Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 180 (2021) 86–92

Procedia Computer Science

www.elsevier.com/locate/procedia

International Conference on Industry 4.0 and Smart Manufacturing

Reaching sustainability through a smart water crisis-proof industry

Ramos Álvarez Adrielly Nahomee[a], Molina Soler Gloriveth de Fátima[b], Flores de la Mota Idalia[a], Soler Anguiano Francisca Irene[a*]*

[a]*National Autonomous University of Mexico, A. Universidad 3000, Ciudad Universitaria, Coyoacán, Mexico City 04510, Mexico*
[b]*Hermosillo Technological Institute, Av. Tecnológico y, Periférico Poniente S/N, Sahuaro, 83170 Hermosillo, Sonora, Mexico*

Abstract

The current and future water crisis is not only affecting the household level, but it is rather tackling every activity that requires even a single drop of water for its development. Although whole countries have been implementing new water management schemes such as the Water Sensitive Urban Design in Australia, the 4 Taps in Singapore, and Sponge Cities in China, among others, there has been a lower interest in the side of the industry for changing the plan of action towards a more sustainable water management.

Although many companies have adapted their infrastructure into the Sponge Cities model contributing to a better administration of the resource by absorbing water from the rain, promoting a natural filtering by the soil and minimizing water waste, their inner processes still struggle to optimize the use of water. Models such as Zero Liquid Discharge and Zero Water Discharge are an important support, despite the resource, energy and infrastructure requirements. In the last decade these efforts have been targeted towards reaching sustainability and resilience. Nonetheless most of the systems are still highly vulnerable to suffer the effects of a human-detonated or natural-phenomena crisis, that is why the aim of this article is to present the concept of a Smart water crisis-proof industry that may be able to reduce water wasting into zero percent with the idea of a catchment device for providing additional scopes and potential water stock, that if implemented might help prevent and mitigate crisis and become a vehicle for reaching sustainability.

© 2021 The Authors. Published by Elsevier B.V.
This is an open access article under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0)
Peer-review under responsibility of the scientific committee of the International Conference on Industry 4.0 and Smart Manufacturing

Keywords: Type your keywords here, separated by semicolons ;

* Corresponding author. Tel.: +1 5554768861; .
E-mail address: fisau3444@gmail.com

1877-0509 © 2021 The Authors. Published by Elsevier B.V.
This is an open access article under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0)
Peer-review under responsibility of the scientific committee of the International Conference on Industry 4.0 and Smart Manufacturing
10.1016/j.procs.2021.01.132

1. Introduction

Currently, many are facing monumental challenges related to natural resources availability and administration due to accelerated population growth, poor management policies, pollution, overexploitation, just to mention some. According to United Nations estimates, by 2050 the world's population will rise in 2 billion people, and for 2030 global water will experience a 40% deficit [2]. Therefore, by the time the world reaches 2050 the number of required resources will eclipse the available amount by far.

Water availability, quality, and access conditions are highly disturbing. Considering that water is essential for living a worthy life, the fact that 2 billion people drink contaminated water, 785 million don't even have access to a drinkable water service on regular basis and that the cause of death of 485 thousand inhabitants is diarrhea because of a bad quality drinking water [3], helps visualize the hydrological crisis the world has been experiencing and that keeps worsening throughout the years. As Edward Barbier has said, "The water global crisis is largely due to inadequate and poor water management." [4] rather than a lack of water.

Mexico City and its metropolitan zone is a clear example of this, having an average of 600 million cubic meters of rainwater per year [5] and an important amount of hydric resources, is, ironically, the 2nd megalopolis with the highest risk of experiencing severe water scarcity [6]. Some of the causes lie in its underground water wells overexploitation at 160% of its own recharge gauge, the 40% of leakages at the city's pipeline network, the cross-contamination of aquifers, the water treatment plants working at 50% of their capacity and the poor management policies. Although Mexico City's government has tried to implement numerous actions for guaranteeing water access, such as creating leakages squads, raising water supply fees for households according to socioeconomic neighborhood divisions or installing brand new water meter systems, still 71% of the granted water volume to the industry is not measured by any mean and only 1.7% of inspections in that matter are being held. While households that use only 10% of the metropolis' water, are under the scope; the industry is having very little regulation despite using 14% of the city's reservoirs of freshwater. Consequently, is not surprising that 75% of the megalopolis' population has severe irregularities in water supply and that scarcity is a daily concern [7].

Worldwide the scene is not far from the Mexican panorama, in fact, urbanization has led to a water decreasing infiltration capacity through the soil in 90% which translates into a considerably less aquifer recovery [8]. Considering the fact that industry water usage represents 19% of total freshwater withdrawals and strict regulations are only seen in fully developed countries where also a high percentage of industrial water extraction lies on, Canadian industry takes 80% of water, U.S. factories require 50%, Central and Eastern Europe countries need over 70% of the hydric resource for its processes, while Chinese industry stands in need of over 20% of its water withdrawals [9]. Emerging market economies, on the other hand, require less freshwater for the industry but lack regulations for which heavily water-polluting industries are taking over their natural resources by lowering their water quality and availability.

Solutions for better water management are changing paradigms. Singapore's 4 taps scheme, Water Sensitive Urban Design in Australia, or Sponge Cities in China are leading whole cities towards a more sustainable system. These successful programs have concentrated their efforts in transforming cities for allowing a more natural water cycle to take over through rainwater caption systems application, permeable pavement installation, wastewater treatment, water distribution models implementation, natural riverbeds restoration. Optimally using resources, minimizing negative impacts, and restoring previous water quality and availability are part of the mentioned strategies' goals. While these schemes are designed for entire urban systems, Smart Water Solutions and Zero Water Waste models focus on industrial purposes. Whereas Smart Water collects, monitors, transmits, manages, and analyses data to provide feasible solutions, Zero Water Waste guarantees that wastewater will be treated and reused, according to its own quality. Even though these last two have been implemented in industry holding Nestlé Zero Water Plant [10] as an example, many solutions leave certain aspects of the Zero Water Waste industry apparently unattended or at least not in the proportion of the solution needed. On one hand, the innovative government projects that integrate broadly the system and on the other, smart water and zero water waste specially designed for industry let a gap visible in the solutions space. Therefore the present paper describes the notion of a Smart Water Crisis-Proof Industry accompanied by an idea of a catchment device capable of providing a contribution to industry sustainable water use as a way to minimize the risk of experiencing an important hydric deficit and a harsher crisis like the one projected for 2030 .

2. Literature Review

The strategies implemented around the world for avoiding monumental disasters in different countries stand as proof that proper diagnosis, objectives, plans, actions, and tools allow to overcome the crisis and set innovative solutions.

2.1 Water schemes

Singapore was characterized by having a low freshwater availability, in fact, the government had to import most of the water from Malaysia. Nonetheless, the 4 taps program combined with NEWater transformed the country into a Water Management World Leader. The scene turned "...from survival to sustainability" [11]. The principal objective was to reach the country's freshwater self-sufficiency by administering the resources more efficiently through a systemic strategy. Resource optimization, non-sustainable water sources dependence reduction, a higher emphasis on defined objectives and politics such as collecting rainwater and an unlimited water reuse policy have allowed to overcome Singapore's water scarcity crisis and guaranteeing freshwater availability, access, and quality for future generations.

Australian Water Sensitive Urban Design integrates a bioinspired water administration system with the purpose of minimizing negative impacts in the water cycle due to urbanization. Even though this program is like others, the main difference lies in their rainwater filtration and sanitation facilities at the caption site. The associated benefits are the protection and renovation of natural systems in urban environments, infrastructure cost minimization, drained water quality improvement, flood risk mitigation, contaminant remotion [12], making this scheme an important upgrade in urban development towards a more natural water management.

China has developed one of the most prominent water administration programs through Sponge Cities implementation. Approximately 30 cities like Shenzhen, Guangxi, Yinchuan, Yuelai, Liangshuihe, and Foshan are radically changing their hydric practices. Infrastructure development, procedure, and technology implementation for a holistic strategy is the main focus. Sponge Cities' focus is to model water governance according to the system element interaction among the urban dynamic, considering hydric vulnerability, climate change, economic, social, and environmental feasibility [1]. It is important to mention that unlike other schemes, Sponge Cities intertwin treatment models and water supply through aquifers multi-criteria analysis for more integral and safe management.

2.2 Zero water discharge model & smart water

The Zero Water Discharge model is a water management scheme designed for industrial purposes. The main objective is to reduce water waste to a minimal volume through the application of advanced technological water treatment processes. Within Zero Liquid Discharge scheme requirements are variations in waste contamination and flow handling, adjustments in chemical treatments, reuse of 95% of the liquid recovery, waste treatment and retrieve byproducts, dry, solid cake disposal production, among others [13]. Tight controls must be applied in order to fulfill regulations, volume, and quality demands. Although Zero Liquid Discharge components rely on every sectors' needs so as to determine the strategy to be taken, the main aspects will depend on the volume of dissolved solids, the system's flow rate, and specific contaminants for instance.

Smart Water monitors transmit and analyze data regarding quality and quantity for domestic, commercial, food, and industrial purposes. Its main objective is to spend less to achieve more while serving as a tool for improving processes.

The technologies it uses are designed "to minimize the impact of human activities on the natural environment and the potential for information technology, data transmission" [14].

3. Comparison and opportunities

In Mexico and the world there have been applied different methods for saving water in the industrial system and the cities, even though this has been helpful there is still a lot to consider, most of the techniques used are not enough to overcome the lack of water that is presented in the country, this is why innovating new ways is a must. The next table shows some of the methods implemented in the world for water saving, presenting the area of impact all of them have, compared to the smart water system, realizing none of the previous schemes solve the need of a new one implemented in every industry independent from the size of it.

Table 1. Scheme comparison according to certain characteristics.

Characteristic/Scheme	4 taps	Urban	Sponge City	Zero Water Discharge	Smart Water
Systemic approach	High	High	High	Medium high	High
City	High	High	High	Low	Medium
Industry	Medium high	Medium-low	Medium-low	High	High
Drought mitigation	High	High	High	Medium	Medium high
Water catching	High	High	High	Low	Medium-low
Aquifers recovery	High	High	High	Medium high	Medium high
Artificial Intelligence usage	Medium-low	Low	Medium-low	Medium	High
Resilience improvement	High	High	High	Medium-high	Medium-high
Crisis-proof	High	High	High	Medium-low	Medium-low
Costs of implementation	High	High	High	High	High

3.1 Opportunities (The gap)

The actions listed above are an important part of the majestic solutions that have been revolutionizing water governance around the globe. Nonetheless, in hydric subjects, there are still crucial aspects to be solved, adapted, and implemented in different scenarios, especially in the ones with higher challenges. Even though programs such as 4 taps, Water Sensitive Urban Design, and Sponge Cities have taken away whole cities from hydric disaster and oriented them towards sustainability, their main concern is municipal water governance in general, lacking specific or exclusive actions for the industry.

Zero Water or Liquid Discharge model, on the other hand, is particularly intended for large industries located in places with severe hydric stress as an ultimate resource due to its high initial costs. Infrastructure changes, advanced technology acquisitions, disposal procedures adaptations, and other actions have to be held in order to adapt to this approach. Despite the increasing need to become zero water discharge worldwide, this model is infeasible for most companies and can be affordable by few.

As a result, the gap lies in a lack of a scheme like 4 taps, Water Sensitive Urban Design, and Sponge Cities specially dedicated for industry. Smart water being an important tool for innovation requires an upgraded data analysis and consequent actions where a systemic point of view may integrate the solutions. Systemic knowledge is what's missing for reaching sustainability and resiliency.

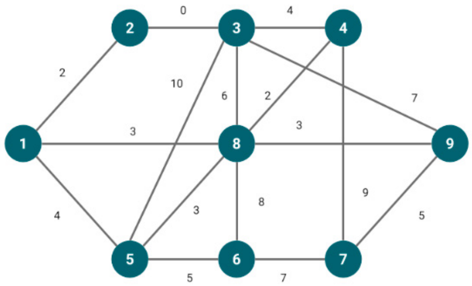
4. Concept of Smart water crisis-proof industry and device

The United Nations defines a crisis as an "event or series of events that represents a critical threat in terms of health, security, and wellbeing of a community or a large group of people"[15], according to it, humanity is facing a crisis due to water scarcity affecting millions of people worldwide. Yet in the middle of the existing crisis, the second sector with higher water usage, industry, is far from adopting practices and actions that apart from fulfilling standards may transform itself into a water self-sufficient system for reducing virtual water among its processes and resisting, absorbing and even preventing the effects of any crisis. Currently, freshwater insufficiency affects companies directly in economic, social, and technical aspects, especially in developing countries where preventing actions are rarely taken. A 5 day programmed water cutoff during 2018, left a 20 million dollar loss in Mexico City's businesses [16]. This allows us to see that companies, in reality, are not prepared to confront either a programmed water shortage or a severe water crisis.

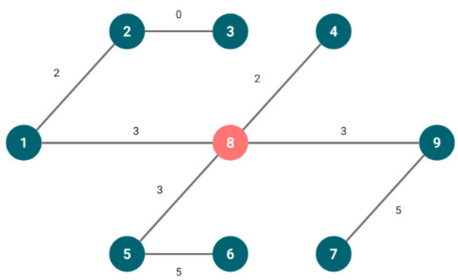
Therefore, a smart water crisis-proof scheme is needed. It should propose a strategy for transforming industries into hydrological sustainable ones through the implementation of artificial intelligence and optimization tools, adaptable technologies, consistent feedback, holistic treatment, supply, recovery models for minimizing water waste, and reaching water self-sufficiency for opposing crises. Unlike the Zero Water Discharge Model, it cares for the entire water life cycle source, the development, and the use.

4.1 Smart water crisis-proof industry concept

Industry 4.0 tools must not be applied randomly or without a defined plan within the smart water crisis-proof industry. But observations and diagnosis of the industry's social, environmental and technical conditions have to be held for building a personalized plan according to the actual needs. It should have the flexibility to decide whether an infrastructure major transformation is required. While water innovations are continually appearing, being able to adapt solutions to industry, and even experimenting with new methods. Fast prototypes can be useful to prove functionality aspects or even human-water interaction. Insights, explorations and iterative solutions should be supported by agent and element based simulation before being implemented. The construction of Digital Twins of the various systems will open up the solution and experiment space significantly.



(a)



(b)

Fig. 1. a) Example of a network representing the water path among processes, where every node represents a process and every arc the interconnection of the processes in terms of water flow. b) Minimal expansion tree of the network presented

While sensors ought to be placed in specific places of the system for ensuring efficient data management and more accurate insights, using communication protocols according to the process they're monitoring is vital. IrDA, ZigBee, Bluetooth protocols may be suitable for small areas, having low energy consumption, while Wi-Fi and HiperLAN2 can cover wider areas with higher energy consumption, wired protocols might serve as well. With this, the water path can be mapped and represented in a network as the one shown in figure 1. A network is helpful for getting to know the water quality, quantity, flow, and behavior in different points of the process or system. Leading to a deep and conscient analysis that could determine blockages, barriers in management, possible losses, and even find out if alternative sources are feasible. AI algorithms are strongly recommended for identifying usage patterns, quality needs according to the process, system failure, leakage recognition and localization, error prevention, and correction.

While Neural Networks, genetic algorithms, and other optimization techniques such as the ones used in dynamic programming for resource assignment are also vital for accomplishing the goals.

Sliding Modes Control can be designed and implemented for specialized industries, according to the feedback obtained during the process. It is essential to mention that in certain circumstances and processes**,** a basic control may be sufficient. It will vary depending on the quality level the process requires and the water availability. This phase is vital for determining the next step of water within the path.

Recovering resources may prevent risks. If the industry's location receives an important amount of rainwater every year or if there's a lot of moisture in the air, everything must be caught and used properly. Proper resource management minimizes waste. So questions like "what can be recovered?" "How risks can be prevented?" "How can the system recover from mistakes?" are vital. Furthermore, a risk and error prevention policy may lead to avoiding significant loss or contamination of water inside the company. An intuitive framework can help stakeholders avoid making mistakes, for diagnosing failures in time is key to avoid risks.

Support networks, problem-solver habits, stakeholder partnerships, and communication can understand, and provide effective feedback to the whole network. As it is understood that industry water management has a high level of complexity, the tools to be used are required to fulfill the expectations. That is why the smart water crisis-proof industry idea could fit any size or kind of industry.

4.2 Water catchment device idea

Given that industrial schemes for zero discharge require large infrastructure adjustments and important investments, companies need to stop production and make a detailed plan for the makeovers. Considering this, the notion of a water harvesting device for industries is presented. The goal is to reduce the effects of water-consuming in an industry, to reach it, it is proposed the water catchment device idea, in order to reuse the water that is exploited. On many processes the use of water is mostly to clean, dissipate heat, or sometimes to submerge any product in it, after that, this water is disposed and not used ever again; that's when the idea of an equipment that works essentially as a cloud which is a container of water residues and this water gets condensed and it is able to re-use it. Not having specific data, if we consider that a company usually doesn't even have measurements of the water it consumes, water keeps being thrown away. This will reduce the water they consume because it will be the same amount of water used all over again, it serves as a sensor that will determine how much water is expelled during the process and can provide inferred data through the AI algorithms.

Hygroscopic, recyclable materials such as Polylactic Acid and PETG and an adaptable grid that provides a resistant structure can be mounted in any convenient place of the fabric. Large infrastructure changes are not required. The cloud is capable of absorbing and condensing humidity through its channels, sanitizing materials can be added to the structure in order to remove contaminants from water so it can be reused and filtered in the same process, or in any other parts of the plant.

Conclusions

The most advanced technologies or the fastest speed in data acquiring and processing are useful but do not represent a real solution to the major scarcity and management problem unless they're accompanied by a wide scheme that considers real needs and suits the industry circumstances. A static plan cannot achieve the solutions needed. A smart water crisis-proof scheme could provide an opportunity to keep advancing in short steps towards sustainability according to resources available and industry demands, it is a plan to head towards hydrological self-sufficiency, while resisting the effects of hazard and heading up to hydric crisis in the complex system of water in industry.

Adaptable technology such as the device idea presented, is needed in the industry transformation towards sustainability. Usually, developing companies are unaware of the water quantity and quality they require for their operations and expensive, complex solutions are unfeasible for implementation in a short term. Thus, low impact technologies, in theory, can provide important results in water management and optimization. Serving as a catapult for changing water paradigms.

Being the industry a key element for enhancing either a stronger crisis or a solution, the smart water crisis industry concept, with the proposed device idea provides an important change of paradigm to approach water problems from a systemic point of view, with the tools of Industry 4.0.

Acknowledgements

This paper was possible thanks to the support and revision of the Master of Arts Elia Soler Anguiano, Engineer Ámbar Molina Soler and Master in engineering Carmen Angelina García Cerrud.

References

[1] Nguyen Thu Thuy, Ngo Huu Hao, Guo Wenshan y Xiaochang C. Wang (2020). A new model framework for sponge city implementation: Emerging challenges and future developments. In Journal of Environmental Management, Vol 253. DOI: https://doi.org/10.1016/j.jenvman.2019.109689. May 2020.
[2] United Nations Water (2020). United Nations Report sobre los recursos hídricos del mundo 2015.
[3] UN Water (2015) Informe de las Naciones Unidas sobre los recursos hídricos del mundo 2015. Agua para un mundo sostenible: datos y cifras. UNESCO. Italia.
[4] Barbier Edward B. (2019). The Water Paradox.The USA. Yale University.
[5]Comisión Nacional del Agua (2018) Datos abiertos, obtenido de: https://datos.gob.mx/busca/dataset?organization=conagua&page=3. Consultado en noviembre 2019.
[6] Chapman, Wilson (21 June 2019) 10 cities most at risk of running out of water. U.S. News https://www.usnews.com/news/cities/slideshows/10-cities-most-at-risk-of-running-out-of-water?slide=12 Consultado en June 2020.
[7] (Merino, 2018) Merino Pérez, Leticia, Velázquez, Alejandro & Buratti, Simone (2018/04/23). Agenda Ambiental 2018 Diagnóstico y propuestas http://agendaambiental2018.susmai.unam.mx/wp-content/uploads/2018/03/Libro-Merino-Agenda-Amb-UNAM-web.pdf
[8] Butler David & John W. Davies (2011). Urban Drainage. United Kingdom. Taylor and Francis Group.
[9]Richie Hannah and Max Roser (2019). Water Use and Stress. Our World Data. https://ourworldindata.org/water-use-stress#:~:text=Globally%2C%20approximately%2019%20percent%20of,%2C%20industrial%20and%20domestic%20uses).
[10] Nestlé Waters achieves zero waste to landfill. (2014). *Food & Drink Technology*, *13*(10), 8.
[11] Public Utilities Board (2018). PUB Our Water, Our Future Report. Singapur. Obtenido de: https://www.pub.gov.sg/watersupply/fournationaltaps. Consultado en mayo 2020.
[12**]** Melbourne Water (2013) Water Sensitive Urban Design Guidelines. Australia.
[13] SAMCO (2017). What is zero liquid discharge and how does it work?. https://www.samcotech.com/what-is-zero-liquid-discharge-and-how-does-it-work/
[14] Lloyd Owen David (2018). Smart Water Technologies and Techniques. UK. Wiley & Sons.
[15] UNISDR (2009). UNISDR Terminology on Disaster Risk Reduction. UN. Switzerland.
[16] El Sol de México (2018). Comercios denuncian pérdidas por 400 mdp por corte de agua. https://www.elsoldemexico.com.mx/metropoli/cdmx/comercios-denuncian-perdidas-por-400-mdp-por-corte-de-agua-2640800.html. Consultado en mayo 2020.
[17] Musicò, F., Marchese, A., Sipala, K., & Di Natale, F. (2019). Application of Zero Water Waste Model in the Brewing Industry by Using Reverse Osmosis. *Procedia-Environmental Science, Engineering & Management*, *6*(2), 187.
[18] Koppol, A. P. R., Bagajewicz, M. J., Dericks, B. J., & Savelski, M. J. (2004). On zero water discharge solutions in the process industry. *Advances in Environmental Research*, *8*(2), 151–171. https://doi.org/10.1016/S1093-0191(02)00130-2
[19] Sharifi, H., Ostovan, K., Tayebi, M., & Rajaee, A. (2017). Dry sliding wear behavior of open-cell Al-Mg/Al2O3 and Al-Mg/SiC-Al2O3 composite preforms produced by a pressureless infiltration technique. *Tribology International*, *116*, 244–255. https://doi.org/10.1016/j.triboint.2017.07.023
[20] Ariu, A. (2016). Crisis-proof services: Why trade in services did not suffer during the 2008–2009 collapse. *Journal of International Economics*, *98*, 138–149. https://doi.org/10.1016/j.jinteco.2015.09.002