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Public Perception of Desalinated Water from Oil and Gas Field Operations: Data from Texas

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Data collected in two counties in north central Texas were used to empirically explore issues associated with public perception of desalinated water from oil and gas field operations. The data reveal that small percentages of respondents are extremely familiar with the process of desalination and extremely confident that desalinated water could meet human drinking water quality and purity standards. The data also indicate that respondents are more favorably disposed toward the use of desalinated water for purposes where the probability of human or animal ingestion is lessened. Lastly, the data show that respondents who are more familiar with desalination technology are more likely than those who are less familiar to believe that desalinated oil and gas field water could safely be used for selected purposes. Possible implications of these findings are advanced, as are suggestions for future research.

Keywords brine, desalination, energy, natural gas, oil, public perception, water

Worldwide, freshwater resources are limited in both quantity and quality. The increasing demands for freshwater are attributable to many factors, including increased population, urbanization, industrialization, economic development, climate

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change, and drought. According to the World Health Organization (WHO) and UNICEF, roughly 1.1 billion people across the globe lack access to safe drinking water (WHO/UNICEF 2005). The need to overcome freshwater shortages and augment diminishing surface and groundwater supplies has led many countries to develop and implement alternative water resource programs and management strategies, such as rainwater harvesting, wastewater reuse, and/or desalination.

Likewise, in many arid and semi-arid parts of the United States a water crisis is looming. Areas in the American West and Southwest are currently facing, or have recently coped with, a series of droughts that have significantly altered land-use behaviors and directly impacted both urban and rural communities. Many places within these regions are also experiencing rapid population growth. Undoubtedly, freshwater quantity and quality issues are being increasingly recognized by state policymakers, local elected officials, and the citizenry at large.

Data available from Texas Cooperative Extension (TCE) show the pervasiveness of these concerns in the state of Texas (TCE 1999). In 1999, TCE, in a major planning effort, gathered information from more than 10,000 Texas residents on critical issues confronting their communities. Those issues associated with water quantity and quality ranked among the top 5 priorities in 184 of the state's 254 counties (TCE 1999). Five years later TCE updated its county-level priority issues and needs database. In 2004, residents in 213 counties indicated a need to address water quality and/or quantity issues (TCE 2004).

It is increasingly apparent that solutions to the pressing water quantity and quality issues in Texas and other places throughout the world will require novel approaches and technologies. One innovative technique currently being studied involves the treatment and reuse of oil and gas field brine (commonly referred to as "produced water") (Burnett et al. 2002; Stewart 2006). *Produced water* is the term that applies to any water present in an underground hydrocarbon-bearing formation that is brought to the surface with the crude oil or natural gas. Oil and gas exploration and production (E&P) operations generate more than 200 million barrels of produced water worldwide each day (Burnett 2007), adding up to over 73 billion barrels per year. In 1995, the American Petroleum Institute estimated that onshore E&P operations in the United States produced 18 billion barrels of water (API 2007). Similar volumes are produced today (PWMIS 2007). Texas generates more produced water than any other U.S. state. Estimates of water produced per day in Texas exceed 400 million gallons (Burnett 2007).

Scientists and engineers in the Department of Petroleum Engineering at Texas A&M University have developed and are currently researching the economic and technical feasibility of reverse osmosis desalination technology that removes contaminants from water produced from oil and gas operations, treats and purifies the produced water, and ultimately creates a beneficial freshwater resource. The brine is treated in the "oil patch" with mobile units that remove contamination and dissolved salts. The newfound resource can be used to supplement current freshwater supplies.

While the technology currently exists and continues to be refined, the extent to which widespread adoption and diffusion of produced water treatment technology will occur raises an empirical question. Concomitantly, the public's acceptance of desalinated water from oil and gas field operations is an issue for scientific investigation. At this time, the authors are unaware of any published literature on the topics. Researchers have, however, speculated that several economic, regulatory, and social impediments must be addressed before such adoption/diffusion will occur (Stewart 2006; Theodori et al. 2006). For example, one hypothesized impediment is that there are no market mechanisms or incentives currently in place for the oil and gas operators to treat water and make it available as a commodity. Oil and gas companies produce petroleum and natural gas, not fresh water. However, the management and disposal of produced water constitute a substantial expense in oil and gas production (Puder and Veil 2006; Veil et al. 2004). Second, current local, state, and federal regulations have classified produced waters as waste materials, not as by-products to be treated, recycled, and reused. In Texas, this classification scheme is beginning to be reexamined (Tintera 2007). And third, speculation exists as to whether or not community leaders and members of the general public are aware of produced water treatment technology and the potential benefits. Even if oil and gas companies began treating produced water, to what extent would individuals be willing to accept its use?

Building upon these suppositions, the purpose of this article is to empirically explore issues associated with public perception of desalinated water from oil and gas field operations. Here, survey data gathered in two counties in north central Texas were analyzed to investigate respondents' (a) level of familiarity with the process of desalination, (b) level of agreement that desalinated water from gas and oil field operations could safely be used for selected purposes, and (c) level of confidence that such desalinated water could meet human drinking water quality and purity standards. Furthermore, the association between level of familiarity with the process of desalination and the proposed potential uses of desalinated water was examined.

Data

Data were collected in a general population survey from a random sample of individuals in two counties located in the Barnett Shale region of Texas.[1] The counties selected as study sites included Johnson County and Wise County (Figure 1). These two counties were purposely chosen to reflect differing levels of established energy development. As of 2005, the year when the present research was conceptualized, the vast majority of natural gas production in the Barnett Shale reservoir had occurred in the Newark East field, which spans portions of Wise, Denton, and Tarrant counties (Hayden and Pursell 2005). From these three counties, Wise County, where much of the initial development was performed after the first well completion in 1981, was selected to represent a site with relatively mature development. Conversely, Johnson County, the county that was referred to at the time as an emerging "sweet spot" (Hayden and Pursell 2005), was chosen to represent a site where large-scale exploration and production activities were just beginning.

In March 2006, interviews were conducted with 6 key informants in Wise County and 18 key informants in Johnson County to help identify timely and salient local social, economic, and environmental issues. The data gathered in the key informant interviews assisted in the development of a household survey questionnaire. Following a modified total design method (Dillman 1978), the household questionnaire data were gathered using mail survey techniques. During the late spring and early summer of 2006, a survey questionnaire was delivered via the U.S. Postal Service to 1,533 randomly selected households in the two counties (749 households in Johnson County; 784 households in Wise County).[2] In order to obtain a representative sample of individuals within residences, a response from

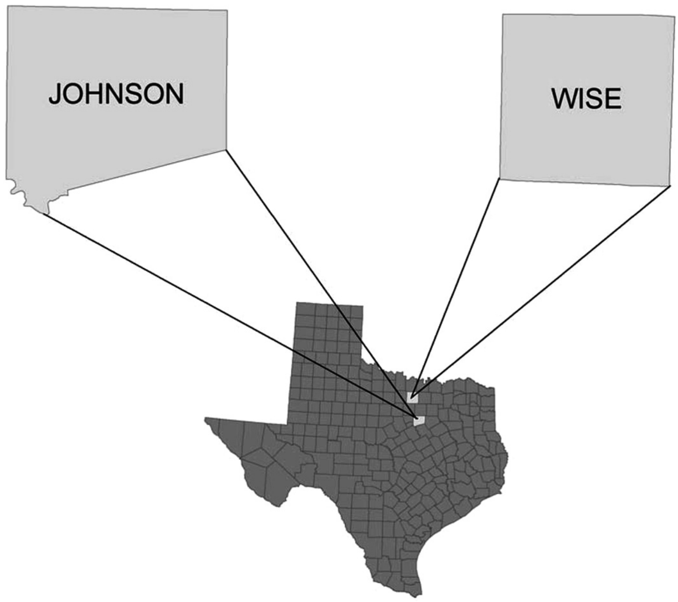

Figure 1. Study sites.

the adult who celebrated his/her birthday most recently was requested. The survey instrument, organized as a self-completion booklet, contained 42 questions and required approximately 60 minutes to complete. After the initial survey mail-out, a postcard reminder, and two follow-up survey mailings, a 39% response rate was achieved. This resulted in 600 completed questionnaires between the two sites (301 questionnaires in Johnson County; 299 questionnaires in Wise County). Comparisons of selected sociodemographic and economic characteristics between the sample and Census data are included in Appendix A.

Measurement of Variables

Measuring Familiarity with the Process of Desalination

Familiarity with the process of desalination was assessed using a single survey item, which, after reverse coding, ranged from 1 (extremely unfamiliar) to 7 (extremely familiar).

Measuring Perceived Safe Potential Uses of Desalinated Water

Perceived safe potential uses of desalinated water were evaluated with a list of nine practices. Respondents were asked whether or not they believed that desalinated water from gas and oil field operations could safely be used for (1) re-use by gas and oil industry operators, (2) industrial use (e.g., manufacturing, etc.), (3) irrigation of farmland and/or rangeland, (4) municipal uses (e.g., watering golf courses and city parks, etc.), (5) watering of livestock, (6) home irrigation purposes (e.g., watering lawns and shrubs, etc.), (7) maintenance of stream flows/reservoir levels, (8) aquifer recharge, and (9) people's drinking water. Each potential usage was dummy coded (1 = yes).

Measuring Confidence that Desalinated Water Could Meet Human Drinking Water Standards

The level of confidence respondents had that desalinated water from gas and oil field operations could meet human drinking water quality and purity standards was assessed using a single survey item that ranged from 1 (not at all confident) to 7 (extremely confident). Exact wording of all survey items is included in Appendix B.

Analyses[3]

Descriptive statistics were utilized to examine respondents' level of familiarity with the process of desalination, their level of agreement that desalinated water from gas and oil field operations could safely be used for selected purposes, and their level of confidence that such desalinated water could meet human drinking water quality and purity standards. Bivariate and multivariate logistic regression techniques were employed to empirically explore the association between level of familiarity with the process of desalination and the perceived safe potential uses of desalinated water.

As shown in Figure 2, approximately 1 in every 4 respondents (23%) reported being extremely unfamiliar with the process of desalination. Conversely, roughly 4% of respondents indicated that they were extremely familiar with the desalination process. The mean level of familiarity with the process of desalination was 3.37 (SD = 1.81).

Given what respondents currently know about desalination technology, an overwhelming majority (94%) believed re-use by gas and oil industry operators to be the safest potential use of desalinated water (Table 1). About 9 in 10 respondents (92%) believed that desalinated water from gas and oil field operations could safely be used for industrial use (e.g., manufacturing, etc.), while roughly three in four respondents agreed that such water could be used for municipal purposes (e.g., watering golf courses and city parks, etc.). Seventy percent reported that desalinated water could

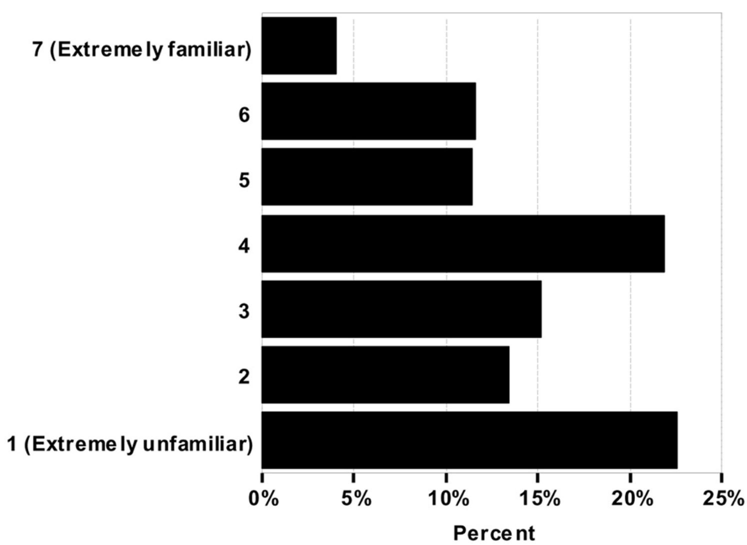

Figure 2. Level of familiarity with the process of desalination.

Table 1. Descriptive statistics for perceived safe potential uses of oil and gas field desalinated water

Ways desalinated water might safely be used:	Yes (%)	No (%)
Re-use by gas and oil industry operators	94	6
Industrial use (e.g., manufacturing, etc.)	92	8
Municipal uses (e.g., watering golf courses and city parks, etc.)	76	24
Home irrigation purposes (e.g., watering lawns and shrubs, etc.)	70	30
Irrigation of farmland and/or rangeland	65	35
Maintenance of stream flows/reservoir levels	47	53
Watering of livestock	44	56
Aquifer recharge	42	58
People's drinking water	21	79

safely be used for home irrigation purposes (e.g., watering lawns and shrubs, etc.); 65% proposed that it could be used to irrigate farmland and/or rangeland. Slightly less than one half of the respondents (47%) believed that desalinated water might be used to maintain stream flows and/or reservoir levels. Approximately 44% and 42%, respectively, agreed that watering of livestock and aquifer recharge could safely be accomplished with the use of desalinated water. Lastly, about 1 in 5 individuals believed that desalinated water from gas and oil field operations could safely be used by humans as potable water.

The associations between level of familiarity with the process of desalination and the safe potential uses of desalinated water were explored using bivariate and multivariate logistic regression techniques. Two individual-level status factors—gender and level of education—were included in the multivariate models as control

Table 2. Logistic regression for perceived safe potential uses of oil and gas field desalinated water on level of familiarity with the process of desalination

	Odds ratios	
Ways desalinated water could safely be used:	Bivariate	Multivariate[a]
Re-use by gas and oil industry operators	1.20	1.17
Industrial use (e.g., manufacturing, etc.)	1.10	1.07
Municipal uses (e.g., watering golf courses and city parks, etc.)	1.00	0.99
Home irrigation purposes (e.g., watering lawns and shrubs, etc.)	1.08	1.08
Irrigation of farmland and/or rangeland	1.07	1.06
Maintenance of stream flows/reservoir levels	1.12*	1.13*
Watering of livestock	1.14*	1.13*
Aquifer recharge	1.02	1.03
People's drinking water	1.15*	1.17*

[a]Odds ratios computed controlling for gender and education.
*Significantly different at $p \leq .05$.

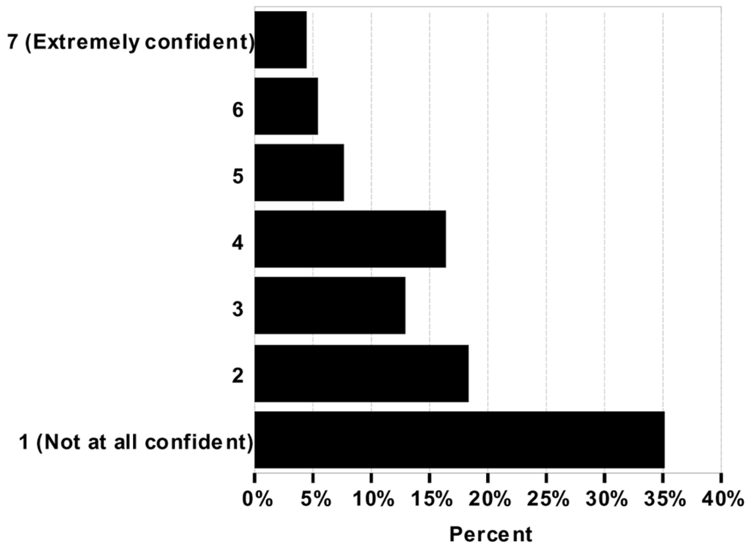

Figure 3. Level of confidence that desalinated water from gas and oil field operations could meet human drinking water quality and purity standards.

variables.[4] Preliminary analyses of these data revealed that both factors were associated with familiarity with the process of desalination. Males and individuals with higher levels of education expressed a greater familiarity with the process of desalination.

As noted in Table 2, the bivariate relationships between level of familiarity with the process of desalination and three of the nine safe potential uses were positive and statistically significant. This indicated that individuals with higher levels of familiarity with the process of desalination were more likely than those with lower levels of familiarity to believe that desalinated water from oil and gas field operations could safely be used for maintaining stream flows/reservoir levels, watering livestock, and drinking by humans.

The multivariate results indicated that controlling for gender and education had very little effect on the nature or significance levels of the odds ratios for the three statistically significant relationships.

As indicated in Figure 3, slightly more than one-third of the respondents (35%) reported being not at all confident that desalinated water from gas and oil operations could meet human drinking water quality and purity standards. Conversely, approximately 5% of respondents indicated that it could meet the standards. The mean level of confidence was 2.77 ($SD = 1.79$).

Summary and Discussion

Energy exploration and production, both onshore and offshore, produce copious amounts of brine. Internationally, three barrels of water are produced for each barrel of oil; in the United States the ratio is roughly 7 to 1 (Burnett 2007). Energy companies use less than 5% of water produced during E&P operations; the remaining 95% is typically disposed of through reinjection into underground formations (either solely for disposal purposes or for enhanced oil recovery practices). The management and disposal of such large quantities of produced water present serious concerns for both industry operators and regulatory agencies.

Reverse osmosis desalination technology can turn produced water into fresh water. Before the widespread adoption and diffusion of produced water desalination technology and the acceptance of treated produced water occur, several economic, regulatory, and social impediments will undoubtedly need to be addressed. In this study issues associated with public perception of desalinated water from oil and gas field operations were empirically explored.

The results of this investigation indicate that approximately one-fourth of the sample was extremely unfamiliar with desalination technology. At the other end of the spectrum, however, less than one-twentieth reported being extremely familiar with the technology. The findings also show that the majority of respondents stated that it would be safe to use desalinated oil and gas field water for re-use in the oil and gas industry, for industrial, municipal, and home irrigation uses, and for farmland and/or rangeland irrigation purposes. At the same time, more than one-half of the respondents stated that desalinated produced water could not safely be used for maintaining stream flows/reservoir levels, watering livestock, recharging aquifers, or making potable water. These results suggest that respondents are more favorably disposed toward the use of desalinated water in instances where the probability of human or animal ingestion is lessened.

The preceding proposition parallels the findings in the literature on the perceptions of the general public about using reclaimed and/or recycled water (cf., Baumann and Kasperson 1974; Bruvold and Ward 1972; Dishman et al. 1989; Dolnicar and Schafer 2006; Stone 1976). Specifically, previous research has shown that opposition to the use of reclaimed and/or recycled water varies directly with intimacy or degree of human contact (see, for example, Bruvold 1988; Bruvold and Ongerth 1974; Hartley 2006; Po et al. 2004; Sims and Baumann 1974).

Logistic regression results reveal that in three of the four scenarios where the increased potential for human or animal ingestion might occur (i.e., maintaining stream flows/reservoir levels, watering livestock, and people's drinking water), respondents who were more familiar with desalination technology were significantly more likely than those who were less familiar to believe that desalinated oil and gas field water could safely be used for such purposes. No statistical difference was uncovered when level of familiarity was regressed on aquifer recharge as a potentially safe use of desalinated water.

This lack of statistical significance between level of familiarity and aquifer recharge as a safe use for desalinated water is likely attributed to various factors. Included here might be respondents' knowledge of aquifer recharge and/or awareness of existing aquifer storage and recovery technologies (cf., Dillon et al. 2006; Fuqua et al. 1992; Missimer et al. 1992; Pyne and Howard 2004; Townley et al. 1992). Perceived spatial and temporal issues (i.e., the water is placed in a natural underground system to be recovered and used at a later date) may also be a contributing factor.

Lastly, the data show that less than two-thirds of the respondents expressed any level of confidence that desalinated water from oil and gas field operations could meet human drinking water quality and purity standards. This finding mirrors the results of previous research on wastewater reuse. Dolnicar and Schafer (2006, 1) succinctly summed it up when they noted that even though wastewater treatment exists, and can produce recycled water quality superior to that of current potable standards, "the notion of drinking wastewater is not a concept that benefits from unconditional public support."

In conclusion, global freshwater resources are limited. New water resource programs and management strategies will undeniably need to be developed and implemented in order to meet the water demands of future generations. Produced water desalination technology may not be the panacea for this natural resource issue; however, it is one innovative and presently available alternative.

In light of the findings presented here, additional research on the diffusion of produced water desalination technology and the public acceptance of desalinated water from oil and gas field operations is warranted. Such studies might explore the potential market mechanisms and incentives that would encourage energy companies to adopt and implement produced water desalination technology. Future research might also examine the current environmental and regulatory issues associated with the management and disposal of produced water and identify the procedures needed to change the established regulations if produced water desalination technology were implemented. Lastly, building upon the extant water reuse literature, assessments of risk perception (Baggett et al. 2006; Salgot et al. 2006; Toze 2006) and examinations of psychological barriers such as the disgust or "yuck" factor (Hartley 2006; Po et al. 2004), as well as explorations of numerous other potentially contributing factors (see Hartley 2006; Po et al. 2004), could provide a more comprehensive understanding of the public acceptance of desalinated water from oil and gas field operations. As research and practice on water reuse has indicated (Hartley 2006; Marks 2006; Po et al. 2004; Sims and Baumann 1974), public acceptance will be a crucial element to the successful implementation of produced water desalination projects.

Notes

1. The Barnett Shale is a natural gas shale reservoir situated in north central Texas. It is the largest natural gas reservoir in Texas and one of the largest onshore fields in North America. The geographic boundaries of the Barnett Shale region are not clearly defined. Known limits of the reservoir are constantly expanding as operators continuously explore areas considered to be on the fringe. For purposes of this article, though, the Barnett Shale is defined as an 18-county region encompassing Bosque, Clay, Comanche, Cooke, Denton, Ellis, Erath, Hamilton, Hill, Hood, Jack, Johnson, Montague, Palo Pinto, Parker, Somervell, Tarrant, and Wise counties.
2. The survey questionnaire was initially mailed to 800 randomly selected households in each county. Fifty one questionnaires were returned as undeliverable from Johnson County; 16 came back from Wise County. None of the 67 undeliverable household addresses were replaced with new ones. Therefore, these 67 households were not factored into the final sample size. The sampling frames from which the samples were drawn consisted of county tax rolls.
3. Cases with missing data on any of the variables used in the analyses were excluded. Hence, a listwise deletion reduced the sample to 448 cases.
4. Gender was dummy coded (1 = male); level of education was coded as follows: (1) less than high school; (2) high school or equivalent; (3) some college or post high school training; (4) associate's degree; (5) bachelor's degree; and (6) training beyond college.

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Appendix A

Selected sociodemographic and economic characteristics of the sample and Census data

Selected characteristics	Johnson County		Wise County	
	Census data	Sample data	Census data	Sample data
Percent 18 to 20 years of age	4.2	0.4	3.7	0.0
Percent 21 to 64 years of age	57.0	71.9	57.4	66.9
Percent 65 years and older	10.0	27.7	10.6	33.1
Percent female	50.1	43.2	49.6	37.0
Percent white	90.0	81.4	91.0	95.4
Percent 25 years of age or older—high school graduate (or equivalent) or higher	77.6	91.8	76.1	92.2
Percent 25 years of age or older—bachelor's degree or higher	13.8	27.0	13.0	26.6
Median household income (dollars)	$44,621	$58,125[a]	$41,933	$61,590[a]

[a]Median values were computed using the formula for the computation of the median from grouped data (see Blalock 1972, 66–68).

Appendix B. Survey Items

Measuring Familiarity with the Process of Desalination

Circle a number between 1 (Extremely Familiar) and 7 (Extremely Unfamiliar) that corresponds to your level of familiarity with the PROCESS OF DESALINATION.

Extremely Familiar------------------------Neutral----------------------Extremely Unfamiliar

1 2 3 4 5 6 7

Measuring Perceived Safe Potential Uses of Desalinated Water

Given what you currently know about desalination technology, do you believe that desalinated water from gas and oil field operations could safely be used for the following purposes?

	Yes	No
a. Re-use by gas and oil industry operators	1	2
b. Industrial use (e.g., manufacturing, etc.)	1	2
c. Irrigation of farmland and/or rangeland	1	2
d. Municipal uses (e.g., watering golf courses and city parks, etc.)	1	2
e. Watering of livestock	1	2
f. Home irrigation purposes (e.g., watering lawns and shrubs, etc.)	1	2
g. Maintenance of stream flows/reservoir levels	1	2
h. Aquifer recharge	1	2
i. People's drinking water	1	2

Measuring Confidence that Desalinated Water Could Meet Human Drinking Water Standards

Circle a number between 1 (Not at all Confident) and 7 (Extremely Confident) that corresponds to your level of confidence that desalinated water from gas and oil field operations could meet HUMAN DRINKING WATER quality and purity standards.

Not at all Confident---------------------Neutral----------------------Extremely Confident

1 2 3 4 5 6 7