Journal of Sustainability Science and Management
Volume 12 *Number* 1, June 2017: 49-59

ISSN: 1823-8556

PERCEPTIONS ON OZONATION WATER TREATMENT USE: AN ALTERNATIVE IDEA FOR ASEAN WATER RESOURCE SUSTAINABILITY

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Abstract: Ozonation (or ozonisation) is a chemical water treatment technique based on the infusion of ozone into water. As early as 1893, this process was used in Europe for the treatment of drinking water and as recently as 2014, the most modern ozone water treatment facility in the world was brought online to protect the waters of Switzerland's Lake Geneva. However, studies vary widely in conditions leading to ozone technology use, and the subsequent factors concerning its effectiveness. From a population of 7,006 Thai industrial estate companies, a sample of 500 executives, managers, and engineers was drawn which completed an 80-item survey which was analysed by use of a structural equation model using LISREL 8.72. Results showed that acceptance had the greatest influence on ozonation treatment technology use, while the remaining five latent variables (ranked in importance) included curiosity, provisional trial, testing, cognizance, and strategy.

Keywords: Health and safety, structural equation model, Thailand, water disinfectant.

Introduction

Ozonation (or ozonisation) is a chemical water treatment technique based on the infusion of ozone into water, which can be a powerful oxidant, destroying a wide range of organic compounds and microorganisms (Environmental Protection Agency, 1999; Tzortzakis, 2016)

In 2014, one of the most modern wastewater treatment plants in the world was brought online in Dübendorf, Switzerland, which was the first facility in the country to treat micro-pollutants by ozonation followed by a proprietary sand filtration process (McArdell, 2015). This plant was designed to protect Lake Zurich in accordance with new Swiss legislation.

Limiting the micro pollutants discharge in the environment has also become a new issue in connection with organic pollution (Abdel-Raouf *et al*., 2012), with organizations needing to recover and preserve their surface and groundwater environments. Conventional municipal wastewater treatment plants (WWTP) have also become important targets for the upgrading and the implementation of advanced ozone water treatment technologies as tertiary treatment appears essential to protect receiving water bodies (Eggen *et al*., 2014; Rice, 2002).

Reasons for this industry's growth are numerous, as it has long been established that ozone neutralizes bacteria, viruses, fungi, and parasites in aqueous media which has prompted the creation of water purification processing plants in numerous major municipalities worldwide (Sunnen, 2003). Also, ozone can be viewed as the most powerful oxidizing and disinfecting agent that is available for pool and spa water treatment (World Health Organization, 1993).

Ozone is additionally being used in multiple industrial, municipal, and residential water systems. These include potable water, wastewater, process water, and semi-conductor applications (BCC Research, 2015).

This is consistent with a report from the Environmental Protection Agency (1999) that ozone has been employed successfully by a large number of European and Canadian water utilities, with Europeans in particular employing ozone for a wide variety of applications which cannot be accomplished on a practical basis by other treatment techniques. Ozone was also found to be highly effective in removing organic chemical contaminants.

Although chlorination has traditionally been used in the disinfection of municipal water systems, ozone has many advantages over chlorine in this application (Evans, 1972):

1. Safety problems of chlorine storage, handling, and transportation are eliminated. Ozone is produced on-site.
2. Ozone destroys both bacteria and viruses, while chlorine is not very effective against viruses.
3. Shorter treatment times (1 - 10 min for ozone vs. 30 - 45 min for chlorine).
4. Lesser pH and temperature effect with ozone.
5. High dissolved oxygen concentration from ozonation improves receiving stream quality.
6. No toxicity to aquatic life has been found in studies of ozone disinfection.
7. No buildup of bio-accumulatable residuals has been observed in ozone-treated effluents.
8. There is no increase in total dissolved solids in ozone-treated water.
9. Wastewater quality improvements such as turbidity reduction and effluent de-colorization accompany ozone treatment.

This is consistent with research by Rogers (1995) which states that ozone technology equipment has promising growth rate in the waste water treatment equipment, in municipalities, and other water treatment segment which include swimming pools and spas. This growth is attributed to the many benefits associated with the technology. High oxidation potential, quicker processing time compared to other traditional disinfection techniques, no harmful by-product and long run cost benefits are some of the major advantages of ozonation (Phapinyo *et al*., 2007; Persistence Market Research, 2014).

Simple technology and lack of regulatory requirement for ozone generators in most parts of the world have led to the emergence of many small private label regional companies, serving their clients with customized solutions. Seeing the current market and domestic growth opportunities as well as the potential sector growth from integration of Thailand into the AEC (ASEAN Economic Community) at the end of 2015, many Thai companies have stepped into the production and marketing of ozone cleaning technology. However, for large buyers, brand image also plays an important role (Persistence Market Research, 2014).

The above detailed health and safety benefits and characteristics therefore played a key role in the rational for further research. Therefore, this study was undertaken to research the determinants of ozonation water treatment technology developed, marketed, and used by Thai industrial and health-care organizations.

Ozone Water Treatment History

Boglarski and Telikicherla (1995) stated that ozone was used as early as 1893 in Europe for drinking water treatment, and today is the most commonly used disinfection process in Europe (Cheremisinoff, 2002). Christian Friedrich Schönbein discovered the ozone molecule in 1839 at the University of Basel and Werner v. Siemens developed the first ozone tube to generate ozone in 1857 (Kogelschatz, 2003). After that date, different ozone applications were investigated, and in the 1890s the first full scale drinking water plants were using ozone to treat water. The first major ozone installations in drinking water plants using ozone for disinfection were built in Paris (1897) and Nice (1904), France, and in St. Petersburg, Russia (1910).

Until the early 1990s, ozone generation was the major industrial application of DBDs (dielectric-barrier discharge), with thousands of installed ozone generating facilities being used in water treatment applications (Kogelschatz, 2003). For this reason, the dielectric-barrier discharge is sometimes also referred to as the "ozonizer discharge".

Although the USA was decades behind Europe in ozone use, it was not until the passage of the US Safe Drinking Water Act in 1973, that the use of ozone to treat drinking water was increasingly encouraged by the EPA (Environmental Protection Agency). With the identification of halogenated organic compounds formed in drinking water as a result of chlorination, the U.S. Congress quickly enacted the Safe Drinking Water Act in 1973. This original SDWA charged the U.S. EPA to develop and promulgate a number of regulatory initiatives. Subsequently, SDWA amendments (1986 and 1996) added additional regulatory mandates to the EPA, many of which encourage the use of ozone (Rice & Overbeck, 1998).

Statement of the Problem

Research from the Netherlands has recently stated that waste water and sanitation infrastructure in Thailand is underdeveloped (Netherlands Embassy in Bangkok, 2016), with the Thai government indicating that of 59 surveyed rivers and six natural reservoirs nationwide, 43% had fair water quality, 34% turned up good water quality, while 23% contained deteriorated water (Wipatayotin, 2017). The researchers therefore wanted to examine how ozone water treatment technologies were being used and what factors were dependent on water ozonation use through use of both a qualitative and quantitative process.

Literature Review

Acceptance

Acceptance is when users make personal decisions to choose a particular kind of product or service (Kotler & Keller, 2006; Suki, 2013) with one of the most commonly accepted models for studying personal intentions to use or adopt technology being the Technology Acceptance Model (TAM).

In research for the Malaysian wireless Internet industry, services were stated as depending on user acceptance, as well as technology improvement (Lu *et al*., 2005).

This is consistent with Davis (1998) which stated that investigating a user's intentions to accept technology has always been a crucial area in information systems research. Acceptance rate is therefore defined as the relative speed with which members of society accept an innovation and measured by the length of time required for a certain percentage of society to adopt an innovation.

Curiosity

For the benefit of analyzing the adoption of technology from people who do not have any or limited knowledge and experience to help them form a clear viewpoint, their curiosity not only greatly increases their insight into possible benefits, but also enhances their confidence in their ability to handle the technology they are considering adopting (Lu *et al*., 2005).

This is consistent with Gayle's (2007) view, which stated that as the consumer wants more information they really begin to wonder if the innovation can help them and are pro-active in seeking out new information, both explicit and tacit. Their quest is also influenced by sources both inside and outside the community.

Provisional Trial

Provisional trail as in the seeding or marketing trial is a form of marketing, conducted in the name of research, designed to target product sampling towards selected consumers. In software development, beta-testing may also be referred to as conducting seeding trials (Marsden & Justin, 2006).

This is consistent with Bhattacherjee (2001) which stated that influencing one's intention to continue using is determined by the user's satisfaction with information systems use and the technology's perceived usefulness. Additionally, the expectation - confirmation model (ECM) has frequently been used to determine the satisfaction and continued use of information technology (IT) after its acceptance.

This theory, which is based in social psychology, has already proven to be useful in the testing of IT post - acceptance behavior (González *et al*., 2009).

Testing

Technology testing and evaluation is embedded everywhere throughout government agencies and corporate entities. It is an integral component leading up to the selection and use of any service or product.

According to the National Research Council (2004) report on improving water security, the Technology Testing and Evaluation Program (TTEP) was implemented to advance effective security-related technologies by rigorously testing their performance free of charge to manufacturers and making this information available to end users.

Cognizance or Awareness

Cognizance or awareness is one of the key components in determining a customer's acceptance behavior with awareness being one of the variables of consumer brand preference (Alamro & Rowley, 2011).

Lionberger (1968) in early research stated that awareness was a key to using innovative technology. Islam & Gronlund (2011) further stated that cognizance is a person's degree of attentiveness and ability to depict beliefs in a certain time and space as an object whilst influence is the process of creating this cognizance.

Sudhir *et al.* (2012) additionally showed that lack of awareness as one of the hurdles in customers not using wireless telecommunications technology.

Strategy

Strategy and objectives were stated by Chotipanich and Lertariyanun (2011) as important components that organizations needed to define and meet the needs of each customer group. Corporate strategy leads to corporate formulation strategy (Harrison, 1995; Kananurak, 2011), which is focused on who will create opportunities to increase income in conjunction with enhancing organizational customer loyalty.

Corporate leaders must provide customers with a more even value proposition (Persson, 2012) with strategies that better serve business opportunity (Hagen *et al.,* 2003), because different strategies will affect different organizations as well and affect the positioning of one's company (Kalafatis *et al*., 2000).

Use

Chen (2010) argued that if users do not perceive a technology's benefits, they may not use them. Thus, perceived usefulness and user satisfaction are important in motivation. Therefore, the perceived usefulness of information technology or computer technology is an extrinsic motivator of instrumental value (Lee, 2010; Venkatesh, 2000).

Other studies have also shown that perceived ease of use directly influences perceived usefulness and behavioral intention to use (Terzis & Economides, 2011). The TAM states that perceived usefulness has a direct effect on user's behavioral intention, and perceived ease of use affects behavioral intention indirectly through perceived usefulness (Davis, 1989).

Therefore, the researchers wish to propose the following hypotheses which are also depicted in the conceptual model shown in Figure 1 below:

H_1: Strategy has an effect on curiosity.
H_2: Cognizance has an effect on curiosity.
H_3: Curiosity has an effect on provisional trial.
H_4: Curiosity has an effect on testing.
H_5: Testing has an effect on provisional trial.
H_6: Provisional Trial has an effect on acceptance.
H_7: Testing has an effect on acceptance.
H_8: Acceptance has an effect on use.

Methodology

Questionnaire Design

Questionnaires were to measure concept definition and practice of ozone cleaning technology use within Thai industrial estates and in the eastern and central regions. To establish questionnaire reliability 50 individuals in their respective fields were selected to test questionnaire reliability using a Cronbach's alpha coefficient, which in this study had a reliability level of 0.97.

Data Collection

Data collection was conducted between July and August 2014. The sample was drawn from a population of 7,006 companies located in Thailand's 56 industrial estates. Using a 2-step method involving probability sampling and multi-stage sampling, the final population was determined to be 6,861 companies located in industrial estates in both the central region and on Thailand's eastern gulf seaboard (Table 1).

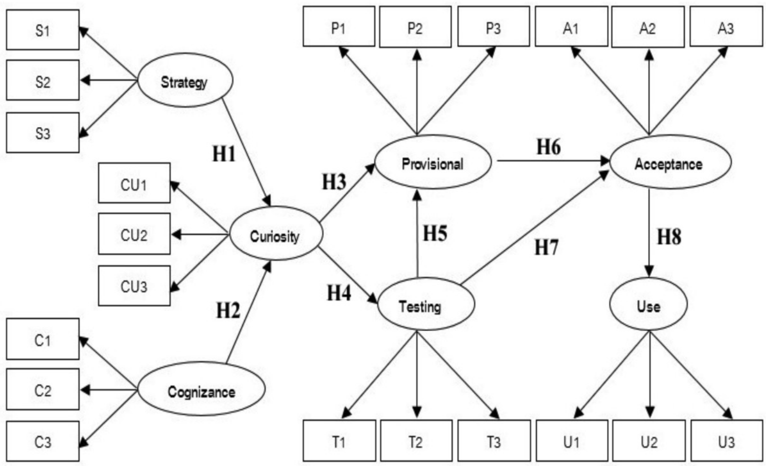

Figure 1: Conceptual model of ozonation water treatment use

This represented a 98% of the total registered industrial estate companies in Thailand in 2014. The sample subsequently included the Bang Poo, Bangplee, and Lat Krabang Industrial Estates, as well as industrial facilities in Amata Nakorn, Amata City. Mataphut, and Laem Chabang Port.

Table 1: Thai industrial estates in 2014

Region	Locations	Companies
Central	17	2,310
Eastern Seaboard	29	4,551
Western	1	-
Northern	5	116
Southern	2	29
Northeast (Isan)	2	-
Total	**56**	**7,006**

Various means were used to inform each estate's management offices of a free seminar which was to discuss ozone water treatment technologies. These offices and their staff along with university students, followed up with emails, letters, and phone calls that eventually led to a total of 840 seminar attendees on multiple days and times. This represented an initial response rate of 22%. The seminar attendees represented decision and policy makers, purchasing agents, executives, managers, engineers, or technicians. Of the 840 attendees, after collection and audit of the 80-item survey, 500 were deemed usable for use within the study on ozone water treatment technologies. This represented a final response rate of 7.29%.

From the sample size determined by Schumacker & Lomax (2010), the researchers used the 10-20 sample size suggested for each variable. Using 20 as the optimum number and with the research consisting of 21 variables, 420 samples were deemed appropriate of which 500 were obtained.

Use

The scales of ozone cleaning technology use consisted of 3 observed variables including testing (U1), business use (U2) and corporate social responsibility (CSR) (U3) use.

Strategy

The scales of strategy have been developed with an analysis tool and questionnaire using a 5-point Likert Scale as a measuring scale (Likert, 1972) which measures three aspects including modern (S1), organizational development (S2) and corporate social responsibility (CSR) (S3).

Curiosity

The scales of curiosity have been developed with an analysis tool and questionnaire using a 5-point Likert Scale as a measuring scale (Likert, 1972) which measures three aspects including working principles (CU1), work methods (CU2) and the beneficial curiosity (CU3).

Cognizance

The scales of cognizance have been developed with an analysis tool and questionnaire using a 5-point Likert Scale as a measuring scale (Likert, 1972) which measures three aspects including learning/training (C1), competitor recognition (C2) and media perception (C3).

Provisional Trial

The scales of provisional trial have been developed with an analysis tool and questionnaire using a 5-point Likert Scale as a measuring scale (Likert, 1972) which measures three aspects of including quality control testing (P1), older systems compliance (P2) and testing impact. (P3)

Testing

The scales of testing have been developed with an analysis tool and questionnaire using a 5-point Likert Scale as a measuring scale (Likert, 1972) which measures three aspects including quality control (T1), compliance verification (T2) and testing impact (T3).

Acceptance

The scales of acceptance have been developed with an analysis tool and questionnaire using a 5-point Likert Scale as a measuring scale (Likert, 1972) which measures three aspects of trial which include standard quality acceptance (A1), performance recognition (A2) and service quality acceptance (A3).

Results and Discussion

The organization or grouping of the items was confirmed by LISREL 8.72 confirmatory factor analysis (Jöreskog & Sörbom, 2001) and the goodness of fit index (GFI) statistics to extract the following: follows the c2 insignificant. Statistically significance is ($p > 0.05$) or the c2 / df <2.00 for Steiger's (1990) RMSEA (root mean square error of approximation) <0.05; for GFI (Goodness of Fit)> 0.90 for AGFI> 0.90 and SRMR <0.05 (Table 2).

The research found that the variables that influence use the most are acceptance, followed by curiosity, provisional trial, testing, curiosity and strategy (Figure 2; Table 2 and 3).

All causal variables in the model have a positive influence on the use of ozone technology within Thai industries. The final structural model was verified to achieve a good fit with the empirical data at 65% because of the decision to use new products in ozone water treatment technology. The product acceptance and use process is a mental process in which the individual goes through a process from first hearing about a new product until final acceptance (Kotler & Armstrong, 2013).

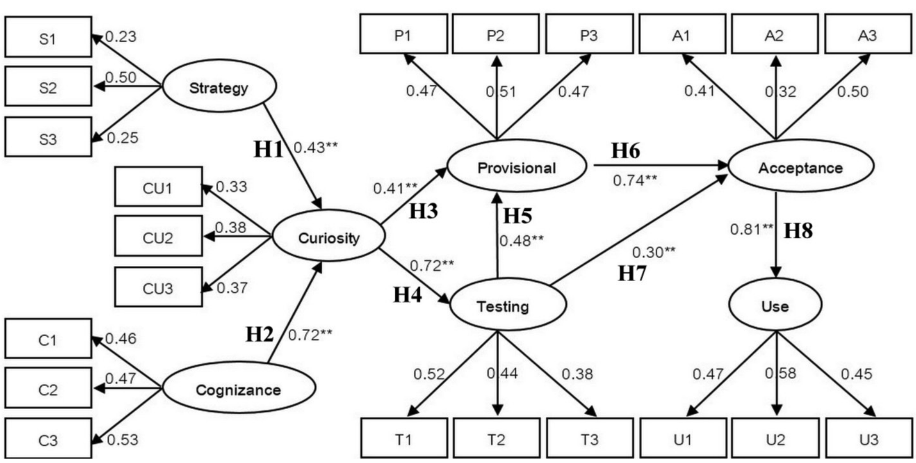

Figure 2: Structural equation final model ozonation water treatment use

Table 2: Direct, indirect and total effects of influencing variables on affected variables

Latent Variables	Curiosity			Testing			Provisional			Acceptance			Use		
	DE	IE	TE	DE	IE	TE	DE	IE	TE	DE	IE	TE	DE	IE	TE
Strategy	0.39** (0.08)	-	0.39** (0.08)	-	0.28** (0.04)	0.28** (0.04)	-	0.29** (0.04)	0.29** (0.04)	-	0.30** (0.05)	0.30** (0.05)	-	0.24** (0.04)	0.24** (0.04)
Cognizance	0.72** (0.10)	-	0.72** (0.10)	-	0.52** (0.05)	0.52** (0.05)	-	0.54** (0.04)	0.54** (0.04)	-	0.55** (0.05)	0.55** (0.05)	-	0.45** (0.04)	0.45** (0.04)
Curiosity	-	-	-	0.72** (0.10)	-	0.72** (0.10)	0.41** (0.10)	0.34** (0.06)	0.75** (0.10)	-	0.77** (0.10)	0.77** (0.10)	-	0.62** (0.09)	0.62** (0.09)
Testing	-	-	-	-	-	-	0.48** (0.08)	-	0.48** (0.08)	0.30** (0.07)	0.35** (0.07)	0.65** (0.07)	-	0.52** (0.06)	0.52** (0.06)
Provisional	-	-	-	-	-	-	-	-	-	0.74** (0.07)	-	0.74** (0.07)	-	0.60** (0.06)	0.60** (0.06)
Acceptance	-	-	-	-	-	-	-	-	-	-	-	-	0.81** (0.05)		0.81** (0.05)
Structural Equation Fit R^2		79			52			67			97			65	

Chi-square=62.09, df=65, P-value=0.58, RMSEA=0.00 GFI=0.99, AGFI=0.96, SRMR=0.02
DE: Direct effects, IE: Indirect effects, TE: Total effects **p<0.01

The information about the service is the first stage of the adoption process that will lead awareness, interest, evaluation, trial and adoption of innovation with the information of the innovation being the first stage of the adoption process (Rogers, 1995) that creates awareness and interest until make decision to adopt or not adopt innovation. During the curiosity stage need is stimulated and information is sought. During the testing stage, the individual weighs the advantages and disadvantages of the purchase. The provisional trial stage consists of the initial purchase to determine how well the purchase satisfies those unfilled needs.

Acceptance follows a satisfactory trail, and subsequently the product is used on a regular basis (Michman & Mazze, 2001). This is consistent with the widely-cited Technology Acceptance Model (TAM) by Davis (1989) which proposed a model for the acceptance and design of technology. TAM predicts user acceptance of any technology is determined by two factors: perceived usefulness and perceived ease of use.

Table 3: Results of hypotheses testing

Hypotheses	**Coef.**	**t-test**	**Findings**
H_1: Strategy has an effect on curiosity.	0.39	5.03*	Supported
H_2: Cognizance has an effect curiosity.	0.72	9.31*	Supported
H_3:Curiosity has an effect on provisional trial.	0.41	3.97*	Supported
H_4: Curiosity has an effect on testing.	0.72	7.50*	Supported
H_5: Testing has an effect on provisional trial.	0.48	5.89*	Supported
H_6: Provisional trial has an effect on acceptance.	0.74	10.01*	Supported
H_7: Testing has an effect on acceptance.	0.30	4.11*	Supported
H_8: Acceptance has an effect on use.	0.81	16.15*	Supported

*Sig. < 0.05

Other scholars such as Venkatesh *et al.,* (2003) added that TAM argues that users' intent to use a technology is influenced by their perceptions of its usefulness and ease-of-use, among other factors. Perceived usefulness is a user's belief in the ability of the device to make common tasks easier. Perceived enjoyment is derived from a user's perceptions of a device being "enjoyable" in its own right apart from any consequence of system usage (Venkatesh, 2000).

Rogers (1995) extended on this theory in stating that groups have the potential for change with diffusion occurring in a five–step decision-making process. Diffusion occurs through a series of communication channels over a period of time among the members of a similar social system. Rogers' five stages or steps which were integral to the theory included: awareness, interest, evaluation, trial, and adoption.

Wood and Moreau (2006) further qualified Roger's steps in which it was stated that innovation acceptance is rarely a short process for customers with research suggesting that acceptance is rarely a neutral process. Additionally, customers can experience strong and sizable feelings and emotions in the early stages of technology use but it is not always straightforward in the sense that "easier is better."

Huijts *et al*. (2012) found that problems related to environmental and societal energy use have spurred the development of sustainable energy technologies, with public acceptance of these technologies being very important for their successful utilization within society. This is supported by Malaysian research by Suki (2013) concerning the labelling and branding of environmentally friendly products. Results revealed that a consumer's perception of the quality of eco-product labeling was the strongest determinant of their actual purchase behaviour of a green product.

Consumer product customization was studied as a component of corporate marketing strategies by Franke *et al*. (2009). In this study a key assumption was researched in which customized products create higher benefits for customers than standard products because they deliver a closer preference fit. The hypotheses turned out to be accurate as it was discovered by the researchers that products customized based on customer preferences bring about significantly higher benefits for customers in terms of willingness to pay, purchase intention and product attitude over standard products.

Benefits gained are higher if customers have a better insight into their own preferences, a better ability to express their preferences and a higher involvement with product. The research further determined that customization has the potential to be a powerful marketing strategy if these conditions are met.

The main findings of this study are the process of technology implementation within an enterprise. There are variables that influence various levels of perceptions and evaluations of the technology utilization from those held in a wider society. Thais however, no matter which social strata or group they belong to; do tend to follow the same psychological evaluation path of technology implementation within an enterprise, from the testing stage, through the implementation stage and finally the use stage.

This is supported by all the causal variables in the model having a positive influence on the ozone water treatment use which can be explained by the variability of ozonation water treatment use at 65%. The final structural model was verified to achieve a good fit with the empirical data.

The latent variables having a direct influence on the use of ozonation water treatment technology is acceptance with the influence of 0.81, while the remaining five of the variants, strategy and cognizance, curiosity, testing and provisional trial having only an indirect influence on the use of ozonation water treatment technology.

This study's determinations are supported further by the fact that ozone is much more effective as a disinfectant than chlorine and is used extensively in Europe to purify water. Research has proven that ozonation technology when used as the basis for the removal of persistent micro pollutants contained in a municipal bio treated wastewater effluent is suitable to remove the major part of the organic micro pollutants. Additionally, from the literature review, ozonation technology was shown to be effective in removing secondary urban micro pollutants effluents regulated by European Directives.

Considering the priority of the variables caused by the combined influence of the individual variables showed, variables that influence the use of ozonation water treatment technology most are; acceptance, curiosity, provisional trial, testing, cognizance, and strategy, 0.81, 0.62, 0.60, 0.52, 0.45 and 0.24, respectively.

Conclusion

The water and waste management industry is gaining importance as growing environmental awareness drives the need to provide sustainable water solutions and use effective green waste management techniques. Water conservation, such as rainwater harvesting and water treatment technologies, are being developed to handle water management problems in big communities, commercial establishments, mining environments, and the like. Additionally, under Thailand's King Rama IX's philosophy of sustainability for survival, water conservation and sustainability have been given a high priority, and formalized as a framework within the national social and economic development plan (2012-2016) (Poungsuk *et al*., 2016).

Acknowledgements

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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