Likelihood of adoption of arsenic-mitigation technologies under perceived risks to health, income, and social discrimination to arsenic contamination

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ABSTRACT: This study aims to assess the likelihood of adoption of arsenic-mitigation technologies under perceived risks in an Indian rural region that confronts severe and chronic groundwater arsenic contamination. A total of 340 households were surveyed in three arsenic-affected villages of Bihar, India. The average population perceives greater health risks and economic risks to arsenic-contaminated groundwater than social discrimination risk, therefore, are willing to adopt arsenic-mitigation technologies. Caste, education, income, sanitation practices, people's prioritization of socio-environmental problems, arsenic awareness, and social capital, were the strongest predictors of perceived economic risk. The same variables as above (with the exception of income, sanitation practices, and social capital) with additional factors like agricultural landholdings, and social trust, were the strongest predictors of perceived health risks. However, in the case of perceived social discrimination risk, the respondents' agricultural landholdings, people's prioritization of social problems, arsenic awareness, and social capital, were the strongest predictors.

1 INTRODUCTION

Risk perceptions play a vital role in the development of government policies and their subsequent adoption, as they significantly influence individuals' proclivities for hazards management that could affect human safety and health, or ecological conditions (Gerber and Neeley 2005). Until now the risk perception framework has been mostly applied in research related to climate change adaptations and natural hazards, and its application in decision-making for areas such as flood insurance, coastal environment protection, landslides, heat waves, chemical industries, air pollution and hurricanes is a recent phenomenon (Bickerstaff, 2004; Carlton and Jacobson, 2013; Damm *et al.*, 2013; Huang *et al.*, 2013; Jones *et al.*, 2013; Peacock, *et al.*, 2005; Tam and McDaniels, 2013). On the issue of groundwater contamination, there are only a handful of studies that have addressed the relationship between perceived risks of groundwater contamination and a significant increase in expenditures on activities aimed at mitigation (Abdalla, 1992; Janmaat, 2007). There are some studies that have applied the risk perception framework to water quality issues (Dupont and Krupnick, 2010; Jakus *et al.*, 2009; McSpirit and Reid, 2011; Nguyen *et al.*, 2010; Onjala *et al.*, 2014; Walker *et al.*, 2006). Studies of decision-making under perceived health risk are still in the rudimentary stage. We did not encounter any existing studies that have evaluated decision-making for better environmental services under perceived risks to income (economic risk) or risk of social discrimination.

Also, none of the studies has attempted to investigate the causal relationships between socioeconomic and demographic factors, knowledge and awareness, institutional trust, social capital, and social trust to risk perceptions in the context of arsenic-contamination. This study aims to address two primary goals related to the aforementioned gaps: a) to investigate people's decision-making to adopt arsenic-mitigation under perceived risks to health, income (economic), and social discrimination to arsenic; and b) to analyze the socioeconomic, demographic, and other factors that construct people's risk perception to groundwater arsenic-contamination.

2 METHODS

2.1 Administration of the survey

Based on the current levels of arsenic severity and the arsenic-mitigation initiatives, three villages, namely Suarwarwa, Rampur Diara, and Bhawani Tola of the Maner block of Patna district in Bihar, India were selected for this study (Singh, 2015; Singh *et al.*, 2018) (Fig. 1). Detailed description of the survey administration, arsenic contamination, and socioeconomic models of arsenic mitigation are provided in other studies (Singh, 2015; Singh *et al.*, 2016, 2017), in brief, the surveyed populations were randomly selected and stratified by the variable of caste, as the castes (forward, backward, and scheduled caste) are the sub-groups of the people in the project area, which are internally homogeneous, but externally heterogeneous (UNSD, 2008).

Figure 1. A map showing the arsenic affected districts of Bihar and the three villages selected for this study with their elevations (Singh *et al.*, 2018).

Figure 2. The conceptual framework of risk perception and decision-making of arsenic-mitigation technology.

2.2 Conceptual framework of risk perception and decision-making of arsenic mitigation technology

The arsenic risk perception model has been conceptualized based on the hypothesis that; a) the arsenic-exposed communities will adopt arsenic-mitigation technologies or programs under perceived health risk; perceived economic risk; and perceived risk of social discrimination; and b): the existing socioeconomic and demographic factors, people's prioritization of socio-environmental problems, and social capital, are significant drivers in constructing people's perceived risks (Fig. 2).

Table 1. Socioeconomic and demographic characteristics of the studied populations.

	Variables	Suarwarwa	Rampur Diara	Bhawani Tola	p-value
Gender	Female	10	2	5	0.038
	Male	101	117	105	
Age group	18-28	9	15	8	0.049
	29-39	16	27	21	
	40-50	36	28	36	
	51-61	23	18	12	
	62 and above	16	12	23	
Caste	Scheduled caste	23	19	20	<0.001
	Backward caste	77	18	37	
	Forward caste	0	62	43	
Marital status	Single	5	9	1	0.015
	Married	95	91	99	
Education level	Illiterate	49	11	14	<0.001
	Primary education	41	40	41	
	Secondary education	8	31	31	
	College	1	18	14	
Household size	≤5	43	36	34	0.569
	>5-10>	51	56	61	
	>10	5	8	5	
Occupation	Unemployed	22	3	2	<0.001
	Labor	51	30	35	
	Agriculture	20	41	39	
	Job + Business	7	25	24	
Income group	BPL(Rs.500<per month)	27	4	2	<0.001
	Lower APL(>Rs.500- Rs.10,000 per month)	60	76	78	
	Upper APL(>Rs.10,000 per month)	13	20	20	
Agricultural landholdings	No landholdings	48	65	55	0.024
	Landholdings	52	35	45	
Housing status	Straw made	19	7	3	0.001
	Thatched roof	29	21	24	
	Kachcha house	30	39	44	
	Pucca house	22	34	29	

2.3 Data analysis

Statistical Package for Social Sciences (SPSS), IBM version 21 in Windows environment, was used for statistical analysis (IBM, 2012; SPSS, 2012). A bivariate analysis was performed between the risk perceptions (health, economic, and social discrimination) and socioeconomic, demographic and other variables (IBM, 2012; SPSS, 2012; Warner, 2012).

3 RESULTS AND DISCUSSION

3.1 Socioeconomic and demographic characteristics of the surveyed population

The detailed socioeconomic and demographic survey results are explained in (Singh, 2015), here we present a village-wise comparison of socioeconomic and demographic survey results that help to understand the socioeconomic and demographic characteristics of the surveyed population (Table 1).

3.2 Perceived risks and decision-making for arsenic-mitigation technologies

The vast majority of individuals (91%) perceived health risk due to drinking arsenic-contaminated water

Figure 3. Participants' responses to statements on perceptions in the context of the adoption of arsenic mitigation options.

and was willing to adopt arsenic-mitigation technologies (Fig. 3).

About 66% of the respondents perceive economic risk from arsenic contamination. Only 46% of the surveyed population connects risk of social discrimination with arsenic contamination. The respondents showed a neutral response to perceived social discrimination risk, with the numbers almost equally split between those who perceive social discrimination risk and others who disagree or are neutral. The respondents of Rampur Diara village were slightly more likely (93%) to adopt arsenic-mitigation under perceived health risk than the respondents of Suarmarwa (90%) and Bhawani Tola (89%) villages.

3.3 Factors influencing likelihood of adoption of arsenic-mitigation technologies under perceived risks

Variables such as caste, education level, agricultural landholdings, housing status, presence and functionality of *Anganwadi*, and social capital (people who participate in panchayat activities), were found to have a contributing effect on communities' perceived health risk. Moreover, people's perceived economic risk was found to be strongly positively correlated with the respondents' health risk perception. In sum, educated higher caste communities who own land, live in better housing structures, and had trust in *Anganwadi*¹ in the area, tend to perceive more health risk. Therefore, under perceived health risk, communities that possess the above mentioned characteristics will adopt arsenic mitigation technology in the arsenic-contaminated areas (Table 2). The results of bivariate analyses showed that there was a very strong positive correlation between respondents' perceived health risk, social discrimination risk, and their perceived economic risk. It further shows that the communities that had high perceived health risk and social discrimination risk were likely to perceive more economic risk (Table 2).

¹ *Anganwadi* (courtyard shelter) is a government of India's child-care and mother-care unit at panchayat levels, comprised of mostly female health workers.

Table 2. Predictors of risk perceptions to health risk, economic risk, and social discrimination risk.

	Health risk perception	Economic risk perception	Social discrimination risk perception
Caste	.174**	.242**	-.062
Education level	.111*	.184**	.102
Agricultural landholdings	.156**	.047	-.127*
Housing status	.112*	.124*	.036
Time spent for water collection	.059	.093	-.171**
Distance from water source	.057	.065	-.120*
Place for defecation	.077	.170**	.082
Materials used to wash hands after defecation	.062	.162**	.082
Lack of land	.081	.184**	.017
Lack of school	.047	.265**	.072
Lack of health facilities	-.099	-.295**	-.093
Flood	-.035	-.122*	-.016
Water accessibility	.046	-.158**	.071
Water quality	-.059	-.228**	.000
Poverty	.032	.325**	-.018
Arsenic awareness	.032	.234**	.110*
Opinion about the presence and functionality of <i>Anganwadi</i>	.139*	-.158**	-.058
Opinion about the presence and functionality of <i>Mahila Samakhy</i>	-.076	-.042	-.197**
Opinion about the presence and functionality of <i>Self Help Groups</i>	.026	.057	-.226**
Trust in NGOs	.106	.161**	.232**
Trust in <i>Panchayat Raj Institutions</i>	.039	.141**	.251**
Trust in private agencies	-.018	.169**	.077
Participation in panchayat activities	.107*	.046	.008
Neighbors and others seek advice and value views	.091	.397**	.191**
Health risk perception	1.000	.268**	.068
Economic risk perception	.268**	1.000	.233**
Social discrimination risk perception	.068	.233**	1.000

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Likewise, a strong positive correlation was derived between caste, education level, housing status, sanitation behavior (place for defecation and material used to wash hands after defecation), people's prioritization of social problems (lack of land, lack of school, and poverty), arsenic awareness, trust in agencies (NGOs, *Panchayati Raj Institutions*, private agencies), and individual social capital, as neighbors and others sought and valued their advice, with the residents' perceived economic risk (Table 2). However, a strong negative correlation was observed between people's prioritization of socio-environmental problems (lack of health facilities, flood/drought, water accessibility, and water quality), and presence and functionality of institutions (*Anganwadi*), with the respondents' perceived economic risk.

In sum, socio-demographic factors (caste, education, and housing status), sanitation practice, people's prioritization of socio-environmental problems, arsenic awareness, presence and functionality of institution (*Anganwadi*), trust in agencies, and social capital, were found to be strong predictors of the perceived economic risk of the communities (Table 2). In comparison to the other two perceived risks (economic and health risks), we found fewer predictors of perceived risk of social discrimination. None of the socioeconomic and demographic factors, except agricultural landholdings, was found to be a statistically significant predictor of the communities' social risk perception. People with larger agricultural landholdings, who spent more time collecting water (and traveled a distance of >50 m), and the communities

that had higher trust in *Mahila Samakhyas*² and *Self-Help Groups*³ were strongly negatively correlated with their social discrimination risk perception. In contrast, those who were aware of arsenic contamination, who had trust in *NGOs* and *Panchayati Raj Institutions*, and the respondents with higher social capital were found to be strongly positively correlated with their perceived social discrimination risk. Furthermore, communities' social discrimination risk perception was found to be strongly positively correlated with their perceived economic risk (Table 2).

4 CONCLUSIONS

This study provides insights into communities' decision-making to adopt arsenic-mitigation technologies under their perceived risks to health, income, and social discrimination to groundwater arsenic-contamination. The findings are potentially advantageous to policymakers, as this helps identify the mechanisms of decision-making to adopt better environmental services for the communities' wellbeing. Risk perception in general, but health, economic and social discrimination risk perceptions in particular, cause individuals to take precautionary measures and support policies aimed at arsenic-mitigation (Botzen *et al.*, 2009). A "one-size-fits-all" approach to promoting arsenic-mitigation is unlikely to succeed owing to the heterogeneous nature of the communities affected. As is evident from this paper, different castes and economic classes, constituting the affected communities, have differing perceptions of health, economic and social risk, because of their varied perceptions and priorities. Upper caste communities should be targeted for immediate arsenic-mitigation, as they are more likely to adopt. This might also help to enhance technology adoption among lower castes due to the fact that the latter seek to emulate the former in many situations. However, it appears that, unfortunately, health concerns take a backseat to pressing issues of economic survival for lower-caste and impoverished households. In the short-term, education and awareness campaigns aimed at arsenic contamination and, specifically, its adverse impacts on livelihoods should be implemented among the lower caste communities, including backward and scheduled caste. Communities with minimal trust in the institutions and low social capital, both owing perhaps to their social marginalization, were most concerned with economic risks and social discrimination risks. However, underprivileged communities for whom social problems were the highest priority had low or no arsenic awareness.

Therefore, to raise arsenic awareness in these communities, campaigns should focus, in the medium to long-term, on strengthening institutions and enhancing social capital activities. Most importantly, these institutions should be involved in village level arsenic mitigation-programs. That groundwater arsenic may not be a priority among poor communities should not be seen as a discouraging finding. On the contrary, it should be seen as an affirmation of the fact that environmental and health perceptions are related to socioeconomic problems like lack of jobs, lack of land, lack of schools, or lack of health facilities. Understanding these linkages could be very useful for understanding how people perceive risks, what the predictors are, and how decisions are made for ultimately delivering better social or environmental services. The identified predictors of the three risk perceptions to groundwater arsenic-contamination will help us model the risk perceptions to arsenic-contamination. The results of this study suggest that severity of groundwater, soil, or food arsenic contamination, while important, should not be the only control on mitigation policies. People's risk perception plays a vital role in the adoption of arsenic-mitigation interventions. Caste, broad measures of economic well-being and markers of social status within the community are important drivers of the different risk perceptions. However, it appears that social marginality, which is a relative social position (as determined by the compounding effect of education, landholding, arsenic awareness, among other factors), is a crucial factor, perhaps more so than absolute measures of income and education. Therefore, socioeconomic and demographic factors, awareness, institutional trust, social trust, and social capital, etc., should necessarily be evaluated before implementing any arsenic-mitigation policy. This approach would help increase adoption of arsenic-mitigation interventions and achieve their sustainable use.

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² The *Mahila Samakhyas* is a women's empowerment program of the government of India, designed to aid socioeconomically impoverished women through increased literacy.

³ *Self Help Groups* are comprised of socioeconomically disadvantaged women in villages in India and other South Asian countries primarily established for social empowerment through micro-finance.

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