.2 Analysis of Influential Journals, Authors, and Documents

The previous explanation provides the broad knowledge and development trend relevant to industrial water management across counties. In this part of the analysis, the researcher extracted and analyzed the data from influential journals, authors, and documents in order to attain a deeper understanding of the industrial water management situation.

4.1.2.1 Analysis of Influential Journals

Table 4.3 Top 20 journals were publishing scholarship on industrial water management ranked by Scopus citations

Rank	Source	Domains[1]	Documents	Scopus citations	Scopus quartile	CPD[2]
1	Journal of membrane science	Bio & ChE	9	1985	Q1	220.56
2	Science	ARAH	2	1304	Q1	652.00
3	Water research	Env Sci	18	1286	Q1	71.44
4	Journal of environmental management	Env Sci & Med	36	1280	Q1	35.56
5	Journal of chemical technology and biotechnology	Bio & ChE	23	1141	Q1	49.61
6	Environmental science & technology	Chem & Env Sci	11	1053	Q1	95.73
7	Water science and technology	Env Sci	64	982	Q2	15.34
8	Science of the total environment	Env Sci	30	883	Q1	29.43
9	Bioresource technology	ChE & Energy	25	668	Q1	26.72
10	Journal of cleaner production	Bus & Energy	30	638	Q1	21.27
11	Journal of hazardous materials	Env Sci	15	526	Q1	35.07
12	Resources, conservation and recycling	Econ & Env Sci	23	499	Q1	21.70
13	Trends in biotechnology	Bio & ChE	3	478	Q1	159.33
14	Renewable and sustainable energy reviews	Energy	4	266	Q1	66.50
15	Desalination	ChE & Env Sci	11	224	Q1	20.36
16	International journal of biological macromolecules	Bio & Med	3	198	Q1	66.00
17	Ecology and society	Env Sci	2	189	Q1	94.50
18	Journal of biotechnology	Bio & ChE	3	187	Q1	62.33
19	International journal of water resources development	Env Sci & Soc Sci	3	186	Q2	62.00
20	Environmental technology (United Kingdom)	Env Sci & Med	12	176	Q2	14.67

[1]Domains: Env Sci= Environmental Science; Bio= Biochemistry; ChE= Chemical Engineering; ARAH= Arts and Humanities related to history and philosophy of science area; Med=Medicine; Chem= Chemistry; Bus= Business; Econ= Economics; Soc Sci= Social Science

[2]CPD= citations per document

Table 4.3 displays the top twenty highly-cited journals, were published three hundred and twenty-seven articles, accounting for 31% of the total industrial water management articles. These twenty journals are offered the insight comprising of domain area, quality, impact, and productivity. First, the breadth of journals on industrial water management mainly covers science and engineering scope. The domain which distinctly found focuses on environmental science alone and also merging itself with another domain, including chemical engineering, medicine, economics, and social science. It is revealed that the integration of biotechnology and chemical engineering is an interesting tendency that has many researchers develop and study in this area. Besides, the group of energy domains has a few publications, but it has opportunities to grow in the industry sector as collaborating with others.

The assistance of Scopus Quartile evaluates the quality of water articles. It is noticeable that 85% of these journals were ranked in quartile one, and the rest was in quartile two of Scopus; as a consequence, the 20 top journals on industrial water management being in high quality and consistency, which is reasonable for research quality.

Another evident spot is citation numbers in the Journal of membrane science where reach 1,985 citations. Even though it has low productivity, still high cited per document. It is indicated that there is a potential impact of scholarship relevant to membrane filtration. The highest CPD is undoubtedly the source journal, namely Science; however, the third-ranking of impact journals is Trends in biotechnology, which emphasizes the conformation of the prior domain analysis, called biotechnology in the industry sector.

In terms of productivity, the top four journals with the highest numbers of publications on industrial water management were Water science and technology (64), the Journal of environmental management (36), Science of the total environment, and Journal of cleaner production were in the same place with thirty publications. This observation was not surprising because, as mentioned in the domain analysis above, the scopes of journals underline the articles regarding the environment and development of innovative science applying to water use in industry.

4.1.2.2 Analysis of Influential Authors

Table 4.4 Top 20 highly cited scholars on industrial water management ranked by Scopus citations

Rank	Author	Nation	Topic focus	Docu-ments	Scopus citations	CPD[1]
1	Drioli e.	Italy	Membrane filtration	4	311	77.75
2	Li z.	China	Water resources management	8	284	35.50
3	Verstraete w.	Belgium	Bioeconomy	7	250	35.71
4	Li j.	China	Water resources management	10	223	22.30
5	Liu y.	China	Water resources management	7	220	31.43
6	Wang h.	China	Bioeconomy	9	179	19.89
7	Cath t.y.	USA	Membrane filtration	5	110	22.00
8	Coday b.d.	USA	Membrane filtration	4	109	27.25
9	Chen y.	China	Water resources management	7	106	15.14
10	Wang y.	China	Water-energy nexus	7	101	14.43
11	Gao l.	China	Water resources management	5	98	19.60
12	Zhang y.	China	Water resources management	8	90	11.25
13	Moran c.j.	Australia	Water resources management	8	89	11.13
14	Liu j.	China	Water-energy nexus	4	82	20.50
15	Wang j.	China	Water-energy nexus	6	80	13.33
16	Li x.	China	Water-energy nexus	4	77	19.25
17	Barrett d.	USA	Water resources management	4	74	18.50
18	Teodosiu c.	Romania	Membrane filtration	4	72	18.00
19	Sun y.	Hongkong	Bioeconomy	4	61	15.25
20	Tsang d.c.w.	Hongkong	Bioeconomy	4	61	15.25

[1]CPD= citations per document

The top 20 highly cited authors, as measured by Scopus citation in industrial water management research, are tabulated in Table 4.4. From screening the articles, it will be categorized as the sub-area that authors are interested in roughly four areas. Firstly, *water resource management* was mainly considered the water balance in the supply and demand side for utilizing water in industry efficiently and improvement of industrial effluent quality releasing to environment and water source of communities along with the sustainability measurement. Secondly, *membrane filtration* emphasized on the innovative technologies purifying in the wastewater treatment process and desalination in the water industry. Thirdly, the *water-energy nexus* or the relationship between how much water is used to generate the energy and how to use the energy efficiency in industry cycle and lastly, *bioeconomy*, which contains many pieces of knowledge about biofuels, bioenergy, biomass, biochar, and bioremediation. It is highlighted that the tendency of articles where authors have a high impact in industrial water management is still the development of environmentally friendly technologies stage with the expectation of solving the whole dilemma comprising of environment, social, and economic dimension.

To gain more insight into this knowledge, it can be seen that the most productive authors in this field include Li j. (10), Wang h. (9), Zhang y. (8), and Moran c.j. (8). As expected, the majority of scholars come from China, and the remaining country is Australia, where both are placed in the top 5 rankings of the most productive publications. They mainly researched in the water resource management area. Also, most citation scholars in industrial water management are Drioli e., Li z., Verstraete w., Li j., and Liu y. Interestingly, the Italian author is the highest author citation under the focal area, namely membrane filtration, whereas the researcher in Belgium, studying in the context of bioeconomy, is in the third rank of impact scholar.

Furthermore, when considered with author co-citation analysis (ACA), it is revealed that the most highly co-cited authors who either published outside of Scopus or in the area indirectly relevant to industrial water management are Wang, x., Hoekstra, a.y., Zhang, y. and Logan, b.e. The first three scholars in both China and Netherland, studied in water resource management, mainly the sustainable tool for evaluating the water use cycle in the industry. The last one who is interested in the bioeconomy comes from the United States. Plus, the scholars who are ranked in both high author citation and author co-citation lists, as symbolized the star in Table 4.5. It is shown a high scholarly impact, and again, the majority of the author is from China that focuses on the various topical areas, especially the water and energy nexus. Outstandingly, Wang, j. studied in the field, which combines computer science to facilitate the analysis of the water and energy flow in the industrial system and simulate the output to be a decision-maker of alternative scenarios.

Table 4.5 Rank order of the twenty most highly co-cited author in industrial water management

Rank	Author	Nation	Domain[1]	Topical focus	Co-Citations
1	Wang, x.	China	Env Sci	Sustainable water tool	201
2	Hoekstra, a.y.	Netherland	Env Sci	Sustainable water tool	187
3	*Zhang, y.	China	Env Sci	Sustainable water tool	181
3	Logan, b.e.	USA	Env Sci	Bioeconomy	181
4	*Liu, y.	China	Env Sci	Water resources management	178
5	*Wang, y.	China	Env Sci	Water-energy nexus	163
6	*Li, x.	China	Env Sci	Water-energy nexus	158
6	Li, y.	China	Env Sci	Water-energy nexus	158
7	Zhang, x.	China	Energy	Water-energy nexus	148
8	*Chen, y.	China	Env Sci	Water resources management	140
9	El-halwagi, m.m.	USA	ChE	Water resources management	138
10	*Wang, j.	China	Env Sci & Com Sci	Water-energy nexus	132
11	*Li, j.	China	Env Sci	Water resources management	131
12	Zhang, j.	China	Env Sci	Wastewater treatment	128
13	*Liu, j.	China	Env Sci	Water-energy nexus	123
14	*Drioli, e.	Italy	ChE	Membrane filtration	121
15	*Wang, h.	China	Env Sci	Bioeconomy	119
15	Elimelech, m.	USA	Env E	Membrane filtration	119
16	Zhang, l.	China	Env Sci	Wastewater treatment	105
16	Liu, h.	China	Env Sci	Bioeconomy	105
17	Wang, s.	China	Env Sci	Water resources management	95
18	Yang, j.	China	Env Sci	Water resources management	94
19	Wang, l.	China	Env Sci	Wastewater treatment	90
19	Verstraete, w.	Belgium	Env Sci	Bioeconomy	90
20	Chen, j.	China	Env Sci	Wastewater treatment	86

[1]Domains: Com Sci= Computer Science
*Determined that authors who also have the high author citation as shown in Table 4.4

4.1.2.3 Analysis of Influential Documents

The analysis of document citation relevant to the industrial water research has a similar investigated approach applied in authors. It is surprisingly the highly document citation that is not dominated by China where has numerous impact authors. Instead, the authors published those documents comes from Australia (1624), the United states (936), and Switzerland (537). Again, the most influential document is located in membrane technologies. If noticing the entire lists in Table 4.6, it can indicate the four types of documents, which mainly learned through reviews, followed by empirical papers, and had only a single paper classified as a perspective article and a conference paper. It could imply that the industrial water field is seeking the solution dealing with various aspects of stakeholders by attempting to improve the existing approach, and also some groups experiment with the innovative technologies aiming at achieving the sustainable goal.

Table 4.6 The twenty most highly-cited industrial water management ranked by Scopus citations

Rank	Documents	Type	Cited by
1	Le-clech p. (2006). Fouling in membrane bioreactors used in wastewater treatment	Review	1624
2	Logan b.e. (2012). Conversion of wastes into bioelectricity and chemicals by using microbial electrochemical technologies	Review	936
3	Comninellis c. (2008). Advanced oxidation processes for water treatment: Advances and trends for R&D	Perspective article	537
4	Morse g.k. (1998). Review: Phosphorus removal and recovery technologies	Review	385
5	Díaz s. (2018). Assessing nature's contributions to people: Recognizing culture, and diverse sources of knowledge, can improve assessments	Review	368
6	Meng f. (2017). Fouling in membrane bioreactors: An updated review	Review	308
7	Blackburn r.s. (2004). Natural polysaccharides and their interactions with dye molecules: Applications in effluent treatment	Conference paper	288
8	Giorno l. (2000). Biocatalytic membrane reactors: Applications and perspectives	Review	286
9	Carpenter a.w. (2015). Cellulose nanomaterials in water treatment technologies	Review	258
10	Guo h.c. (2001). Pollution control technologies for the treatment of palm oil mill effluent (POME) through end-of-pipe processes	Review	201
11	Wu t.y. (2010). A system dynamics approach for regional environmental planning and management: A study for the Lake Erhai Basin	Empirical paper	199
12	Medema w. (2008). From premise to practice: A critical assessment of integrated water resources management and adaptive management approaches in the water sector	Review	189
13	Valladares linares r. (2014). Forward osmosis niches in seawater desalination and wastewater reuse	Review	187
14	Pappu a. (2015). Advances in industrial prospective of cellulosic macromolecules enriched banana biofibre resources: A review	Review	184
15	Shen y. (2015). An overview of biogas production and utilization at full-scale wastewater treatment plants (WWTPS) in the United States: Challenges and opportunities towards energy-neutral WWTPS	Empirical paper	162

Table 4.6 The twenty most highly-cited industrial water management ranked by Scopus citations (cont.)

Rank	Documents	Type	Cited by
16	Behera m. (2010). Rice mill wastewater treatment in microbial fuel cells fabricated using proton exchange membrane and earthen pot at different pH	Empirical paper	157
16	Abma w.r. (2010). Upgrading of sewage treatment plant by sustainable and cost-effective separate treatment of industrial wastewater	Empirical paper	157
17	Van hulle s.w.h. (2007). Influence of temperature and pH on the kinetics of the Sharon nitritation process	Empirical paper	156
18	Grishkewich n. (2017). Recent advances in the application of cellulose nanocrystals	Review	150
19	Gude v.g. (2016). Desalination and sustainability - An appraisal and current perspective	Review	146
19	Bogardi j.j. (2012). Water security for a planet under pressure: Interconnected challenges of a changing world call for sustainable solutions	Review	146
20	Huang c. (2006). Electrodialysis with bipolar membranes for sustainable development	Review	145

In terms of the topical focus, the authors read these articles to narrow the scope and extend more detailed information in each sub-area (water resource management, membrane technologies, and bioeconomy). It is found that water resource management and membrane technologies are the most concerning topics among scholars. More specifically, water resource management in the database contains the two mains considered. The first one is the development of industrial ecology. It is a concept that utilizes the materials from a natural resource, industrial waste, and a by-product as an input into another process. Also, the transformation of the traditional process called linear to cyclical is implemented a completely closing loop system under the criteria of environmental impact and socio-economic barriers and challenges. Then, the second focus is the application of water and wastewater treatment in both manufacturing industries and water industries that need to meet the environmental policy, particularly in terms of physical and chemical properties testing in industrial effluent in order to reduce the water pollution. So, the water resource management associated with the industrial sector covers the industrial management and technology aspects.

For the membrane technologies, forward osmosis becomes a promising technology to alleviate the water sustainability issue leading to lower energy consumption and more sustainable fouling control in a dynamic process. However, it has a remarkable spot that the studies also find the new approach toward the integration of membrane filtration and biotechnology, which has the two concepts; firstly, the environmental remediation with membrane water filtration. These studies aim to be more purified industrial water collaborating with higher surface-area-to-volume of bionanomaterials, which causes lower environmental impact rather than the use of pure chemical reaction. The second concept is about water purification along with energy recovery and generation due to rapid industrialization, population growth, as well as energy- and cost-intensive from the development of technologies. Some studies delve into the experiment of the bioelectrochemical method supporting by a microbe in wastewater. Thus, standalone of membrane filtration and merging with other science branches are the technology solution to achieve the three elements of sustainability. In the view of bioeconomy, the papers focus on the efficiency of industrial waste use and by-product during wastewater treatment for conversion into bio-based energy via biochemical branch.

Next, the author employs the document co-citation analysis (DCA) that enable us to investigate and enhance the critical literature between documents in the Scopus database and broader literature not be located in the review database. So, the DCA is a useful bibliometric method since it provides a more extensive assessment of research influence than the limitation of the extent to only the Scopus index, and the result of the document list appears in Table 4.7.

It is represented that the number of document co-citation is relatively low. This can affirm that the works of literature have not developed in the vast number of scholarly impacts based on industrial water management scope. Several documents focus on two broader terms, including water management and membrane filtration, particularly forward osmosis. It is ensured the analysis of citation documents above that two focal areas have a strong influence and interest across the authors.

Table 4.7 The ranking of twenty most highly co-cited documents on industrial water management

Rank	Documents	Type	Co-Cites
1	Strathmann h. (2010). Electrodialysis, a mature technology with a multitude of new applications	Review	7
2	Cath t.y. & Elimelech m. (2006). Forward osmosis: Principles, applications, and recent developments	Review	6
3	Gregory, k.b.& Vidic, r.d. (2011). Water management challenges associated with the production of shale gas by hydraulic fracturing	Article	6
4	Hickenbottom, k.l. & Cath t.y. (2013). Forward osmosis treatment of drilling mud and fracturing wastewater from oil and gas operations	Article	6
5	Tan r. & Foo d.c. (2008). Synthesis of direct and indirect interplant water network	Article	5
6	El-halwagi m. (1992). Synthesis of reverse-osmosis networks for waste reduction	Article	5
7	El-halwagi m.m. (2012). Sustainable design through process integration: introduction to sustainability, sustainable design, and process integration	Book	5
8	Galan b. & Grossmann i.e. (1999). Optimization strategies for the design and synthesis of distributed wastewater	Article	5
9	Foo d.c., El-halwagi m.m.,Tan r. (2011). A superstructure optimization approach for membrane separation-based water regeneration network synthesis with detailed nonlinear mechanistic reverse osmosis model	Article	5
10	Langmuir i. (1918). The adsorption of gases on plane surfaces of glass, mica and platinum	Article	5
11	Tan r.r. & Foo d.c.y. (2009). A superstructure model for the synthesis of single-contaminant water networks with partitioning regenerator	Article	5
12	Tsiakis p. & Papageorgiou l.g. (1995). Optimal design of an electrodialysis brackish water desalination plant	Article	5
13	Yang l. & Grossmann i. (2014). Water network optimization with wastewater regeneration models	Article	5
14	Bagatin r. (2014). Conservation and improvements in water resource management: a global challenge	Article	4
15	Chisti y. (2007). Biodiesel from microalgae	Review	4
16	Coday b.d. & Cath t.y. (2014). The sweet spot of forward osmosis: treatment of produced water, drilling wastewater, and other complex and difficult liquid streams	Article	4
17	Cote c.m. & Moran c.j. (2010). Systems modelling for effective mine water management	Article	4
18	Foo d.c.y. (2009). State-of-the-art review of pinch analysis techniques for water network synthesis	Review	4
19	Gunson a.j. & Klein b.(2012). Reducing mine water requirements	Article	4
20	Hilson g. & Murck b. (2000). Sustainable development in the mining industry: clarifying the corporate perspective	Article	4

4.1.3 Intellectual Structure of the water management in industry

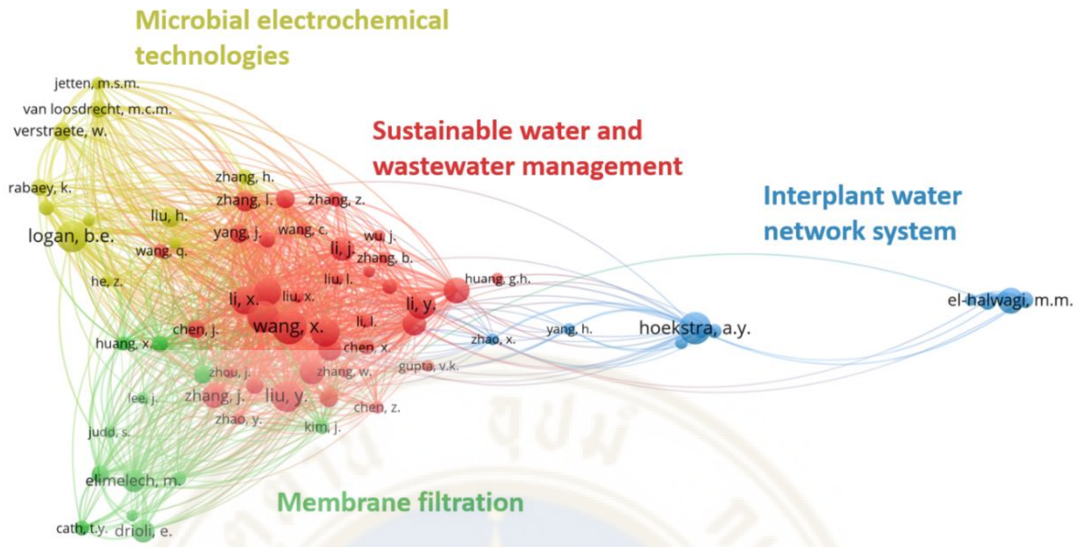

Figure 4.3 Author co-citation analysis of industrial water management, 1990-2020 (threshold 50 citations, displays 71 authors)

This part conducts author co-citation analysis (ACA), which has been popularly applied in science mapping. The use and analysis of the VOS viewer are not only able to calculate the author co-citation analysis but also create a visual mapping to represent the relation of authors based on their frequency of co-citation. The size of the node reflecting the number of author co-citation; the more significant node means they have higher co-citation and more substantial influence. Also, the proximity of each node indicates the level of intellectual affinity.

The result from the VOS viewer shows that a total of 66,680 authors contained in the reference list, and the minimum number of author co-citation is set to fifty co-citations per author, and seventy-one met a threshold. So, the yield of the author displayed in the map consists of seventy-one authors, and they will be four grouped into the colored clusters served as "School of Thought."

Figure 4.3 depicted that scholars are grouped into the four clusters depended on the context of similarity work, which is directly related to industrial water management. Cluster 1 is the most significant cluster in red color located in the center of the map, comprising of thirty-seven scholars associated with the *Sustainable water and wastewater management*. A majority of authors come from China. The leading scholars in this school of thought are Wang, x., Zhang, y., and Liu, y. These authors have reviewed and improved the overall industrial cycle toward the connection between water resource management and sustainability, such as the circular economy and sustainable water quality. Some scholars explored in a specific process, for example, the water treatment from the natural resource for supplying to the manufacturing industry and also the wastewater treatment to indicate the socio-economic outcome and environment effect for predicting the future consequence and suggestion to cope with. Lastly, seeking the new approach or framework by merging the water and energy flow in the industrial process aims at the less industrial water utility, higher energy recovery corresponds to reduce operating cost, and renewable energy employing some parts of the treatment process.

Cluster 2 in green color concerns with the *Membrane filtration*. There are twelve authors led by Drioli, e., Elimetech, m., and Fane, a.g.. This includes popular membrane filtration type that uses in wastewater treatment in industry depended on the pore size, substance filtrated through the membrane, equipment life, energy consumption, and cost. (e.g., nanofiltration (NF), ultraviolet filtration (UF), forward osmosis (FO)) It aims to improve the water quality of both the on-going process and industrial effluent to external sources. Besides, the authors have figured out the reduction of energy use in industry and implement the alternative energy, leading to decrease the greenhouse gas emission and save the cost of production.

Cluster 3 is in yellow located on the top-right region of the network visualization map. The dominant authors who have more than one hundred co-citations are Logan, b.e. and Liu, h. The studies of the scholars in this cluster mainly focus on the *Microbial electrochemical technologies*, pointing out a single type of technology called microbial fuel cell system. This system allows the oxidation of organic and some inorganic substance through the catalytic activity of microbe, also known as the bioelectrochemical approach, to generate the electricity during the wastewater treatment. Thus, the combination of three science subjects (biology, electricity, and chemistry) creates the novel platform to wastewater process; as a result, energy, water, and nutrient recovery together with water quality improvement within a single system.

Scholars categorized in Cluster 4 (blue color), led by Hoekstray, a.y. and El-halwagi, m.m. relevant to the *Interplant water network system*. Among two scholars, Hoekstray, a.y. is a leading researcher emphasizing the application of water footprint and sustainable water tool to evaluate the system. El-halwagi, m.m. develops the sustainable design of the industrial system through process integration of water and energy to optimize the energy and water consumption, leading to minimizing the operating cost and thereby improving overall sustainability.

4.1.4 Topical Foci of the industrial water management knowledge base

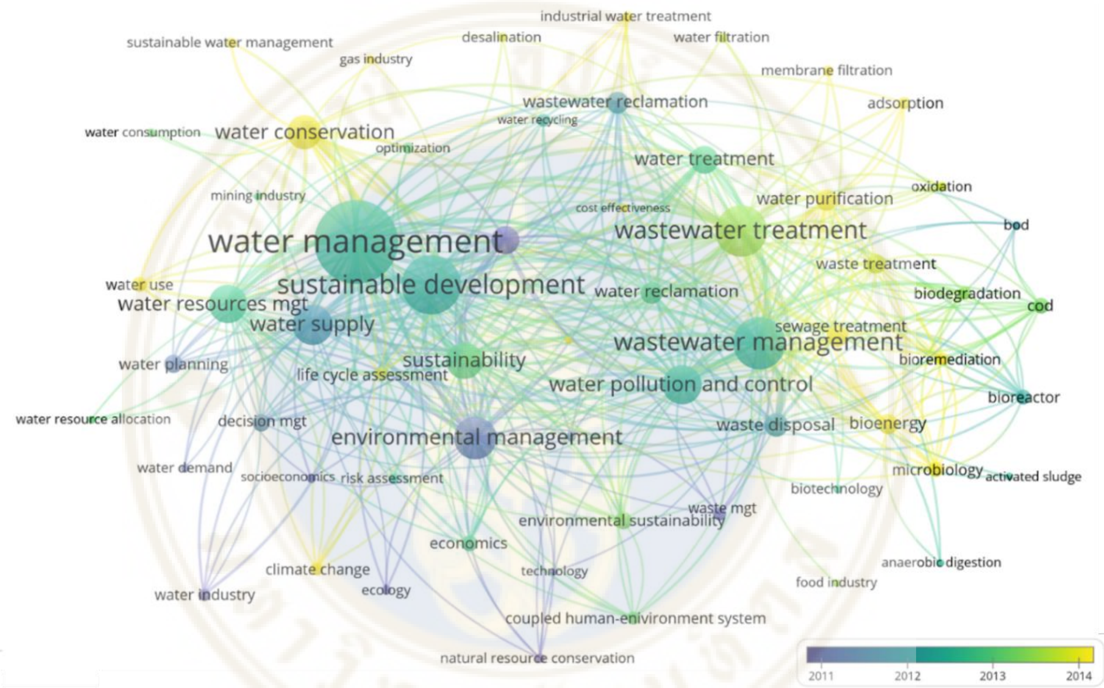

Figure 4.4 Temporal overlay on a keyword co-word occurrence map for industrial water management documents published from 1990-2020 (threshold 30 co-occurrences, display 61 keywords)

The last section of bibliometric analysis addresses a keyword co-occurrence analysis or co-word analysis to identify the topical trends in industrial water management. The size of the circle represents the occurrence numbers of each keyword, and the curve is the relationship between the keywords, which means the closer proximity of the circle, the more relevant the keywords. Then, the color of temporal nodes indicates the recency of the different keywords to determine the hot topic or the "research front" in the industrial water management literature. So, the keyword node displayed the yellow or bright green color appears as the most recent time of review.

In this analysis, the VOS viewer is set co-occurrence keyword threshold of a least thirty cases and yielded a sixty-one-keyword illustrated on the temporal overlay map (Figure 4.4). It is found that the most frequent keywords were water management (654), sustainable development (419), wastewater management (352), wastewater treatment (343), environmental management (275), water supply (248), water pollution and control (245), water resource management (238), sustainability (220), and water conservation (202). Thus, this gives the boarder concept of industrial water that concern about the impact on the environment dimension followed by the social aspects of water use balance.

Based on the co-word map, the most studies keyword, from past until 2012, is mainly concern under the scope of the water accessibility and water quality with the clarifying question of "How do we supply safe water to everywhere?"

Then, between 2012 and 2013, as shown the green to dark green nodes, the keyword added from the past few years is about wastewater management as well as the water pollution and control of the manufacturing industry. So, the topic of this period associates with the water and wastewater management in order to solve the question of "How do we eliminate the industrial wastewater efficiently along with minimizing health and environmental harm surrounding industry?" They tried to improve and expand the idea of a coupled human-environment system and apply it to the industry business by promoting the two-issues related to social and environmental perspectives.

For the light green nodes located during 2013-2014, it is found that employing technologies are playing an essential role in seeking a suitable solution to the industrial activities as well as the financial problem. The example of keywords contains water filtration, desalination, waste treatment, wastewater treatment, membrane filtration, and cost-effectiveness. These keywords are grouped into the topic called the implementation of new water technology relevant to operating cost efficiency under the question of "How do we develop the technologies (e.g., membrane filters) to remove tiny suspended particles from water effluent together with the efficient allocation of the cost?"

Next, the keywords (2014 onward) displayed yellow color, consist of water purification, bioenergy, bioremediation, microbiology, life cycle assessment, water conservation, and climate change. It is reflected that this period attempted to apply and adapt the sustainable industrial water management aspects to proper each type of industry. Besides, the integration between biology and the existing system becomes an attractive alternative for environmental protection, energy recovery during the process; as a consequence, these advanced technologies probably answer covering the triple bottom line or three elements in sustainability. Therefore, this topical trend from visualizing the VOS viewer illustrates the global evolution of industrial water management, as summarized in Figure 4.5 below.

Figure 4.5 The global trend or the evolution of the research front in industrial water management

4.1.5 Conclusion of comparison between four foreign countries and Thailand

To answer research question 1 (RQ1), the previous bibliometric analysis with the assistance of the VOS viewer and will be summarized in the Table 4.8 below. The top 4 productive countries, including the United States, China, India, and United Kingdom, have the same goal, which is sustainable industrial water management, to improve the water quality with the concern about the triple bottom line. In China, it is found that the number of both productivity and citation is numerous, and it is interesting that they have many outstanding researchers covering all aspects of water in industry, such as water resource management, water-energy nexus, membrane filtration, and bioeconomy. This means that they tend to study every area from water use efficiency, water quality, to energy use efficiency over the prior period. Until now, they are trying to develop and merge water and energy flow in the industrial system. The reason behind that there were increase publications considerately in China due to government support on investment of research and development, particularly innovative.

The tendency of the United States emphasizes on two areas, which are water resource management framework and adoption of member filtration technologies, respectively. This can imply that they study in the use of water resources first and then try to use technologies to improve water quality. Even though other two countries, including India and the United Kingdom, have high productivity but less citation or impact on industrial water management literature, from country analysis, it is found that India experiment and develop the wastewater treatment technologies to purify the industrial wastewater following by integrating the water and energy generation. This has the same direction as China's current situation. For the United Kingdom, they have a similar development of industrial water management to the United States that is water use and water quality; however, the researchers and industries in Thailand mainly focus on the efficiency of water use throughout the years and a bit concern about the energy with water.

It is indicated that the productive foreign countries have a considerable resource to invest and develop research on innovative technologies and industrial water framework in industry efficiently, along with many researchers studying in water resource management, leading to building a stable and robust base from downstream to upstream of industrial ecology.

Table 4.8 Comparison between four productive foreign countries and Thailand on industrial water management

Countries	Industrial water management focuses on		
United State	**Water use:** water resource management	**Water quality:** member filtration technologies	**Water and energy:** bioeconomy
China	**Water use:** water resource management	**Water quality:** member filtration technologies	**Water and energy:** water-energy nexus, bioeconomy
India	**Water use:** water resource management	**Water quality:** wastewater treatment technologies	**Water and energy:** integration of the water and energy flow
United Kingdom	**Water use:** water resource management	**Water quality:** wastewater treatment technologies	
Thailand	**Water use:** water resource management		**Water and energy:** implement of the water and energy flow

4.1.6 Current situation of industrial water management in Thailand through supporting from an interview

To answer research question 2 (RQ2), the publications of industrial water management in Thailand are not pervasive, which still lacks information about the current situation. The researcher needs to gain more insight through the interview as supporting evidence to the bibliometric analysis. Thereby, this part contains a brief background of interviewees and then the content analysis reflecting the interviewee's perspectives on current circumstances in Thailand.

4.1.6.1 Interviewee demographic information

A total of ten semi-interviewees participated in the interview covering the current situation and future of industrial water management in Thailand with different dimensions of current internal aspects in the manufacturing industry and external driving forces shaping the next five years. The background of the interviewees who have experienced in the medium and large private companies and state-owned enterprises in Thailand is shown in Table 4.9. The category or criteria of participants have three groups; working background or the job title, employee position level in the company, and year working and experiencing relevant to water management in the industry. Seventy percent of participants work at management level (seven people), and the rest of them (30%) is the experts in water and environment area including environmental engineer, environmental officer, and two environmentalists. The 3-10 years' working experience has two people (20%). In participants who have worked more than eleven-year experience (80%), four of them have 11-20 years' experience, and the remaining is more than twenty years' experience.

Table 4.9 Background information on eleven participant interviewees

Category	Classification	Number
Working background	Business owner	1
	Environmental project manager	1
	Technical engineering manager	1
	Utility engineering manager	1
	General manager	2
	Environmental engineer	1
	Environmental officer	1
	Environmentalist	2
Position level	Top management	1
	Management	5
	Senior specialist	4
Year of experience	3-10 years	2
	11-20 years	4
	More than 20 years	4

4.1.6.2 Content analysis of current industrial water management in Thailand

From the trend analysis of Thailand industrial water management via bibliometric analysis, the researches, manufacturing industries, and government sectors pay attention to the efficiency of water use with promoting the environmental awareness of wastewater effluent throughout the years. It is a good sign of the Thailand industry. However, the improvement of water quality is still less motivation and engagement among government and industries. So, it can be one of the reasons that the SDG 6 index of wastewater received treatment illustrates the orange color, which needs to improve in the future. Since the current publications on industrial water literature in Thailand have a minimal amount, the author used the evidence from perspectives of the ten experienced interviewees to support and gain more aspects concerning the current situation of industrial water management in Thailand below and are summarized in the Table 4.10.

1) Manufacturing process

Currently, the manufacturing process manages under the concept of resource efficiency. The resources mostly encompass raw materials and energy. Thai industries evaluate resource consumption and attempt to use both raw materials and energy efficiency, along with the consideration of water utility during the process. Around sixty percent of interviewees express that the industries implement the partial recycling process by using the output waste and wastewater to minimize the losses and reduce the raw material cost. The two managers in the large industries explained that the companies have research and development where they can experiment and develop their wastewater treatment process corresponding to facilitating other production units. For example, the team can increase water quality along with produce the energy based on the biological approach or called bioenergy as an alternative energy source and can save the operating cost. At the same time, one of the medium industries employs solar cells to save energy usage under the criteria of the cost and ease of use.

However, there are two significant barriers claimed by eight interviewees. First, the improper allocation of the wastewater treatment areas is related to the existing engineering design process and inefficient space utilization leading to operating inefficiency, higher energy consumption, and lose space to build or expand other production units. The second thing is the utility cost that mainly comes from the electricity cost during operation. Furthermore, six interviewees concern the sludge and waste releasing after treated wastewater. The industries seek the solution to generate income from the waste instead of landfill or discharging into the environment, leading to ecosystem destruction.

2) Wastewater treatment technologies

In Thailand, most of the industries supply the wastewater treatment technologies from aboard through the suggestion of suppliers to find the low cost but highly efficient technologies as well as facilitate the installation and after service when the problem occurs. Generally, if the industries need to enhance water quality with high filtration technologies, the investment cost is high as well. This is the obstacle among enterprises that want to take the response to environmental protection, claimed by the manager and business owner. Then, two senior environmental experts said that "In the large companies, they have wastewater specialists that can understand and select suitable technologies for process purposes while the medium enterprises lack the employees who experience in this area. So, this causes a loss of opportunity to grow in the industry sector."

3) Awareness

Awareness comprises both environmental and social aspects. People's minds, beliefs, and experiences are significant factors to increase awareness. Interviewees said that the group of those people was classified into two groups: direct and indirect stakeholders. The direct group, in terms of role relevant to industrial activities, is the one who causes the environmental impact, such as the entrepreneurs who have the manufacturing industries located in the industrial estate and the outside or remote area, the top management team in large companies as well. They are the head to drive the strategic planning and encourage the others through vision and policy. The second group is the communities living around factories. Some Thai entrepreneurs or top management do not recognize that water management and treatment are a vital part of maximizing the profit. This process still available but is ignored by the authority. When untreated effluent or landfill, the communities nearby receive the harmful effect and protest the industries later. The solution is negotiation and compensation. This case happens in a remote area, and the chaos cycle reiterates over time; as a result, the responsibility and awareness of social and environmental impacts when mismanaging the industrial wastewater effluent is fading away.

4) Knowledge management

The knowledge management is relevant to share and understand among employees and community nearby about the industrial water management containing the use of treatment technology, wastewater reclamation process, cost of wastewater treatment, and the harmful effect for water mismanagement. Seven interviewees agree that this topic is the problem, whether it be in medium or large companies, and need to find the solution for employees at any level as well as the way to communicate appropriately to the community surrounding the industry. Besides, it is found that one of the causes why employees lack the knowledge, is related to the top management vision. The environmentalists and engineering managers emphasize that when the entrepreneur and some top management do not have the awareness and responsibility of water treatment, the manufacturing workers behave like father like son, leading to neglecting and focusing only their physical needs. As a consequence, there is no encouragement from the top; there is no staff training related to water topics. The workers lack the knowledge and understanding of industrial laws and the right procedure matching with suitable technologies.

5) Law and regulation

Five people gave the same opinion that Thai law and regulation less strict. It is not affordable for the government officers to punish those disobeyed the law. Plus, the officers cannot monitor and control the manufacturing process and facilities of the factories located outside the industrial estate area. One of those interviewees provides the reason that Thai law and regulation compromise many factories located outside the industrial estate. He said, "to make the law stricter; it needs to have a clear and strict penalty for manufacturers and the reason behind links to government attention level of environment problem that this sector gives priority to environmental issues or not. Also, some Thai people still believe in the traditional statement that Thailand is country rich in natural resources. This may cause Thai to neglect environmental awareness, whereas the factories consider that profit maximization is the first essential goal rather than achieve in the social and environmental outcomes." One of the interviewees states that the less attention of the government sector, the less power and strictness of law, leading to less environmental awareness among people.

Incredibly, in the private sector side, the manufacturing industries located in industrial estate obey the law and realize the water effluent quality standard and installation of wastewater treatment unit properly. They collaborate with outsources experienced in water quality and control to adopt the Internet of Thing (IoT) system. This allows them to monitor real-time processing in order to control and evaluate the water flow, volume, and organic and inorganic concentrate solute in water. Once the water effluent quality does not meet the standard range, they can detect the cause of the problem more accurately. Thus, it can be said that currently, the private sector drives industrial water management in Thailand.

6) Government support

Two out of ten interviewees claim that it might be related to the indetermination of national plan and roadmap. Even though this sector attempt to promote a sustainable way for the industrial process, many industries are not able to respond to that system since some industries lack capital investment. So, industries need supporting investment from the government sector.

Table 4.10 The current problems of industrial water management in Thailand through SWOT analysis

Strengths	Weaknesses
Manufacturing process -Large industries have an efficiency of water use and reuse. -The water effluent from large industries meets the standard quality due to investment in research and development. -Both medium and large industries employ alternative energy (e.g., solar energy and bioenergy) to save energy and utility costs. -Implement the partial wastewater recycling system in the process. Awareness -Top management in large companies pays attention to supporting water management, leading to a gain in innovative technologies and updated information relevant to water in industry.	Manufacturing process -Improper allocation of the wastewater treatment areas Wastewater treatment technologies -Entrepreneurs have insufficient investment costs in technologies. -Lack of experts specialized in the wastewater treatment areas in Thailand. -Medium enterprises lack the know-how of the selection of appropriate technologies with process purposes. Awareness -Some Thai entrepreneurs do not have both awareness and responsibility for social and environmental impacts. -Other departments perceive the wastewater treatment does not generate profit for the company.

Table 4.10 The current problems of industrial water management in Thailand through SWOT analysis (cont.)

Strengths	Weaknesses
	Knowledge management -Employees and working staffs do not understand the industrial laws and how to act the proper implementation.
Opportunities	**Threats**
Wastewater treatment technologies -Supply the new wastewater technologies from abroad, such as membrane filtration. -Outsources in Thailand have experience in water and wastewater treatment. Government support -Ministry of Industry introduces the sustainable method, including 3R and circular economy.	Awareness -Communities surrounding the factories have less awareness of social and environmental impacts. Law and regulation -Thai law and regulation are less strict. -Government officers are unable to monitor and control the factories located outside the industrial estate area. Government support -Lack of support for investment from the government sector.

In conclusion, the six key elements influence on industrial water management. The manufacturing process is the most considering item located in the strengths more than weakness. It is indicated that Thailand is in the implementing stage of sustainable water management by adopting water reuse, water recycling, and energy conservation through alternative energy; however, the existing wastewater treatment sites are not effective space use. Then, the wastewater treatment technologies emphasize on the appropriation of selecting technologies' purpose and their investment cost. They are decided in the weak part of water management while the industry gains opportunities from suppliers and outsourcing services to facilitate the plant. The next element, namely awareness appearing in strength, weakness, and threat, is related to the mindset of the top management team, entrepreneur, working staff, and community nearby. Without awareness, knowledge management will be a pin in weakness. Besides, the law and regulation locate in threats that need to improve the level of strictness and determination of government officers. Even though the government support promoting the sustainable water approach, it requires a considerable cost of investment that some industries lose the opportunity due to instability finance. Therefore, the six key elements represent the reason why the water quality is missing part as compared with other countries, and it corresponds to the assessment of SDG 6 in the part of water quality shown in red color.

4.2 Future trend in industrial water management in Thailand

This section uses the horizontal scanning with PESTEL analysis as a tool to categorize and describe the macro-level factors relevant to the next five years of industrial water management in Thailand from the interview. These driving forces are external factors shaping the futures industry. Then, the authors explain the internals factors referring to eleven interviewees who have lots of experience in this field. After analyzing both external and internal factors, the authors use the SWOT analysis for developing the strategy in the next section.

4.2.1 The overview of future water management in the Thailand manufacturing industry

From the interview of the future change in industrial water management, it can divide the opinions into two sides: 55% of interviewees said, "There is not much change," and 45% of them express that "It will be better." For the reason of the first group mostly, they claim that many factories and entrepreneurs still lack the motivation from the government sector to raise awareness of water use and treatment. Instead, the large private company will become the pioneer driver to bring the novel solution to figure out how to minimize the investment cost and enhance operational efficiency, which includes water use, water quality, and energy consumption. Even though supplying the new technologies from abroad is suggested to employ in the industrial process, these technologies are still expensive for medium industries, and some technologies may not correspond to the Thai working lifestyle in the province area.

Conversely, another group answers against that in the next five years, Thai people will significantly increase environmental awareness together with the government sector will issue the strict laws covering both capital, industrial activities, and environmental issues. Also, the population growth and consumption will increase as well as the company will be able to develop its technologies that meet the criteria, such as the ease of use and operational cost reduction. As a result, it will encourage many entrepreneurs to build factories in the future.

When analysis of the trend and opinion of interviewees, it can estimate that the stakeholders related to shaping the future are separated into two groups. The first group is called insiders, including the working staff operating in the factory and the research and development department. The second group refers to outsiders, such as the government sector relevant to law and regulation, suppliers who bring the new wastewater treatment technologies into the market, community living nearby factories, entrepreneurs, and demands who consume the product from the manufacturing industry. It is noticed that the insider group or internal factor is one of the barriers to limit the future change, while the outsiders or external factors are the opportunities to improve and drive the future of the industrial water management. Interestingly, the government sector is located in both barriers and opportunities from the Thai interviewee's perspective. Therefore, this part will be a guideline in further PESTEL and SWOT analysis.

4.2.2 Potential driving forces of future

This part will explore the entire possible factors impacting on the future of industrial water management in Thailand through interview. Then, they will be categorized into horizontal scanning, wildcard analysis, and internal factors.

4.2.2.1 Horizontal scanning or PESTEL analysis

1) Political dimension

The political dimension in the next five years can be separated into two issues. The first issue, called policy and national strategic planning, has two aspects. The industrial promotion policy will be added to the topic covering all aspects of environmental awareness and responsibility among industries located in everywhere, said by three participants. That causes the demand for wastewater management in

Thailand industry is growing and will become an inevitable process in the industry. Besides, one general manager gives the opinion that in the future, the philosophy of sufficiency economy belonging to Majesty King Bhumibol Adulyadej will be promoted as a national strategic planning to raise the virtuous among Thai people again. The middle path will be a guideline to increase the ethical and innovative solution, such as less dependence of foreign chemical substance and the increase in recycling the waste output from the industry by ourselves. These are the resilience in the philosophical framework. Meanwhile, another aspect expresses that the policy or strategic planning will continuously focus on other segments, such as national health, transportation in airlines, and national defense. This will reduce the motivation of manufacturers to develop and invest in the environmental dimension.

Nine out of eleven interviewees have an agreeable view of political instability. It can affect other dimensions. For instance, the production capacity in the industry will decrease or stop; as a consequence, the export receives an adverse impact. At the same time, the currency will fluctuate due to the uncertainty of politics, leading to economic contraction. Investors and entrepreneurs will be less confident to invest and be challenging to negotiate. Thus, people focus on survival in the economic and political dilemma. This makes less responsibility for the environment and decreases in the demand for wastewater treatment in the industry.

2) Economic dimension

The consequence of better policy and strategic planning above will encourage many manufacturing industries to construct the wastewater treatment area and consider industrial water quality standards, leading to an increase in fair competition in the market. The meaning of fair competition is that every manufacturing industry has the wastewater treatment process, which is the cost of the product as claimed by two interviewees. Plus, almost all participants (eight people) explain that the future interest of value-added waste remaining from industry will be higher by recycling and transforming the characteristic of waste products, causing an increase in the revenue of the industry. Then, the rise of globalization and industrialization will facilitate many manufacturers to supply the machine and chemical substances from overseas easily; however, when the demand for water quality improvement grows, in the supply side, the cost of utility expense and chemicals purified wastewater will increase together with the tax rate, exchange rate, and inflation changes over a period, said by general managers.

3) Social dimension

In the future, the impact of growth in population density and resource consumption will make the amount of industrial wastewater effluent increase, which needs the water management more to proceed and control in the process. In contrast, an environmentalist and an engineer illustrate that the limited wastewater treatment location and area are still a problem that cannot support this contaminated water. Also, the wastewater storage has a limit of the capacity level. So, this untreated water will release improperly and harm to the natural water resource. Then, it will contaminate the main river using by communities in that area, leading to health issues. Another aspect is that there will have two groups of people. The first group is a negative side, including the local communities and city people. Seven participants agree that the communities in rural areas who believe in the natural spirit will gather and ban the construction of wastewater treatment plants.

In contrast, some city people's minds will refuse the treated water even though the water quality standard the same as drinking water. However, two interviewees reveal that the trend of environmental conservation will be more influential among entrepreneurs and consumers. These group will act the role play as inspectors to monitor the activity of each industrial activity that take responsibility for the environment or not.

4) Technological dimension

It is revealed that many industries will import and adopt a higher amount of water treatment technologies from abroad with the expectation that can save the investment cost and operation cost, including minimizing the use of chemicals treated and the heat circulated in the industrial system. Besides, three people said that these technologies would be able to operate the two tasks, comprising water purification and alternative energy generation within a single system. Notably, it will rise in the new research and development of solar energy and bioenergy toward the wastewater treatment process. In other words, many Thai researchers and educations are going to experiment and produce innovative technologies to face the manufacturing challenges in the Thailand industry. One general manager claims that since the environmentally friendly trend will increase among consumers, the use of green technologies in the industrial process will be one of consumer decision making when buying the products, and, in other aspects, it is relevant to water use efficiency. Two interviewees express that in the future, when the law accord with the water technologies, the industrial water cycle system in the industry will be able to utterly close in a single loop, which means the water can flow with zero leaking. The wastewater can recirculate into wastewater treatment to become treated water input with zero untreated discharge to the surrounding industry. Three engineering managers said that in terms of sludge, the chemical property, including organic and inorganic matters, will play a critical role in research and development to increase the value and reduce waste effluent.

5) Environmental dimension

The next five years of natural water resources will be better in terms of less harmful environment and biodiversity in animals toward an increase in the corporate social responsibility (CSR) of private sectors in Thailand. It is the correlations between social aspects (e.g., local communities and private companies) and environmental aspects (e.g., forest, soil, river, and natural reservoir). So, people will recognize the environment recovery as the most critical topic when doing industrial activities, leading to an increase in bioremediation in the future, said by two interviewees. Furthermore, when linking to economic aspects that are the growth of consumption, the pollution among water and air increases significantly also. This worst scenario will be massive pressure on the government for prioritization of environmental issues to encourage more and support the industrial wastewater treatment. Plus, the government will release the plan of water management to improve covering three segments, such as residential, agricultural, and industrial sectors. For climate change and natural disasters, they are unpredictable but probably to occur in the future. Three participants explain that these events will affect the water supply fluctuation and damage to infrastructure. So, this will link to the aspects of technology that the research and development in some private companies where increase the plan to prepare and control working efficiently as well as the system design that needs to consider the dynamic change of temperature to deal with the uncertainty. With the trend of drought more severe every year, many entrepreneurs will focus on bringing the treated wastewater to use in industrial activities and also purifying seawater through the desalination as water input will increase. So, the environmental change is one of the motivations among the manufacturing industries to develop and employ the new system and technologies.

6) Legal dimension

Owing to the rise in the trend of environmental protection, the law, and regulation in Thailand will be up to date and adjusted following the global and developed countries with the expectation of five participants. Nevertheless, the other six oppositions explain that the law will not correspond to the development of water technologies because Thai research and development fall behind compared with other countries. Also, Thai people will resist to the new transformation of technologies. Although the law enforcement of the Department of Industrial Works, Pollution Control Department, and the international law will become strict about covering the manufacturers, government officers, and foreign investors, they are many sectors relevant to water management. This causes the redundancy by the law of factory audit that will increase and have more complexity, leading to higher operating costs and confusing to practice following the law.

Table 4.11 Driving forces shaping the future of industrial water management for eleven interviewees

Driving forces	Type
Political instability	Political
The policy of industrial promotion on environmental awareness and responsibility	Political
Philosophy of sufficiency economy	Political
Government emphasis on other sectors; national health, transportation in the airline, and national defense	Political
Increase in fair competition among manufacturing industries	Economic
Increase in the trend of value-added waste products	Economic
Easy to supply machines and chemical substances due to globalization	Economic
Increase the cost of utility and chemical substances	Economic
Change in the tax rate, exchange rate, and inflation	Economic

Table 4.11 Driving forces shaping the future of industrial water management for eleven interviewees (cont.)

Driving forces	Type
Growth in population density and resource consumption	Social
Limited wastewater treatment location and area	Social
Local communities banned and city people refused	Social
Increase in the trend of environmental conservation from the new generation	Social
Adopt the technologies from abroad	Technological
Development of integrated water and energy technologies	Technological
Bring and improve the industrial water system from foreign counties	Technological
Increase in bioremediation	Environmental
Water management plan covering household, agriculture, and industry	Environmental
Climate change and natural disaster	Environmental
Updated law and regulation	Legal
Law is not corresponding to the use of technologies	Legal
More strict laws	Legal
Redundancy by the law of factory audit	Legal

4.2.2.2 Wildcard analysis

This part will do the content analysis to digest what kind of situation that manufacturing industries predict to less happen but have a significant impact on their water management. It is found that situations can divide into three categories. First, during the operating process in the industry, three interviewees have a similar opinion that the sudden change in ingredient quality and quantity as a requirement of food standards and fluctuating consumer preference. Even it will have a small chance to occur, the impact on wastewater treatment is enormous because when designing the process, we need to consider the entire of solid, liquid, gas flow from the input, process until output along with measurement and control of temperature, pressure, acidity, and chemical stability in a particular condition. One manager explained, "As known, the wastewater treatment is the last area receiving the output of each unit. If the amount of waste excesses the capacity level and the concentrate of chemical is over the condition, the system cannot hold for a while, and finally, it needs to shut down all the processes in the plant. It effects on supply chain and our finance." The second situation refers to the rapid change in the law and regulation that forces all industries to follow and act immediately. Inevitably, the last situation relevant to the spread of severe and new diseases across countries, and four interviewees think about the second round of coronavirus will happen soon. It has a dreadful consequence in every part of the manufacturing industry, government sector, and other stakeholders relevant. The factories need to stop working, and some workers are laid off due to poor financial performance, for example.

4.2.2.3 Internal factors

From the interviewee's perspective and the content analysis, it is found that there are five critical topics concerning. The first internal factor is related to the industrial process, as claimed by three interviewees. In the next five years, the process will implement efficiently under the concept of the green economy where have the appropriate tools for manufacturing industries, such as environmental assessment, social impact assessment, and green procurement standard. Besides, the large industries will bring the new approach and system that can reuse and recycle the wastewater output to use the water efficiently. Also, the process will segregate the waste out of the water line before delivering to the treatment pond to minimize the organic matter in the wastewater, leading to reducing the chemical use. So, the number of chemical substances purified the wastewater will be used at a smaller level to protect the environment indirectly. For waste, the wastewater system will be able to handle certain types of waste or excess capacity, as resulting in reducing dispose of in that outside area. However, it will have a few sludge that cannot be recycled at all because of their chemical property, which must be sent to the burner. Thus, the industrial process will seek the way of resource efficiency or closing the industry cycle.

The second factor is the technologies for treating water, as explained by four participants. They will focus on the biochemistry integrated with alternative energy to reduce the cost and improve water quality. Therefore, the third factor is the utility cost during operation, particularly electricity cost. Many industries will find a solution to increase productivity while saving energy with renewable energy technologies. Next, the two managers said that the employees as critical internal factors to drive the industry are talked about two levels of position. The staff who design the process and control will develop the process flow design by considering the environmental and social impact, which means they will be able to increase the awareness and responsibilities based on the triple bottom line. However, the working staffs who control and check the real-time process in plants still lack knowledge and understanding about the awareness of the environment and society. Lastly, the location and area will be the problem of how to select a proper place with following the law and regulation. Also, it is relevant to the size of the wastewater treatment area where will use ample space as claimed by three participants.

4.2.3 SWOT analysis

After analysis of both external and internal factors, this part will conduct the IFE and EFE matrix by discussing and scoring from interviewees, as tabulated and calculated in the Table 4.12 and Table 4.13 below.

Table 4.12 The internal factor evaluation matrix of the industrial water management in the next five years through the interviewees scoring

IFE Matrix			
Strengths	**Weight**	**Rating**	**Weighted score**
S1: The process will implement efficiently under the concept of a green economy.	0.04	3	0.12
S2: Increase in the development of integrated water and energy technologies in large industries.	0.08	4	0.32
S3: The large industries will bring and improve the industrial water system from foreign counties.	0.06	3	0.18
S4: Many industries segregate waste before the wastewater treatment process.	0.05	3	0.15
S5: Increase in the research of recycling the sludge output efficiently.	0.15	4	0.60
S6: Combine biochemical technologies with alternative energy to reduce the use of synthetic chemicals.	0.04	3	0.12

Table 4.12 The internal factor evaluation matrix of the industrial water management in the next five years through the interviewees scoring (cont.)

IFE Matrix				
Strengths	**Weight**	**Rating**	**Weighted score**	
S7: Percentage of utility cost saving will increase.	0.16	4	0.64	
Weaknesses	**Weight**	**Rating**	**Weighted score**	
W1: The process is not able to utterly close the loop. It still has a bit amount of unwanted output releasing to nature.	0.10	1	0.10	
W2: The working staffs lack the knowledge and understanding about awareness of the environment and society.	0.07	1	0.07	
W3: The new technologies will be expensive and not affordable for medium industries.	0.14	1	0.14	
W4: Staff does not know how to select the proper location for wastewater treatment.	0.04	2	0.08	
W5: The size of the wastewater treatment unit is vast.	0.02	2	0.04	
W6: The law and regulation still hard to understand among many industries.	0.05	2	0.10	
Total	1.0		**2.66**	**=Total IFE weighted score**

Table 4.13 The external factor evaluation matrix of the industrial water management in the next five years through the interviewees scoring

EFE Matrix			
Opportunities	**Weight**	**Rating**	**Weighted score**
O1: The policy of industrial promotion adds environmental awareness and responsibility.	0.06	3	0.18
O2: Strategy planning applies the philosophy of sufficiency economy.	0.02	1	0.02
O3: Increase in fair competition among manufacturing industries.	0.04	2	0.08
O4: Increase in the trend of value-added waste products.	0.10	4	0.40
O5: the machines and chemical substances easily supply due to globalization.	0.03	2	0.06
O6: Increase in the trend of environmental conservation from the new generation.	0.05	3	0.15

Table 4.13 The external factor evaluation matrix of the industrial water management in the next five years through the interviewees scoring (cont.)

EFE Matrix			
Opportunities	**Weight**	**Rating**	**Weighted score**
O7: Increase in the trend of bioremediation.	0.02	1	0.02
O8: Government has a water management plan covering household, agriculture, and industry.	0.03	2	0.06
O9: Law is stricter about controlling water effluent quality standards.	0.14	4	0.56
O10: Updated law and regulation aligning with developed countries.	0.08	4	0.32
Threats	**Weight**	**Rating**	**Weighted score**
T1: Political instability.	0.05	3	0.15
T2: Government emphasis on other sectors; national health, transportation in the airline, and national defense.	0.03	1	0.03
T3: Change in the tax rate, exchange rate, and inflation.	0.05	4	0.20
T4: Growth in population density and resource consumption.	0.02	1	0.02
T5: It has limited wastewater collection and treatment location and area.	0.04	3	0.12
T6: Local communities ban the construction, and city people refuse to drink treated water.	0.04	3	0.12
T7: Climate change and natural disaster.	0.02	2	0.04
T8: Law is not corresponding to the use of some technologies.	0.08	4	0.32
T9: Redundancy by the law of factory audit.	0.10	4	0.40
Total	1.0		**3.25**

= Total EFE weighted score

A total of 13 internal strengths and weaknesses were weighted for the IFEM. The weight assigned for seven strengths ranging between 0.04 and 0.16. The increase in the percentage of utility cost-saving received the highest priority and followed by the research on recycling the sludge output (0.15). This expected priority of future water management referred to the integration of water, waste, and energy to save water, save operation costs, reducing waste, and adding the waste value. Conversely, six weaknesses had weight ranges between 0.02 and 0.14. The maximum weight is provided to expensive new technologies and unaffordable for medium-sized industries. If considering the elements given as one rate, interviewees believe that the weaknesses in Thailand industries are still the inability to purchase the new water technologies among medium-sized entrepreneurs or lack of capital investment. This will cause inefficiency in the closing system due to the unavailable technologies. Interestingly, lack of knowledge and understanding about the environment and social awareness continuously embed among staff as given in the third place of weaknesses. The total weighted rate of IFEM was 2.66, as summarized in the Table 4.12.

EFEM, shown in Table 4.13, contains nineteen external opportunities and threats. Among them, ten driving forces were opportunities, and nine barriers were threats. The weighted range is assigned in opportunities between 0.02 and 0.14. The stricter law controlling water effluent quality standards got maximum weight, followed by an increase in the trend of value-added waste products and updated law and regulation aligning with developed countries, respectively. On the contrary, the threats factors weighted range between 0.02 and 0.10. Still, the maximum weight relevant to the law, which is redundancy by the law of factory audit (0.10), and then the law is not corresponding to the use of some technologies. Interviewees explained that even though, in the next five futures, law and regulation will be updated to respond to the global transformation and follow the developed countries' law, some parts of the law context will not be able to facilitate the adoption of new water technologies in the industrial system. This means that deliberating over the law is very important; otherwise, the law will be far behind the innovative technologies. In total, the sum of all EFEM was 3.25.

The weighted rating of IFEM was 2.66; therefore, strengths were more than weakness. Besides, the weighted rating of EFEM designated 3.25, so that the threats less than the opportunities. Indeed, the strengths and opportunities dominate in the future industrial water management in Thailand if the future direction is promised as interviewee expectation, as illustrated in the position of industrial water management in Thailand in the Figure 4.6 below.

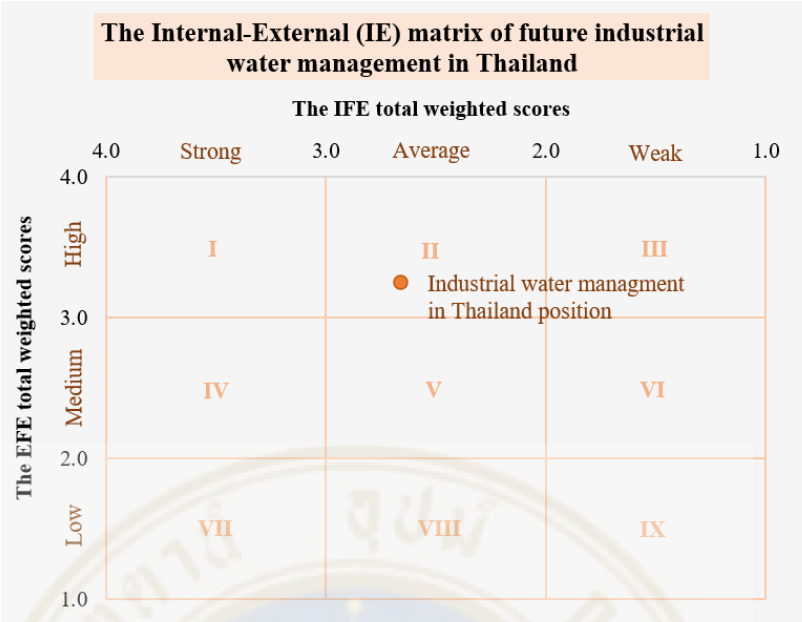

Figure 4.6 The internal-external factor evaluation matrix of the industrial water management in the next five years through the interviewees scoring

4.3 Strategic foresight with future five years challenge in Thailand industries

4.3.1 TOWS matrix and strategic options

Table 4.2 TOWS matrix of industrial water management in Thailand

	Internal factors	
External factors	**Strength (S)** S1: The process will implement efficiently under the concept of a green economy S2: Increase in the development of integrated water and energy technologies in large industries S3: The large industries will bring and improve the industrial water system from foreign counties	**Weakness (W)** W1: The process is not able to utterly close the loop. It still has a bit amount of unwanted output releasing to nature W2: The working staffs lack the knowledge and understanding about awareness of the environment and society

Table 4.14 TOWS matrix of industrial water management in Thailand (cont.)

External factors	Internal factors	
	Strength (S) S4: Many industries segregate waste before the wastewater treatment process S5: Increase in the research of recycling the sludge output efficiently S6: Combine biochemical technologies with alternative energy to reduce the use of synthetic chemicals S7: Percentage of utility cost saving will increase	**Weakness (W)** W3: The new technologies will be expensive and not affordable for medium industries W4: Staff does not know how to select the proper location for wastewater treatment W5: The size of the wastewater treatment unit is vast W6: The law and regulation still hard to understand among many industries
Opportunities (O) O1: The policy of industrial promotion adds environmental awareness and responsibility O2: Strategy planning applies the philosophy of sufficiency economy O3: Increase in fair competition among manufacturing industries O4: Increase in the trend of value-added waste products. O5: The machines and chemical substances easily supply due to globalization O6: Increase in the trend of environmental conservation from the new generation O7: Increase in the trend of bioremediation O8: Government has a water management plan covering household, agriculture, and industry O9: Law is stricter about controlling water effluent quality standards O10: Updated law and regulation aligning with developed countries	**Strategic options** **SO strategies** 1. Exchange knowledge of the water technologies and the law through a social platform (S3, O1, O10) 2. Evaluate and monitor the quality of water effluent in each industry. (S1, S5, O1, O3, O4)	 **WO strategies** 1. Create awareness and culture within the factory. (W2, W4, W6, O1, O2, O6) 2. Encourage the projects to correspond to circular water management. (W1, W3, W5, O5, O6, O7)

Table 4.14 TOWS matrix of industrial water management in Thailand (cont.)

External factors	Strategic options	
Threats (T) T1: Political instability T2: Government emphasis on other sectors; national health, transportation in the airline, and national defense T3: Change in the tax rate, exchange rate, and inflation T4: Growth in population density and resource consumption T5: It has limited wastewater collection and treatment location and area T6: Local communities ban the construction, and city people refuse to drink treated water T7: Climate change and natural disaster T8: Law is not corresponding to the use of some technologies T9: Redundancy by the law of factory audit	**ST strategies** 1. Develop and educate sustainable water how factory impact to the community and community benefits. (S1, S2, S5, S6, T6)	**WT strategies** 1. Set appropriate planning for local communities and many industries to understand the law and ethical behavior. (W1, W5, W6, T6)

4.3.2 Strategic foresight of industrial water management in Thailand

Developed strategies for industrial water management in Thailand are given in Table 4.14 above. The strategies represent a bundle of strategy options through TOWS analysis. It is found that the result of analysis identifies and categorizes the critical approach into five critical areas as following:

4.3.2.1 Fit-for-purpose technologies and laws

The critical issue confronting both medium and large industries is how to select appropriate treatment and water technologies since it affects the water quality used in the further process. The recycling projects directly receive the consequence either lack of understanding water tech or law is far behind adopting new technologies. The suggested strategy is that exchange knowledge of the treatment and water technologies with the law through a social platform (S3, O1, O10). It will be an alternative channel to follow up the updated information and water knowledge to increase the understanding of treatment, water technologies, and the law among business owners and those who want to start the business. For example, the guideline specifying the quality of water for each specific end-use and the water technology mix in a specific industry, the criteria of technology benchmark, and the open discussion of the week leading by the water experts or consultant's opinion in each type of industry. The expected outcome will encourage business owners in many industries to keep learning the suitable treatment and technologies corresponding to the law.

4.3.2.2 Monitoring water quality and reward

The evaluation and monitoring of water quality effluent in each industry as a strategy developed with the collaboration between the private and government sector. (S1, S5, O1, O3, O4) It is necessary to act in every industry; however, this suggestion will emphasize how to engage the industries to treat the water effluent, followed by the law. The project, namely "Smile and frown project," use the behavioral economic claimed as a sustainable tool. The objective is to inspect the water quality releasing from each industry and raise awareness and responsibilities among business owners. Tools used, such as a water map, represent each industry's water quality index in Thailand. The government officer gives the measurement to each industry, such as one smiley face if meet water quality standard for a month, two smiley faces if meet for a year, and a frowny face for who below the standard. All evaluated faces will show on the water map on the governance website. The method deploys the social influence to motivate those who received frowny face among the smiley face of industry surrounding to find the suitable water technologies under sustainable water management. To maintain the engagement, the reward is essential to motivate and achieve further, which contains reputation reward, endeavor reward, and notoriety reward, for example. Therefore, the expected outcome can improve the overall industrial water quality and encourage business owners to adopt water technologies.

4.3.2.3 Active top management support

The problem that working staff lack knowledge and understanding about awareness of the environment and society, the law and regulation, and the selection of wastewater treatment locations have been found over the period. The strategy offered refers to create awareness and culture within the factory. (W2, W4, W6, O1, O2, O6) The key to this strategy's success needs the support of top management of the company or leader in each factory. Since business leaders realize the importance of the relationship between water, environment, and society, they focus on conducting innovative solutions for sustainable industrial water management. Then, the skill development of working staff is considered through the training program. The program provides adequate practical knowledge of environmental and social awareness and the consequence of illegal action during operation. The details need to show how the knowledge fits with their duties in the wastewater treatment plant and demonstrate positive and negative action on each stakeholder. They can perceive that it is a critical topic that one problem can potentially impact stakeholders. To maintain sustainable leadership, the suggestion is to apply the sufficiency economy philosophy as an organizational culture with the three key elements; moderation, reasonableness, and immunity. The study is found that after running a business under this philosophy, the company can operate the business with lower cost but still quality together with understanding their role and environmental issue. Thus, this recommendation's expected outcome can increase the level of environmental and social awareness of leaders to realize sustainable water management in the industry and enhance the staff knowledge in wastewater treatment and the industry's water cycle.

4.3.2.4 Project recovery integration

Since the challenges of water and wastewater management become complicated with the many factors relevant as well as the global trend attempt to address systems seen as a partial solution for the sustainable industrial water management, the systems considering just water, wastewater, energy, and waste processes will be a less effective solution for the sustainable enterprise. The strategy suggested is that encourage the projects relevant to technology integration under the circular water management. (W1, W3, W5, O5, O6, O7) That relieves the pressure on not only water quality and quantity but also an emphasis on resource recovery from wastewater and the collaboration across sectors between industry and government. The recovery technology integration into the wastewater treatment process enables to increase the value creation of resources used, such as energy, waste, reagents, and nutrients. For instance, India's research and development team develops the waste technology combining with wastewater treatment areas that help recover the useful substance and remove the hazardous component from waste.

Noticeably, the first indication to select the preferable resource recovered is the estimation of resource market prices and do the benchmark to maximize long term profitability. For example, the value of energy recovery from sludge leaving wastewater treatment plants through anaerobic fermentation process compares to the value of recovery of thermal energy collected in the wastewater stream or integration phosphorus technology into the wastewater treatment process as known that leads to highest value products. However, the invention of new innovative technology projects would not have happened without receiving support from the government, including funds, stricter monitoring, and policy enforcement. Mandatory by the government can resemble an industry pressure, leading action on technology integration.

Subsequently, the monitoring process's technical assessment is also vital after combining new technology into the process. The existing dimension assesses the treatment performance evaluated by the removal efficiency of contaminants requiring by the industrial law of effluent quality. This needs to identify other indicators playing in the environmental issue and also make the law stricter. The operation performance determines which technology is useful and suitable for integration into the existing process toward economic and environmental assessment. Significantly, the resource recovery performance has to assess to quality of recovered resource and recovery efficiency. The quality of recovered resources should diagnose either human health safe or marketable perception from customers. Another is recovery efficiency assessed by the recovery rate of substance recovered in each process.

Therefore, the outcome of project integration can enhance innovation through resource flow in the industrial process and measure the technology employed in the old process with government support and motivate the business owner to consider the innovative project and implement it in the industry.

4.3.2.5 Stakeholder engagement

One of the significant barriers to industrial water management is that local communities ban the construction due to extensive space utilization encroaching on their living area and odor pollution of wastewater effluent nearby industry. The strategic recommendation is to develop and educate sustainable water on how the factory impacts the community and community benefits. (S1, S2, S5, S6, T6) as well as set appropriate planning for local communities to understand the industrial law. (W1, W5, W6, T6) For example, a community education workshop about water and wastewater involved how waterworks in the industry and the solution that is already done or implementing with representing the outcome of community benefit. The message delivering needs to be transparent, credible, and careful by making the message relevant to the audience. This can enhance their motivation to learn new information. It needs to include open question sessions to give the stakeholder opportunity to share their perspectives. Therefore, stakeholder involvement is an essential part of creating the integration solution between society and water technology and building each other's trust. Consequently, the benefit purpose of this action is to increase the support and minimize the stakeholder resistance to the industrial process.

In the case of public refusing to drink treated water, they generally perceive the product come from wastewater as unsafe for their health but actually, the water quality standard equal to drinking water. The suggestion needs to receive the support of the government institution as it is a large-scale audience. The deliberate message is crucial to motivate the public to change the mindset and overcome the adverse emotional reaction to wastewater reuse. In Singapore, Public Utilities Board creates a careful message through media coverage by avoiding the negative term, such as wastewater or sewage, and select the word for the recycled water products as "NEWater" instead, focusing that is "new and improved characteristic."

Hence, identifying the message's aim and delivering the appreciate word through the public media is a key component to motivate their behavior and perception to accept the new era of water and help reduce the conflict of community.

CHAPTER V
CONCLUSION

This research has studied the strategic foresight of industrial water management in Thailand with the two specific objectives; firstly, to identify the current situation of industrial wastewater treatment in Thailand and compare with foreign countries; secondly, to study the future of wastewater treatment in the next five years in Thailand. The main results from VOS viewer tools and semi-structured interviews are summarized in the conclusion and discussion relying on these objectives. Then, the limitations of the study and recommendations for future study are represented.

5.1 Conclusion and discussion

5.1.1 The current situation of industrial water management in Thailand, compared to the top four productive countries on the water studies

The bibliometric analysis via the VOS viewer program is found that the number of industrial water management research is at a moderate level with continuously growing between 1990 and 2020. The top four productive countries on industrial water management research are United States, China, India, and the United Kingdom, being in the same place as India, while Thailand is ranked in the thirty-third order. Compared to past studies, it distinctly represents the research in the environmental science field and a few merging to biotechnology, chemical engineering, and energy. It is indicated that there are opportunities to grow in the manufacturing industry to seek and experiment with an innovative solution. With this citation analysis, the Journal of membrane science has citation numbers highly, referring to membrane filtration's potential impact. The author co-citation analysis is revealed that industrial water management is comprised of four schools of thought. It includes sustainable water and wastewater management, as numerous scholars, mostly from China, followed by membrane filtration, microbial electrochemical technologies, and interplant water network system. Then, the topical foci of industrial water management began with water accessibility and water quality from the past decades. In the next year, global research concerns the area of water and wastewater management; thus, water technologies with cost efficiency were developed. Until the present, the global tendency focuses on sustainable industrial water management, as illustrated in Figure 4.5.

Furthermore, the scholar representing both author citation and co-citation analysis is from China, covering all aspects of water management in industry, comprising water resource management, water-energy nexus, membrane filtration, or water quality concern, and bioeconomy due to the government support. Besides, the United States scholars are significantly attentive in bioeconomy, water use, and water quality improvement, respectively. Although India and the United Kingdom receive high productivity, they have fewer citations; consequently, the scanning literature from the database is allowed to gain more information from the two countries. In India, researchers attempt to improve the technologies, especially wastewater treatment units, by considering the minimization of water use and integrating the system of less energy consumption to respond to the world market demand. That has the same direction as China's research combing water and energy system. The researcher in the United Kingdom mainly concerns water scarcity or water use efficiency and suggests the approach to purify the water quality, following the law standard.

When the comparison of publication number and topic focus among these top four foreign countries with Thailand, the number of publications in Thailand is relatively lower; however, the interesting is, in 1997, the Thai pioneer research suggest the zero liquid discharge system in industry; followed by the efficiency of water use together with paper concerning the water and energy system over the years. It is indicated that the studies in Thailand lack water quality improvement in the industry compared to other countries, as seen in Table 4.8. This can be one of the supporting evidences that the SDG index measuring in wastewater treatment values 12.1% or on the red scale.

To gain more insight into Thailand's current situation, the semi-structured interview of medium and large-sized companies is allowed in this study to support the bibliometric analysis and understand the reason behind low water quality. It is found that presently, the six key elements have a potential impact on industrial water management in Thailand, including the manufacturing process, wastewater treatment technologies, awareness, knowledge management, and law and regulation. The manufacturing process is considered the strengthening part, meaning that Thailand is implementing sustainable water management. They mainly focus on water use efficiency, water recycling, and energy conservation via alternative energy. The technologies are decided on the weak part of industrial water in Thailand regarding the improper selection and high-cost investment; however, the industry can gain opportunities from suppliers sourcing innovative water technology to facilitate the wastewater treatment plants. According to the interviewee's perspectives, the other elements are categorized into barriers, such as awareness of the environment and society, knowledge among staff, less strict law, and lack of government support in funds and policy.

5.1.2 The future of water management in the Thailand industry and the strategic recommendations in the next five years

The study is found the possible driving forces shaping the future are given as the strong strengths, focusing on the new researches that the increase in the percentage of utility cost-saving in the industry; followed by the interest of sludge recycling research with the expectation of enhancing the wastewater treatment in Thai industries to reach the sustainable water management goal. Interviewees proposed that there are the potential opportunities to support the future direction of industrial water are firstly about the law and regulation controlling water effluent quality become stricter and updated complying with other developed countries. Secondly, the trend of value creation on wastes will increase. However, Thai entrepreneurs in medium-sized companies still confront their internal challenges. These unavoidable issues are expensive and unaffordable water technology, the lack of capital investment, and some top management's ignorance of water sustainability. The noticeable factors continuing to be found and embedded from the past are the lack of knowledge and understanding about technology, law, environmental and social awareness among staff in many companies. Besides, some interviewees pointed out that the law of factory audit still has redundancy. Some law context will not facilitate adopting the new wastewater technologies in the existing industrial process; in other words, the law is far behind the water technologies. Aside from the law, the misunderstanding relevant to the water cycle is probably growing in the local community. Another worrying challenge in developing future water management is the public unacceptance of recycling water, even meet the drinking water standard. This study indicated that the challenge of industrial water management in Thailand, especially water quality, is not only the adoption of water technologies and investment cost, but the law, mindset of leaders, staff knowledge, community aspect, and public acceptance as well.

Therefore, the future of industrial water management has to concern broader aspects and relationship of those factors, such as the consistency of technology and law, the development of suitable wastewater treatment technology and process, the government support of enterprise funds, the awareness and staff knowledge, the perspective of managerial level, local community, and the public in Thailand.

The strategic recommendations based on identifying the driving forces and barriers generate the five fundamental guidelines to help entrepreneurs in the manufacturing industry who know at amateur and medium level to understand the importance of wastewater treatment and encourage them to consider applying the sustainable industrial water management in their industry. In some guidelines, the business owners can implement and apply to fit with the company, but some need the expert participant to inform accurate information and government support. The five guidelines summarize as follows:

a. Fit-for-purpose technologies and law as a social channel to provide and discuss the knowledge and water issues, especially wastewater treatment technology and law by the experts and companies experienced in water issues. This benefits for decision making among business owners who need updated information to benchmark and select an appropriate technology for the existing process and understand the law and regulation.

b. Monitoring water quality and reward aim to improve the industrial water quality in Thailand through social influence and monitoring systems and encourage business owners who neglect the environmental and social issues to adopt the wastewater treatment technology in their industrial process. It is necessary to collaborate between the private and government sectors to achieve this initiative.

c. Active top management support as key to lead the company direction. The suggestion is to change the mindset of water management or apply the sufficiency economy philosophy in the company's culture to sustain and maximize long-term profitability. This can guide top management to understand how to behave as a sustainable enterprise. When leaders have a positive attitude to environmental awareness and responsibility, they attempt to support staff knowledge through training programs and build staff engagement to the environment or water issues.

d. Project recovery integration is relevant to encourage Thai business owners to consider innovative projects, integrating more than one resource, such as energy and waste, under the circular water management, emphasizing resource recovery.

e. Stakeholder engagement is also essential, particularly industry located in the local community area. The industry needs to deliver transparent, credible, and careful messages by sharing knowledge of the industrial water cycle and education workshop to increase understanding and positive attitude in industrial water management.

5.2 Recommendations

5.2.1 Recommendation for applying this research result

This research provides the main two situations of industrial water management in Thailand in the current and future through the VOS viewer application and foresight method to be a source of information for business owners in the manufacturing industry and managerial level relevant to industrial water management. Plus, it identifies the future challenges of water in industry and suggests the strategic recommendations as guidelines for business owners to create their industry strategies under the sustainable industrial water management concept.

The entrepreneurs in medium and large-sized industries can gain the new perspective of industrial water management that need to emphasize not only the water use efficiency but the water quality improvement and integration of water and other fields, such as water and waste, to generate alternative income and raise the value of wastewater treatment unit. So, in the short run, the companies can prepare the material recovery plan. They can determine the material or by-product remaining in the industry and research the process converting it to the new products under control of operating cost.

Moreover, providing the education of the industrial water cycle among employees and working staff is essential in both sized industries, leading to increased water knowledge and innovative solutions for the company. For a large company, the workshop can provide practical knowledge and discussion suitable for the employee who has a basic knowledge of water. Meanwhile, the staff of medium companies lacks this knowledge. The interactive training program with a coach can be one of the alternatives for staff because they can train experience along with an increase in understanding of essential water management. Significantly, the medium industry needs to recheck the culture and mindset of the top management team on how the water and wastewater are vital for them and the company. This can reflect their awareness level of water.

When the knowledge and understanding of industrial water are developed in the company, in the long run, the medium industry can launch the campaign within the company to continuously enhance the environmental and social awareness and responsibility. The different point between medium and large industry is stakeholder engagement. It is reminded of a medium industry that does not imitate how the big company does. The project size needs to consider who your stakeholders are, what level of community knowledge understands the water in industry, and what level of knowledge can provide, meaning that the appropriate selection of engaging plans needs to fit with the company stakeholders. So, the researcher suggests that the medium company initiatively focuses on the nearby manufacturing plants, whereas the large company expands the awareness project to society outside the factory area. When the company takes social and environmental responsibility and has the mindset that is acceptable to the water importance, the problem of water management in the industry will relieve and develop into sustainability. Then, the creative idea will be formed and launch the new product from waste and wastewater. The delivering message through marketing content is crucial, which needs to be transparent, credible, and careful to raise customers' acceptance.

Furthermore, with the global trend of industrial water management, historical data of the prosperous foreign countries, and the entrepreneurs' view to the water in Thailand, this information will allow the government sector to be more attentive to Thailand's industrial water management and clearly understand the water problem in the industry. In the short run, the researcher suggests developing the water inspector system to monitor and control accurately. The government can then reduce the gap between water technologies and law through consulting experts in technology, industrial process, water management in industry, and industrial law. Lastly, prepare the budgeting plan and contract to be financial support for the entrepreneur.

Consequently, the water system will be launched to monitor the water effluent from the industry in the long run. Simultaneously, the government staff performance is evaluated toward the ethical criteria to prevent unethical behavior among staff in both the government and private companies. Then, a law conforming to water technology, and the industrial process is issued. For the government support in the fund, the entrepreneur receives financial support along with sign a year contract that is relevant to improve the water performance to meet the industrial law and regulation. Solving the right problem will allow the industries that can be driven increasingly to sustainable industrial water management.

Importantly, the additional recommendation is the presentation addressing the main industrial water problems from private's perspectives and demonstrating successful case studies in other countries. This helps the government sector realize the new perspective of stakeholders and capture and cover the industrial water issue. There are four main units in sustainable industrial water management that can be directly responsible for those fundamental guidelines suggested. First, the pilot project in the industrial estate area can implement under the control of the Industrial Estate Authority of Thailand (IEAT). They can assess the registered industries by the five guidelines as criteria and deliver the appropriate practices in each industry. The Pollution and control department (PCD) will determine the standard of discharge then collects and tests the water sampling in each type of plant to be a database for developing the water inspected system along with evaluating the ethical performance among government officers. The

Water and Environmental Institute for Sustainability (WEIS), one of the institutes in the Federation of Thai Industries (FTI), will coordinate between private and government sectors to encourage and exchange knowledge and idea about water technologies and industrial law. Plus, promote and educate the recovery research or disseminate academic for Thai researchers and industries to figure out the sustainable industrial water solutions with the appropriate law. The information from each responsible unit is considered and consulted to issue the law by the Department of Industrial Works (DIW). Along with following up the overall industrial water performance in Thailand to reveal the monthly, quarterly, and annual reports to entrepreneurs and the public.

Table 5.1 Guidelines for the development of industrial water management in Thailand

Stakeholders	Short-run	Long-run
Entrepreneurs in medium-sized industry	-Check leader mindset to industrial water and wastewater awareness -Educate the water knowledge from the root to staffs through a training program -Explore the valuable material or remaining in the industry to brainstorm an idea and prepare the recovery plan	-Launch campaign within the company to promote staff awareness and product creativity as well as evaluate the staff performance -Set the small project relevant community engagement
Management level in the large-sized industry	-Research and develop the innovative plan of material recovery from wastewater in each plant -Provide the staff workshop based on their water and wastewater knowledge	-Launch new products from recovery and promote marketing content to raise customer acceptance of wastewater -Expand the awareness and knowledge project to engage society outside the industry

Table 5.1 Guidelines for the development of industrial water management in Thailand (cont.)

Stakeholders	Short-run	Long-run
Government sector	-Develop the monitoring water system for preparation of accurate data collection -Consult the experts in water technology and industrial process to create the appropriate industrial law -Prepare the budgeting plan and contract for supporting financial entrepreneurs	-Launch new water inspector platform -Evaluate staff performance, including ethical index -Issue a law to support the technology and existing process - Provide the budget to an entrepreneur with a year contract, including evaluating water performance

5.2.2 Recommendation for future research

The two recommendations contain the VOS viewer and foresight tool. First, this study uses one of the databases, namely Scopus, for mining the research relevant to industrial water management. The researcher suggests using more than one database to gain more accurate and broader information. Second, the selection of foresight tools in each stage is significant since each stage of foresight methodology needs to be compatible and consistent for applying the previous step to the next step through the combination of the method by nature and capability illustrated in Figure 2.9. Due to the qualitative and quantitative methods used in this research, the further suggestion is the semi-quantitative tool, such as cross-impact analysis and MICMAC tool, to increase the creditability of each potential factor's relationship. Besides, the advice for SWOT analysis considered as a qualitative method can integrate the analysis with decision-making tools, such as the Analytical hierarchy process (AHP), using the mathematic to deeply analyze the prioritized factors in the complex decision among various forces.

5.3 Study limitations

Most of the information used for describing the situation of industrial water management in Thailand is from the perspective of the business owner, management level, and specialists in the private sector. It may not reflect coverage of water management in the manufacturing industry, especially the information on implementing the plan in the government sector.

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APPENDICES

Appendix A: Semi-structured interview form

College of Management
Mahidol University

Semi-structured interview

Title of study: Strategic foresight of industrial water management in Thailand

Explanation: The purposes of this semi-structured interview include

1. To identify the current situations of water management using in industry in Thailand and compare the situation between Thailand and foreign countries.
2. To study the future of water management in industry in the next five years (2020-2025).

Note: The information collected from the semi-structured interviews will be kept confidential by the researcher with great care and the information presented in the study will not identify or disclose the interviewer's data. Data gathered from semi-structured interviews are either locked in the cabinet or encrypted to open the file in case of recording on a computer. These documents and files will be used for educational purposes only and will be destroyed after research is done in accordance with IRB principles.

The questions of semi-structured interview contain three sections:

1. Interviewee information
2. Current situation toward industrial water management in Thailand
3. Foresight of industrial water management in Thailand

Semi-structured interview form

General information
1. Company name: .... 2. Your position: .... 3. Years of experience: ....

Part 1: Current situation toward industrial water management in Thailand
Introduction 1. In your opinion, what are the overall of current water management or wastewater treatment process being used in industry in Thailand? And what problems do you have in your company? 2. Currently, are there any differences in the water management approaches and wastewater treatment systems in operation in the industrial sector between Thailand and foreign countries? how? Internal factors of industrial water management in Thailand 3. Does your industry have sustainable competitive advantages? And how? 4. What are those strengthening factors to implement wastewater treatment in your industry? *(e.g. employee knowledge specializing in wastewater*

treatment, adoption of circular economy, use of sustainability tools) Could you please give each factors a score from 1 to 3, where 3 is a high positive impact on industrial water management?

Factor 0	*Adoption of wastewater treatment technologies efficiently*	*score*	*2*
Your reason			

Factor 1		Score	
Your reason			
Factor 2		Score	
Your reason			
Factor 3		Score	
Your reason			

5. What are the factors that need to improve or weakness factors that negatively effect on water management in your industry? *(e.g. high electricity cost of wastewater treatment process, the inappropriate monitoring water program, lack of knowledge in staffs, high operation cost)* Could you please give each factors a score from 1 to 3, where 3 is a major weakness on industrial water management?

Factor 1		Score	
Your reason			
Factor 2		Score	
Your reason			

Factor 3		Score	
Your reason			

Suggestion

6. In your opinion, if you would like to improve the efficiency of water management or wastewater treatment in your industry, which part you want to improve? *(e.g. wastewater technologies, increase in employment, the capital investment)*

7. According to answer of no. 6, how could you prepare and take action to increase the effectiveness mentioned above?

Part 2: Foresight of industrial water management in Thailand

Introduction

1. What do you think about the future of industrial wastewater treatment in Thailand in the next five years?

Horizontal scanning (macro-environmental factors)

2. In your opinion, what are the significant **political** barriers or opportunities affecting industrial water management? *(e.g., industry promotion policy, government support of SME, national strategic planning, political stability)*

How do these factors affect the company? Furthermore, what are the suggestion for coping with these factors?

Factor 0	*Political stability*	*Opportunity or Threat*	*Threat*
Effect on company			
Suggestion			

Factor 1		Opportunity or Threat	
Effect on company			
Suggestion			
Factor 2		Opportunity or Threat	
Effect on company			
Suggestion			

3. In your opinion, what are the significant **economic** barriers or opportunities affecting industrial water management? *(e.g., decrease in interest rate, the machine and chemical taxes, economic slowdown)* How do these factors affect the company? Furthermore, what are the suggestion for coping with these factors?

Factor 1		Opportunity or Threat	

Effect on company			
Suggestion			
Factor 2		Opportunity or Threat	
Effect on company			
Suggestion			

4. In your opinion, what are the significant **social** barriers or opportunities affecting industrial water management? *(e.g., customer behavior, community's knowledge and understanding of wastewater treatment process)* How do these factors affect the company? Furthermore, what are the suggestion for coping with these factors?

Factor 1		Opportunity or Threat	
Effect on company			
Suggestion			
Factor 2		Opportunity or Threat	
Effect on company			
Suggestion			

5. In your opinion, what are the significant **technological** barriers or opportunities affecting industrial water management? *(e.g., use of alternative*

energy in water process, selection of membrane filtration such as ultrafiltration, reverse osmosis) How do these factors affect the company? Furthermore, what are the suggestion for coping with these factors?

Factor 1		Opportunity or Threat	
Effect on company			
Suggestion			
Factor 2		Opportunity or Threat	
Effect on company			
Suggestion			

6. In your opinion, what are the significant **legal** barriers or opportunities affecting industrial water management? *(e.g., outdated law and regulation, strictness of the Department of Industrial Works and the Pollution Control Department)* How do these factors affect the company? Furthermore, what are the suggestion for coping with these factors?

Factor 1		Opportunity or Threat	
Effect on company			
Suggestion			
Factor 2		Opportunity or Threat	

Effect on company	
Suggestion	

7. In your opinion, what are the significant **environmental** barriers or opportunities affecting industrial water management? *(e.g., natural disaster, drought, global warming, water and industrial waste pollution)* How do these factors affect the company? Furthermore, what are the suggestion for coping with these factors?

Factor 1		Opportunity or Threat	
Effect on company			
Suggestion			
Factor 2		Opportunity or Threat	
Effect on company			
Suggestion			

<u>Wildcard</u>

8. In your opinion, what low probability factors/events could have a dramatic effect on industrial water management? *(e.g. Covid-19 crisis, new normal behavior)*

9. According to no.8, how do you solve those issues?