Desalination and Water Treatment
www.deswater.com
doi: 10.1080/19443994.2016.1141325

57 (2016) 24231–24239
November

Taylor & Francis
Taylor & Francis Group

A game theoretic approach to implementation of recycled drinking water

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Received 9 September 2015; Accepted 6 January 2016

ABSTRACT

Singapore is known as a successful example of implementing recycled drinking water (NEWater) policy. Acceptance of recycled water could be seen as a new social norm (NEWater norm). We first use a discourse analysis to investigate people's perception on recycled drinking water. Such perceptions incorporate psychological disgust ("yuck" factor) as well as social concerns (water security, economic incentives, long-term sustainability). Based on these perceptions, game theory approach is applied to analyze the emergence and evolutionary process of the NEWater norm. We find that, a "thick" perception on recycled drinking water entails the possibility of new norm formation; in such an environment, acceptance of NEWater will gradually penetrate into the whole population from an even small portion of leaders.

Keywords: Recycled drinking water; Water reuse; Implementation; Perception; Game theory; Social norm; Evolution

1. Introduction

Recycled drinking water represents one of the most obvious and technologically reliable sources of urban water. A United Nations report in 2012 [1] on water states that: "While most cities would refrain from using treated wastewater as a source of drinking water, this avenue is also available and has been implemented, for example, in water-scarce Singapore and the International Space Station, without ill effects." The UN has also recommended the strategy of recycling wastewater to water-stressed countries, citing the particular case of Singapore.

Yet, recycled drinking water remains one of the least implemented solutions. The issue as it is currently framed pits the scientific community against consumers and users, arguing that it is the failure to remove psychological and emotional barriers that results in the failure of implementation. For example, water reuse is "constrained by policy and community reluctance to seriously consider any form of potable use" [2]. More specifically, water-reuse policies have been resisted by the public who do not have sufficient information. Within water policy debates, the argument has centered on poor communication of technical information, education of the public and the important role of scientific knowledge. Lastly current research also shows that the only factor that has been empirically identified as a statistically significant variable for the implementation of water-reuse policies is the "yuck" factor, a psychological and social norm [3,4]. The case of Singapore presents a counter to the hypothesis that the "yuck" factor is a social factor that

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cannot be overcome. Since 2001, Singapore has successfully implemented recycled drinking water (named NEWater), and been frequently cited as a positive model of such implementation and water management [5–8].

This paper attempts to investigate the idea of "public acceptance" of recycled drinking water as an informal institution or "social norm". The authors rely on institutional studies of perceptions, informal institutions, and institutional change, working off the premise that ideas are the key drivers of change. It uses game theory to show how under conditions of perfect rationality, a community can change its social norms and gradually accept recycled drinking water. It demonstrates this using the specific case of Singapore in implementing its water-reuse policy.

The work pulls together different theoretical and methodological approaches to give an exposition of how individuals perceive the recycled drinking water in Singapore and make strategic choices according to their different beliefs, how norms are formed through social interactions, and finally, how they affect the implementation of water-reuse policies. Given these research questions, we shall propose the following hypotheses:

H1. Preferences of individuals are heterogeneous in terms of acceptance levels, and do not fall neatly into a pro-anti dichotomy.
H2. Acceptance of NEWater is a social norm whose emergence can be understood through strategic interactions of individuals.

Overall, the aim of this work is to tie the issue of water-reuse implementation to research on social norms/informal institutions and use this framework to examine whether, why and how people would accept recycled drinking water.

2. Literature review

It is widely acknowledged that public perception, especially public acceptance of recycled drinking water is the key determinant of the policy implementation [9,10]. As asserted by Dishman [11]: "… the issue of public acceptance could kill the (reuse) proposal. In view of this very possible scenario, a strategy (based on applied behavioral analysis and social marketing) should be developed to deal with public unwillingness to drink reclaimed water". Earlier works have been done in the US and the researchers majorly find the following [12–17]:

(1) Public perception of recycled water depends on factors such as knowledge/information, education, as well as trust in authorities.
(2) Psychological feelings such as disgust, unconscious fear of contamination, risk perception also matter.
(3) Some demographic variables may play a role in public acceptance, e.g. age and gender.
(4) People are readily accepting non-potable use of recycled water such as irrigation and industrial water reuse, but reluctant of potable use.

A significant amount of research has been done in various countries and regions including Puerto Rico [18], Australia [19–23], the United Kingdom [24,25], Greece [26,27], the United States [28,29], the State of Bahrain [30] and Kuwait [31]. Most of the research has adopted a survey method to study the general acceptance level for different uses of recycled water, and empirically tested the hypothesized factors that will influence the public perception on water reuse. Similar evidences are found to support the above-mentioned arguments [18–20,25,26,28]—that people are very open to using recycled water with low personal contact, but reject the uses with highly personal contact such as for drinking or bathing a baby. Singapore has been widely cited to be a successful case of water reuse [3,32]. Leong [33] takes a quantitative method to examine the "yuck" factor and the role of media in shaping the public opinions on NEWater. Mainali et al. [10] also point out that public awareness of water security of the nation largely attributed to the implementation of the policy. However, there has been little empirical evidence to reflect the status quo of public perception on the recycled water in Singapore.

The second series of relevant research is on social norm and institutional change. Institutions are "humanly devised constraints that structure human interactions", which consists of formal constraints (e.g. rules, laws, constitutions) and informal constraints (e.g. norms of behavior, conventions, self-imposed codes of conduct). In short, institutions "define the incentives in the society." [34]. In terms of water institutions, Saleth and Dinar [35] define institutions as "subjective constructs", emphasizing that it is not information perse, but the perception of information that accounts for how institutions are constructed and changed. Knowledge and institutions are regarded as substitutes, which provide the basis for making sound decisions. They propose the subjective construction and the concept of "perceptional convergence", which occurs when there is wide consensus or "the articulation or solidification" of the demand for institutional change. Such change could be expedited by cultural

influences, the persuasive power of moral authorities, as well as information flow and learning.

Institutions are not immutable but change through time. North [34] has presented a theory of institutional change and pointed out that the "agent of change is entrepreneur, the decision-maker in organizations." He argues that choices that lead to institutional change are triggered by a mixture of external and internal change. In particular, informal institution changes "occur gradually and sometimes quite subconsciously as individuals evolve alternative patterns of behavior consistent with their newly perceived evaluation of costs and benefit". Modifying North's theory, Baumgartner and Jones [36] argument of institutional change emphasizes the interaction of beliefs and values concerning a particular policy and the prevailing set of political institutions. They found that political institutions both formal and informal progress through "punctuated equilibrium", i.e. periods of relative stability, punctuated by crisis and change. Culpepper [37] has adopted a more micro level of analysis, and demonstrated that institutional change progresses in three stages: crisis, experimentation, and consolidation.

There are several works on the implementation of water policies, adopting the theoretical framework of institutional change and social norm evolution. In explaining the unsuccessful urban stormwater management, Brown [38] points to the inertia caused by technocratic norms and institutional power and expertise as well as values and leadership. Meinzen-Dick [39] found that norms such as the authority from religious figures, affect the success of irrigation projects in India. Pahl-Wostl [40] examined the water management regimes and transition processes in Europe and found that change is due to "adaptive management" from social and collective learning, and is impeded by a set of "interconnected" factors for maintaining the status quo. Miller and Buys [41] studied a water recycling program in Australia and concluded that people perceive a serious water crisis with support for implementing water-reuse policy, despite the existing norm of personal revulsion against drinking recycled water.

The most relatable work to ours is the evolution theory of social norms. The emergence and change of social norms could be understood as an evolutionary process [42–46]. According to this approach, individuals carrying the more successful strategies for an environment reproduce at a higher rate. After many iterations, the more successful strategies come to prominence in the population. Social norms, which are defined to be shared understandings about actions that are obligatory, permitted, or forbidden [47], are then gradually formed; and norms could be learned and could evolve, similar to human's inherited propensity to learn grammatical rules [48]. Guth and Kliemt [49] propose the indirect evolutionary approach, in which social norms may impose different subjective utilities to individuals and thus lead them to behave differently in the same objective situation, depending on how they perceive and value the current norm. We are going to use this approach to construct an evolution game of the water norm in our context.

3. Singapore water story

Singapore has been importing water since 1927 [50]. In 1961, the City Council signed the Water Agreement with the State of Johor in Malaysia, under which Singapore had gained use of the water within the Gunong Pulai and Pontian catchments, as well as the Tebrau and Scudai Rivers for 50 years [50]. In 1962, another agreement was signed "for the supply of up to 250 million gallons of water per day (mgd) from the Johor River, until 2061" [51]. Singapore achieved full internal self-government (from the British) in 1959, and became part of Malaysia in 1963. Three years later, it was clear that the political merger of Singapore with Malaysia had failed. This failed merger led to difficult bilateral relations, including water and notwithstanding the 1961 and 1962 Water Agreements.

At the time, there were approximately 1.6 million people living on the island. Public health provision was poor, and waterborne disease such as cholera was common because of poor sanitation. During the wet season, many parts of the city were underwater, whereas during the dry months, water had to be rationed. Water demand grew exponentially in the 1980s and 1990s. Water-saving devices such as constant flow regulators and self-closing delayed action taps were made mandatory in all non-domestic premises. Fortunately for Singapore, this was a period of amicable relations, during which Singapore was increasing water imports from Malaysia through water agreements, Memorandums of Understanding to construct reservoirs and agreements to construct more dams.

But ties deteriorated after the Asian Financial Crisis in 1997–1998. In 1999, three meetings were held between Singapore and Malaysia to make progress on water and other bilateral issues. In the early 2000s, Malaysia suffered water shortages, and thus the Singaporean leaders were more concerned about the water issue. It was clear that a crisis had been reached and Singapore had to seek alternative solutions, such as recycled water.

Singapore had been experimenting with recycled water since 1974. Its first pilot water reclamation plant, a $1.3-million project with a capacity of 381,360 L of

water a day, had problems such as a strong smell of ammonia. It was subsequently shut down in late 1975 after the trial, and never released to the public [52]. At the time, there was no technology available for economically attractive and reliable recycled water. But by the 1990s, with the advances of technology there were better quality membranes and the cost had halved. In 1998, Public Utility Board (PUB) and the Ministry of the Environment revisited the idea to recycle water and formulated a reclamation study. The $6.5-million demonstration plant, located on a site downstream of the Bedok Water Reclamation Plant, started functioning in May 2000, and produced 10,000 m^3 of water per day [52]. The reclaimed water from this plant was monitored regularly over a period of two years, when an expert panel gave it a clean bill of health in terms of quality and reliability [53]. The quality of treated water was found not only to be better than the water supplied by PUB but also met the water quality standards of the Environmental Protection Agency of the United States and the World Health Organisation [54]. The government was inspired by the achievement and thus increased the investments in 2003 of the order of S $116 million [55]. During the period of 2002–2004, the amount of wastewater treated had increased from 1.315 to 1.369 MCM/day [56].

By 2001, PUB released recycled water for non-potable use—wafer fabrication processes, non-potable applications in manufacturing processes as well as air-conditioning cooling towers in commercial buildings. In September 2002, the name NEWater was given to recycled drinking water, an additional source of drinking water. A small amount of NEWater (2 mgd in 2002 and 5 mgd in 2005, or about 1% of the daily consumption of the country) is blended with raw water in the reservoirs, which is then treated for domestic use [53]. By 2014, up to 35 mgd of NEWater was injected into the reservoirs per day in dry seasons from January to March to maintain reservoir stock levels. With a 100% sewer connection, all wastewater is collected and treated. NEWater currently meets 30% of Singapore's water demand and this is set to increase to up to 55% in the long term [57].

4. Perceptions and preference of NEWater—a discourse analysis

Limited studies have investigated in depth, the public perception of NEWater in Singapore. Howe and Mitchell [58] focused on the intentional public education campaign from the PUB, including introducing the recycled water technology, changing the terminology from wastewater to "NEWater", relating and communicating with different stakeholders, as well as setting up of the NEWater Visitor Centre. Thus, Singapore was said to be successful in promoting the idea of recycled water to the public, "by building the water-reuse campaign on public confidence and acceptance, NEWater has been from zero to the hero of Singapore's water sustainability, as well as the global water fraternity" [58]. Leong [59] studied the role of media in shaping public perceptions. From a review of 223 reports on recycled water from 1997 to 2008 in Singapore, it was found that 171 of these carry positive tones or opinions on NEWater and only 9 reports had negative tones or opinions. In Singapore, media mostly employs a supportive language such as "costless", "purified", and "tried and tested". Furthermore, the news coverage has consistent key messages which help to reduce the uncertainty in the public perception and reinforce the concept of NEWater.

Besides these qualitative descriptions, statistical evidence is even less with regard to the public acceptance of recycled water. The most officially cited[1] independent poll by Forbes Research in October 2002 showed an astonishing 98% acceptance of NEWater among the subjects, with 82% indicating that they were ready to drink it directly, while 16% were prepared to drink it indirectly through mixing with the reservoir water. However, another report cited two rough surveys conducted by the New Paper and the Straits Times, which led to different results: both found that more than 80% of the subjects show reluctance or regard NEWater as tasting different from tap water. They even choose to pay more for imported water than drink NEWater [61].

The current paper examines the public attitude toward NEWater based on a Q sort. Q methodology has been increasingly used by policy analysts for its ability to uncover and represent stakeholder positions and their interrelations [62–64]. According to the Q sort conducted by Leong [65], three themes of discourses are identified with eight significant factors that represent the key attitudes of the public. The three main discourses include the technology issues, the security and economic issues, and the long-term sustainability issues. The discourses and factors are summarized in Table 1.

The first discourse shows that technology is perceived to be a key component to not only ensure the water supply, but also to shift the attention away from the water source (wastewater) by focusing on the treatment process. The two factors here highlight the role of technology and reason: rather than pitching

[1]The data was cited in various incidences of government documents, including PUB report [60], National Archive of Singapore, as well as PUB officers' public presentations.

Table 1
Public perceptions towards NEWater

Discourse 1	*Technology can change current paradigms*
Factor 1	Technology can overcome water shortages
Factor 2	Water security remains a real problem for Singapore
Discourse 2	*Water security is a problem with an economic cost*
Factor 3	Water should be priced to reflect cost of supplying it
Factor 4	Innovations in water management, such as pricing and recycling, help ensure good supply of water
Factor 5	Singapore has severe physical and energy constraints and needs to choose the most cost-efficient way of producing water
Discourse 3	*Environmental and global realities make it imperative to recycle water*
Factor 6	Recycling water is a way of preserving independence and continued growth
Factor 7	The science of recycling still needs to be better known and there is still an instinctive rejection of drinking sewage water ("yuck" factor)
Factor 8	As climate change and global water scarcity take root, recycled drinking water is a way to ensure water supply

"yuck against science", it is "science against scarcity". It is the country's endeavor to deal with water problems with science and technology, and the public is kept informed by the highly technical details.

The second discourse reflects the general attitude over the status quo of water and how the particular perception of recycled water is formed. Water, as is essential to life, holds a strong security and strategic dimension which is particularly conspicuous to Singapore. It is widely agreed by Singaporeans that the nation remains vulnerable to its neighbor Malaysia due to the reliance on imported water. However, via open discussions and comparison on recycled water and other alternatives such as desalinated water, many people are aware that NEWater is a more economical option. The notion of secured water supply, in a Singaporean context, is tied inextricably with economic cost.

The third discourse relates to the "larger" issues beyond the immediate and individual interest. When individuals are concerned about long-term and irreversible effects (such as climate change, global scarcity of fresh water), they are inevitably imposed with more weight on the desirability of NEWater. Considering the intrinsic rejection to recycled water—the "yuck" factor—it is clear that one is not immune from such psychological concerns. Instead of being eliminated, it is rather overcome by a larger need to cope with global environmental challenges.

These narratives reveal the perceptions and preferences of individuals toward the recycled drinking water. Singaporeans (who are exposed to an extremely severe situation of water scarcity and national security) perceive the water issue from a more strategic perspective. From a personal survival perspective, safe drinking water needs to be an economical incentive. Further to the strategic consideration of long-term sustainability, people are prudent in considering this issue [65]. Hence, the common understanding that public resistance/acceptance of water reuse mainly roots on the "yuck" factor should be revisited and the public attitude is far beyond the dichotomous discourse of pro- vs. anti- recycled water. Furthermore, individuals put different weight on these factors and hence the levels of acceptance differ across a population. Such heterogeneity of preference builds the foundation of the individual choice in social interactions and thus enables the process of norm formation and evolution, which shall be discussed in the next section.

5. Emergence and evolution of newater norm—a game theoretic approach

Social norms do not appear without context. Norms, which could be seen as shared beliefs of how people should behave or act in particular circumstances, emerge from some choices already made by forerunners. Hence, the individuals' choices and interactions make the foundation of norm formation, and game theory in rigorous research. To analyze the particular norm of accepting recycled drinking water, which is referred to as the NEWater norm, we adopt an indirect evolutionary approach proposed by Guth and Kliemt [49]. This theory elaborates how individual choice evolves to the social collective choice, and helps us to understand how a new social norm is developed.

We shall start from a simple "NEWater game", where people only have "thin" preferences on recycled water. Suppose in the population, individuals are

randomly paired to play a strategic "NEWater game", the strategy each one could choose is either "accept" or "reject" to drink the recycled water. Such interactions happen in practice in the form of interpersonal communication or peer influence. When asked to express opinions or make a decision, one should take into account the intrinsic taste (such as "yuck" factor) as well as common social factors (such as long-term water supply of the nation). These preferences determine one's "payoff", or utility, or gains from accepting or rejecting NEWater. The above-mentioned "thin" preferences implies that the payoff structure is in a simple form. So, we can construct the following game form.

NEWater Game[2]

		Player 2	
		Accept	Reject
Player 1	Accept	(*M*, *M*)	(0, *H*)
	Reject	(*H*, 0)	(*L*, *L*)

The payoff assigned to each individual given different combinations of choices are parameterized with the assumption that *H(igh) > M(edium) > L(ow) > 0*. This assumption could be interpreted as a synthesis of individual and social values. Due to the scarcity of water resources, the NEWater program is more than necessary for the island country; thus if all the citizens reject the program, the situation of water supply in the long term would deteriorate and the welfare of all would be compromised. Hence, the socially optimal choice is for everyone to "accept" the recycled water. Yet, one particular individual would like everybody else to use NEWater while he himself chooses not to do so, so that he could then avoid the psychological distaste of water reuse but benefit from the cooperative action of acceptance from others. In other words, each rationally selfish[3] player has an incentive to defect. This is hence a well-known prisoners' dilemma, ending with the consequence of (reject, reject) for both players. Therefore, given that peoples main concern is the "yuck" factor, such interpersonal interactions only lead to the non-cooperation of the whole society.

Fortunately, from the previous section we can confidently say that Singaporean's preference on NEWater is not a static one, but multifaceted in terms of different factors and concerns that are associated to the attitudes toward water reuse. The game should then be modified to fit the more realistic public perception, or "thick" preference of recycled water. To model the heterogeneous preferences, a term of "subjective utility" S is introduced to add to the (objective) payoff parameter if a player i chooses the strategy "accept". Thus, the individual's total payoff becomes $M + S_i$ instead of M. Note that the subscript i captures the fact that the subjective utility could be different across individuals. Now, the modified NEWater game played is illustrated as follows.

Modified NEWater Game

		Player 2	
		Accept	Reject
Player 1	Accept	$(M + S_1, M + S_2)$	(0, *H*)
	Reject	(*H*, 0)	(*L*, *L*)

With the new construction, the result of the game is not as straightforward as previously demonstrated. The equilibrium choice depends, by and large, on the values of S_i, as well as the type of player one has encountered.[4] For simplicity of analysis, let S_i be binary[5] between $\{S^h, S^l\}$. This essentially means that we identify two typical preferences in Singaporeans, highly supportive of NEWater vs. less supportive of NEWater. Reflected in the payoffs, the values of parameters are assumed to be $S^l < H–M < S^h$, which implies that the highly supportive type is ready to overcome the "yuck" factor and behave in a cooperative manner, while the less supportive type remains reluctant to use the recycled drinking water. The latter is quite a common phenomenon in reality, especially in the early stages of a water-reuse program. People may be more or less concerned about water security, cost efficiency as well as long-term sustainability; however, such concerns may not be strong enough to incentivize the determination of accepting NEWater against the instinct disgust. That is, the acceptance level is low. For this outcome, we investigated the interactions of individuals to see how a small portion of coop-

[2]This is a game representation with two players, whose strategies are either "accept" or "reject". By making one's own choice, the resulting strategy pair corresponds to each bracketed pair of payoff parameters for the players. Conventionally, the first parameter is the payoff for row player (Player 1) and the second parameter refers to the payoff for column play (Player 2).

[3]The term "selfish" does not refer to any emotional sense. It is a neutral description of individual player who aims to maximize his own payoff in decision making. This is fundamental assumption of rationality in game theory.

[4]We differentiate players' types by his or her subjective utility of accepting recycled water. This is a conventional assumption in game theory literature.

[5]A wider or even continuous range of S_i does not alter the main results though.

erative behaviors evolve to a social norm that the whole population follows.

We label the highly supportive type as "leader" of recycled drinking water, with an initial fraction of p in the population, and the less supportive type as "conservative" with a fraction of 1–p. When a conservative interacts with another conservative, it is exactly the case of aforementioned prisoners' dilemma game, with the strategies (reject, reject) prescribed and the payoff of (L, L) for each. When a leader interacts with another leader, the game yields the equilibrium of (accept, accept) with a payoff profile ($M + S^h$, $M + S^h$).[6] Noteworthy is the case when a leader (player 1) encounters a conservative (player 2), as is demonstrated in the "Leader-Conservative NEWater Game" below. It is apparent that "reject" is the dominant strategy for the conservative, regardless of what the other player chooses. However for the leader, if his counterpart chooses "accept", he shall also choose "accept"; he shall readily choose "reject" if the conservative rejects —which is however, as we have argued, the deemed action of the conservative. That being said, the only result of the game is (reject, reject), corresponding to the payoff profile of (L, L).

Leader-conservative NEWater game

		Conservative 2	
		Accept	Reject
Leader 1	Accept	($M + S^h$, $M + S^l$)	(0, H)
	Reject	(H, 0)	(L, L)

So far, it is legitimate to conclude that in the population, the leaders are better off than the conservatives simply because the players discriminate their choice when confronted with different types of counterparts.[7]

Next, we shall present the dynamic evolution process to complete the analysis. Throughout the evolution, we would expect the conservative types to gradually transform to the leader type, and finally the choice of "accept" NEWater would become the new social norm. We define a (reproductive) success function R (S_1, S_2), which refers to the average objective payoff of the players in a particular round of game[8]:

$$R(S_1,S_2)=\begin{cases}(M+M)/2=M, & if\ S_1=S_2=S^{\mathrm{h}}\\ (L+L)/2=L, & if\ S_1=S^{\mathrm{h}},S_2=S^{l}\\ (L+L)/2=L, & if\ S_1=S^{l},S_2=S^{\mathrm{h}}\\ (L+L)/2=L, & if\ S_1=S_2=S^{l}\end{cases}$$

Suppose the population initially attains a fraction of p (the leaders) and *1-p* (the conservatives). The expected payoff of both the leaders and the conservatives can be written as follows:

$$\begin{aligned}Exp\Pi(S^{\mathrm{h}}) &= pR(S_1=S^{\mathrm{h}},S_2=S^{\mathrm{h}})+(1-p)\\ &\quad\times R(S_1=S^{\mathrm{h}},S_2=S^{\mathrm{l}})=pM+(1-p)L\\ Exp\Pi(S^{\mathrm{l}}) &= pR(S_1=S^{\mathrm{l}},S_2=S^{\mathrm{h}})\\ &\quad+(1-p)R(S_1=S^{\mathrm{l}},S_2=S^{\mathrm{l}})=pL+(1-p)L\end{aligned}$$

In such a setting, the expected payoff of leaders is higher than that of conservatives for all values of $p \in (0, 1)$. This implies that the former is always more successful than the latter, independent of the population composition. In other words, "being a leader" is a dominant "evolutionary strategy" than "being a conservative". Now it is obvious that even from a very small portion of leaders, this type will infiltrate the whole population until the monomorphic state of $p = 1$ is achieved and it shall remain stable. That is to say, the NEWater norm of accepting recycled drinking water shall gradually emerge and dominate in the society through numerous interactions of individuals and their dynamic adjustment induced by the pursuit of higher payoffs.

6. Conclusion

We have looked into the micro foundation of the formation of the NEWater norm and its evolution process. The key assumption of multi-type players (leaders vs. conservatives) builds on the findings of a discourse analysis on Singaporean's attitude toward recycled drinking water. From the multi-disciplinary analysis we conclude that the experience of Singapore NEWater is an evolutionary process of a new social norm. People's perception on NEWater is found to be

[6]Note that in fact the game by two leaders is a coordination game with two Nash Equilibria, (accept, accept) and (reject, reject). Classic social evolution theory has provided sophisticated tools for such equilibrium selection problems as well as rich evidences. It is well documented that the equilibrium with higher payoff is superior, shall survive and remain stable in an evolutionary process. Refer to [66–69] for further information.

[7]This phenomenon is not only intuitively understandable: one loves to cooperate with cooperators but be tough to egoists; but also has well-established theoretical foundations: such behavior stems from the individuals' reciprocal and fairness concerns [70–73].

[8]In decision making, individuals consider the total (objective and subjective) utility; while in the evolutionary process, it is the objective payoff that matters.

multifaceted; although the "yuck" factor always exists, other social concerns such as economic incentive, security and long-term sustainability also play different roles. These social factors may or may not dominate the psychological disgust and motivate individuals' willingness to accept recycled drinking water immediately; but they validate the existence of individuals with different acceptance levels in the society. NEWater norm first emerges among a small group of leaders who believe that recycled drinking water is imperative to Singapore, and will readily accept it. Gradually, leaders' choices would impact the conservatives in a way that the latter would learn and change their social beliefs to the former type, simply for the incentives of pursuing higher individual payoff. This social norm evolution is realized through individual's rational interaction in the society.

Further research is needed to be done on issues, such as which factors are key to influencing the normative beliefs on recycled water, and how fast or slow the evolutionary process can take. One important issue to address is how policy-makers should proceed in expediting the social norm formation.

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