TABLE 2. Mortality: Preflood and Postflood[a] Mortality in the Flooded and Nonflooded Areas. Rate Ratios of Flooded Compared With Nonflooded Areas

	No. Deaths		Rate per 1000		Crude RR (95%CI)	RR Controlled for Preflood Period (95% CI)	RR Controlled for Preflood Period and Seasonality[b] (95% CI)
	Nonflooded	Flooded	Nonflooded	Flooded			
Preflood							
−3 years	796	361	0.11	0.11	1.00 (0.89–1.14)		
−2 years	831	406	0.11	0.12	1.07 (0.95–1.20)		
−1 year to −26 weeks	442	174	0.11	0.10	0.86 (0.72–1.02)		
−25 to −21 weeks	115	40	0.16	0.12	0.76 (0.53–1.08)		
−20 to −16 weeks	84	30	0.12	0.09	0.77 (0.51–1.17)		
−15 to −11 weeks	79	29	0.11	0.09	0.80 (0.52–1.22)		
−10 to −6 weeks	89	39	0.12	0.12	0.95 (0.65–1.38)		
−5 to −1 weeks	66	35	0.09	0.10	1.15 (0.76–1.73)		
Flood	70	36	0.10	0.11	1.11 (0.74–1.66)	1.14 (0.76–1.72)	1.10 (0.71–1.73)
Postflood							
1 to 5 weeks	70	39	0.10	0.12	1.20 (0.81–1.78)	1.23 (0.83–1.84)	1.25 (0.81–1.94)
6 to 10 weeks	78	42	0.11	0.12	1.16 (0.80–1.69)	1.19 (0.81–1.74)	1.22 (0.80–1.87)
11 to 15 weeks	95	45	0.13	0.13	1.02 (0.71–1.45)	1.05 (0.73–1.50)	0.87 (0.59–1.30)
16 to 20 weeks	107	59	0.15	0.17	1.18 (0.86–1.63)	1.22 (0.88–1.68)	1.08 (0.76–1.55)
21 to 25 weeks	106	54	0.15	0.16	1.09 (0.79–1.52)	1.12 (0.80–1.57)	1.26 (0.86–1.83)
26 weeks to 1 year	455	202	0.12	0.11	0.95 (0.81–1.12)	0.98 (0.81–1.17)	0.99 (0.82–1.20)
2 years	890	396	0.12	0.11	0.95 (0.85–1.07)	0.98 (0.85–1.12)	0.97 (0.85–1.12)
3 years	907	401	0.12	0.12	0.95 (0.84–1.06)	0.97 (0.85–1.11)	0.97 (0.84–1.12)

[a] Flood period is defined as week 29 to 33 in 2004 (5 weeks, from 15 July to 18 August).

[b] Controlled for season by meta-linear regression with Fourier transformed functions with annual cycle up to an order of 6.

TABLE 3. Estimates of Flood-related Impact on Mortality, Diarrhea, and Acute Respiratory Infection by Selected Potential Risk Modifiers. Controlled Ratio of Outcome Rate Relative to Preflood Period[a]

	Death		Diarrhea		Acute Respiratory Infection	
Possible Modifier of Flood Impact	During the Flood Period RR (95% CI)	During the 24 Weeks After the Flood RR (95% CI)	During the Flood Period RR (95% CI)	During the 24 weeks After the Flood RR (95% CI)	During the Flood Period RR (95% CI)	During the 6 Months After the Flood RR (95% CI)
All	1.10 (0.71–1.73)	1.11 (0.92–1.34)	1.16 (0.77–1.74)	0.99 (0.80–1.22)	1.00 (0.73–1.35)	1.25 (1.06–1.47)
Age (years)						
0 to 15	0.71 (0.25–1.99)	0.98 (0.59–1.65)	1.05 (0.68–1.63)	0.84 (0.66–1.08)	—	—
15 to 60	0.95 (0.33–2.75)	0.96 (0.61–1.52)	0.82 (0.31–2.16)	1.08 (0.74–1.60)	—	—
≥60	1.39 (0.75–2.56)	1.22 (0.96–1.55)	3.92 (0.28–55.47)	1.16 (0.33–4.14)	—	—
Income level						
Low	1.11 (0.32–3.83)	1.06 (0.62–1.82)	1.64 (0.65–4.19)	0.87 (0.56–1.35)	1.25 (0.85–1.83)	1.32 (1.06–1.64)
Middle	1.20 (0.65–2.22)	1.15 (0.89–1.49)	1.15 (0.67–1.97)	1.13 (0.84–1.52)	0.98 (0.69–1.39)	1.23 (1.01–1.51)
High	0.89 (0.35–2.27)	1.21 (0.82–1.81)	1.07 (0.52–2.21)	0.83 (0.58–1.18)	0.86 (0.58–1.27)	1.23 (0.98–1.54)
Drinking water source						
Surface or Filtered	1.00 (0.28–3.59)	0.76 (0.33–1.78)	0.46 (0.07–3.24)	0.53 (0.16–1.69)	1.07 (0.56–2.06)	1.05 (0.73–1.52)
Tube well	1.01 (0.61–1.66)	1.15 (0.94–1.41)	1.31 (0.86–2.02)	1.01 (0.82–1.26)	1.02 (0.76–1.36)	1.33 (1.12–1.57)
Latrine						
Nonsanitary	0.98 (0.59–1.62)	1.12 (0.91–1.38)	1.15 (0.75–1.77)	0.93 (0.75–1.17)	1.03 (0.77–1.37)	1.28 (1.08–1.51)
Sanitary	0.60 (0.17–2.09)	0.94 (0.54–1.63)	1.22 (0.47–3.14)	1.15 (0.70–1.90)	0.91 (0.52–1.59)	1.20 (0.90–1.62)
Service area						
ICDDR,B	1.13 (0.60–2.11)	0.94 (0.72–1.24)	1.17 (0.75–1.83)	0.93 (0.74–1.17)	1.01 (0.73–1.40)	1.29 (1.06–1.56)
Government	0.84 (0.43–1.61)	1.25 (0.93–1.58)	0.86 (0.37–2.01)	0.94 (0.62–1.44)	0.68 (0.47–0.98)	0.77 (0.62–0.96)

[a] The rate ratio for flooded versus nonflood area, controlling for the analogous ratio in the preflood period and seasonality, as explained in the text. Baseline is 3 years before the flood for death and diarrhea and 2 years for ARI.

TABLE 4. Diarrheal Illness: Pre- and Postflood[a] Episodes in the Flooded and Nonflooded Areas

	No. Diarrhea		Rate per 1000		Crude RR (95% CI)	RR Controlled for Preflood Period (95% CI)	RR Controlled for Preflood Period and Seasonality[b] (95% CI)
	Nonflooded	Flooded	Nonflooded	Flooded			
Preflood							
−3 years	619	371	0.09	0.12	1.32 (1.16–1.51)		
−2 years	786	479	0.11	0.14	1.33 (1.19–1.49)		
−1 years to −26 weeks	322	254	0.08	0.14	1.72 (1.46–2.02)		
−25 to −21 weeks	55	44	0.08	0.13	1.74 (1.17–2.58)		
−20 to −16 weeks	55	27	0.08	0.08	1.06 (0.67–1.69)		
−15 to −11 weeks	124	52	0.17	0.16	0.91 (0.66–1.26)		
−10 to −6 weeks	92	56	0.13	0.17	1.32 (0.94–1.84)		
−5 to −1 weeks	69	69	0.10	0.21	2.16 (1.55–3.02)		
Flood	75	75	0.10	0.22	2.16 (1.57–2.98)	1.55 (1.12–2.15)	1.16 (0.77–1.74)
Postflood							
1 to 5 weeks	74	43	0.10	0.13	1.25 (0.86–1.83)	0.90 (0.61–1.32)	0.96 (0.62–1.51)
6 to 10 weeks	65	49	0.09	0.15	1.62 (1.12–2.35)	1.16 (0.80–1.70)	1.12 (0.72–1.75)
11 to 15 weeks	86	47	0.12	0.14	1.18 (0.82–1.68)	0.84 (0.59–1.21)	0.90 (0.58–1.40)
16 to 20 weeks	86	56	0.12	0.17	1.40 (1.00–1.96)	1.00 (0.71–1.41)	1.11 (0.73–1.69)
21 to 25 weeks	90	47	0.12	0.14	1.12 (0.79–1.59)	0.80 (0.56–1.15)	0.91 (0.59–1.41)
26 weeks to 1 years	338	235	0.09	0.13	1.49 (1.26–1.76)	1.07 (0.89–1.28)	1.01 (0.82–1.23)
2 years	698	556	0.09	0.16	1.70 (1.52–1.90)	1.22 (1.07–1.39)	1.16 (1.00–1.35)
3 years	616	392	0.08	0.12	1.36 (1.20–1.54)	0.98 (0.84–1.13)	0.95 (0.81–1.12)

[a] Flood period is defined as week 29 to 33 in 2004 (5 weeks, from 15 July to 18 August).
[b] Controlled for season by meta-linear regression with Fourier transformed functions with annual cycle up to an order of 6.

TABLE 5. Acute Respiratory Infection (ARI): Pre- and Postflood[a] Episodes in the Flooded and Nonflooded Areas

	No. ARI		Rate per 1000		Crude RR (95% CI)	RR Controlled for Preflood Period (95% CI)	RR Controlled for Preflood Period and Seasonality[b] (95% CI)
	Nonflooded	Flooded	Nonflooded	Flooded			
Preflood							
−2 years	10,646	4729	54.20	50.17	0.93 (0.89–0.96)		
−1 years to −7 months	5036	2483	49.99	52.01	1.04 (0.99–1.09)		
−6 months	633	306	37.57	38.51	1.02 (0.89–1.17)		
−5 months	599	320	35.35	40.13	1.14 (0.99–1.30)		
−4 months	684	343	40.38	42.89	1.06 (0.93–1.21)		
−3 months	546	270	32.20	33.56	1.04 (0.90–1.21)		
−2 months	398	193	23.41	23.91	1.02 (0.86–1.21)		
−1 months	285	151	16.71	18.61	1.11 (0.91–1.36)		
Flood	501	227	14.64	13.95	0.95 (0.81–1.11)	0.97 (0.83–1.14)	1.00 (0.73–1.35)
Postflood							
1 months	310	214	18.00	26.05	1.45 (1.22–1.72)	1.48 (1.24–1.76)	1.23 (0.82–1.84)
2 months	384	188	22.26	22.83	1.03 (0.86–1.22)	1.05 (0.88–1.25)	1.22 (0.81–1.83)
3 months	164	100	9.47	12.10	1.28 (1.00–1.64)	1.30 (1.02–1.67)	1.34 (0.85–2.11)
4 months	151	93	8.71	11.17	1.28 (0.99–1.66)	1.31 (1.01–1.70)	1.37 (0.86–2.17)
5 months	163	94	9.42	11.27	1.20 (0.93–1.54)	1.22 (0.95–1.58)	1.17 (0.74–1.86)
6 months	195	119	11.19	14.16	1.27 (1.01–1.59)	1.29 (1.03–1.62)	1.23 (0.79–1.91)
7 months to 1 year	898	533	8.59	10.60	1.23 (1.11–1.37)	1.26 (1.13–1.40)	1.22 (1.00–1.49)
2 years	1570	947	7.80	9.78	1.25 (1.16–1.36)	1.28 (1.18–1.39)	1.28 (1.11–1.48)

[a] Flood period is defined as July to August in 2004.
[b] Controlled for season by meta-linear regression with Fourier transformed functions with annual cycle up to an order of 6.

ratory infection in a rural population of Bangladesh following the severe monsoon flood of 2004. Somewhat against our expectations (and contrary to previous reports[13,16]), there was no clear evidence of flood-related increases in mortality or diarrhea, either during the flood period itself or afterward, once analyses were controlling for preflood rate differences between flood and nonflood areas and seasonality.[18] This was true also for cause-specific forms of diarrheal illness (cholera, noncholera, and rotavirus infections). Although our results do not exclude a flood effect on diarrhea, the upper bound of the confidence interval (RR = 0.99 [95% CI = 0.80–1.22] in Table 3) suggests that an excess of >22% above the preflood rate is unlikely for the 6 months after flooding, and an excess of >74% is unlikely for the flood period itself (1.16 [0.77–1.74] in Table 3).

With less stringent control for confounding, there was some evidence of an increase in diarrhea risk during the flood period itself in analyses carried out without seasonal control. However, we interpreted this as residual confounding by season, rather than as evidence of a flood effect.

The evidence for acute respiratory infection in children under 5 years was more equivocal. There was no evidence of increased risk during the period of flooding itself, but for 6 months and longer after flooding, the rate ratios showed higher risks in the flooded populations even after adjustment for both preflood rate differences and seasonality. The difficulty of interpretation here arises from 2 features of the data: (1) the apparent persistence of the relatively high acute-respiratory-infection rates in the flooded population for an implausibly long period after the flood (evident as an undiminished relative excess in the second year after the flood); and (2) an apparent and unexplained steep decrease in the number of acute-respiratory-infection cases recorded in both flood and nonflood areas from around the third month after the time of the flood. These observations weaken the evidence for a causal association.

The broadly negative evidence of our analyses for diarrhea contrasts with that of some previous reports. For example, a study of Hashizume et al[19] reported a persistent flood effect on both cholera (until 8 weeks after the end of the flood) and non-cholera diarrhea (until 4 weeks postflood) after the1998 flood in Dhaka. Studies also have reported an apparent diarrhea effect that was greater in population subgroups with poorer hygiene and sanitation or lower socioeconomic status.[19,20] However, these findings were from an analysis of diarrhea cases irrespective of flood exposure of individuals, and where potential seasonal differences in the flood effects between flooded and nonflooded populations were not considered. A limitation of many previous published studies of flood-related diarrhea was that they lacked outcome data in the preflood period or for control areas. In our analyses, adjustment for preflood differences and seasonality had an appreciable impact on the interpretation, reducing an apparent diarrhea increase into a smaller and less certain difference. By controlling for season, our analysis specifically tested whether the 2004 flood was associated with excesses in the diseases above those seen seasonally in normal years, and not simply whether flooding was associated with any increase.

The difference in findings between our study and earlier studies could also be due to the different settings (particularly regarding urban or rural locations). Generally, water sources, sewerage, and waste-disposal systems more severely affect the community's health in crowded areas. Different types and patterns of flooding may also be relevant; sudden and prolonged flooding is likely to have a different impact on health than more gradual and transient inundation associated with heavy seasonal rainfall.[21] In the 1998 flood in Bangladesh, the water level remained high for 2 months, whereas in 2004, although much heavier rainfall occurred, the water level remained high for only 1 month.

The persistence of diarrhea risk after flooding may also be influenced by local environmental conditions and by variation in disaster management and adaptation strategies. In a region where some degree of flooding is common, and health systems are prepared to treat the infectious-disease outbreaks that occur, there may be a more rapid return to baseline levels of disease (even after an exceptional event), compared with regions in which such events are rarer and the infrastructure and health systems are not adequately prepared. It is possible that people in other settings may experience greater and more persistent increases in rates of diarrhea following floods.

There are fewer robust studies on the effects of flooding on acute respiratory infection. Our observation of a modest increase in acute respiratory infection in the period after flooding, although somewhat unclear, is broadly consistent with previous evidence. For the 1998 Bangladesh floods, respiratory problems were the second-most-common (14%) health problems among flood victims after diarrhea (27%).[20] Acute respiratory infection was also the second-most-common cause of illness (17%) and death (13%) among victims of the 1988 flood.[22] However, it is not clear whether the high number of postflood acute respiratory infection cases was due to the flood or was the result of a usual seasonal increase, because these studies had neither baseline incidence data nor detailed exposure status of the subjects. Acute respiratory infections are a recognized problem among populations displaced by natural disasters,[5] and the risk of death appears to be related to crowding, exposure to indoor cooking using an open flame, poor nutrition, and lack of access to health care facilities and antimicrobial agents for treatment. The reported incidence of acute respiratory infection increased 4-fold in Nicaragua in the 30 days after Hurricane Mitch in 1998,[23] and acute respiratory infection accounted for the highest number of cases and deaths among those displaced by the tsunami in

Aceh in 2004.[24] There was no major population displacement in Matlab during and after the flooding in 2004.

Several limitations also merit comment. First, exposure to the 2004 flood was indirectly ascertained—based on the results of an interview with the head of each *bari* in 2008. Although there was no major flood or heavy rainfall after the summer 2004 flood, until the date of the interview, the long time interval could cause recall bias. If our flooded *baris* are more likely than nonflooded *baris* to experience flooding in other years, our reported effects may be overestimated. However, the interview also sought information about the experience of flood or heavy rainfall from 2000 through 2003, and the stratified analysis by those experiences showed no difference in the effect estimates of the 2004 flood.

Second, there was also imprecision in definition of the flood period. Redefining the flood period with more precise data on its duration in this region might reveal slightly different patterns of rates, but this is unlikely to have a material effect on the overall results, given the 3-year pre- and postflood observation period.

Third, because most people (84%) in the Matlab area use tube-well water, it was more difficult to examine variations in vulnerability to diarrheal illness. Luby et al[25] found that tube wells in flood-prone regions of Bangladesh were commonly contaminated with low levels of fecal organisms, regardless of its external characteristics. Latrine sharing has also been found to be associated with increased risk of cholera.[26] We had no measure of the number of people sharing latrines in this population, or of various other potential risk factors such as distance to surface water, that could be a reservoir of pathogens during and after the flood. Similarly, we did not know the distance to the nearest hospital and treatment centers, which could affect ascertainment.[27]

In conclusion, our analyses show the importance of careful control for temporal confounding in the analysis of the affects on health of monsoon floods. For mortality and diarrheal illness, we found little evidence of elevated risks once the analyses were controlled for preflood rate differences and seasonality. We can exclude a relative excess of >74% in diarrheal illness for the flood period itself and of >22% for the 6 months after the flooding. The evidence for acute respiratory infection was more equivocal, with evidence of a persistent, moderate elevation of acute respiratory infection risk over the 2 years after the flood, although questions remain about the interpretation of this as a direct causal effect of flooding.

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カンボジア国村落部における地下水砒素汚染に関する研究

―援助機関による介入の変遷と砒素慢性疾患(Arsenicosis)症例について―

Study on Arsenic Pollution of Groundwater in Rural Areas in Cambodia

- Interventions by Donors and Prediction of Arsenicosis Cases -

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<要約>バングラデシュ国における安全な水供給から地下水砒素問題に至る国際機関等の介入経緯と、カンボジア国の砒素問題発生の経緯の類似点に着目することで、カンボジア国でも同様の介入結果によるArsenicosis 症例の増加傾向があるとし、同国のドナーやNGOsの介入の経緯、水系性疾患症例の減少及びArsenicosis 症例数増加の簡易予測を検討した。

<キーワード> BHN、安全な水供給、砒素汚染、健康影響、環境保健、ドナー介入

1. 研究の目的

バングラデシュ国（以下「バ」国）おけるUnicef等による井戸建設等による安全な水供給の介入、地下水砒素汚染の拡大及び健康への影響（水系性疾患(WBDs: Water Boren Diseases)症例の減少と砒素慢性疾患症例(Arsenicosis)の増加）及びその後の地下水砒素問題への国際機関等による介入経緯と、「カンボジア国（以下「カ」国）の同砒素汚染発生経緯の類似点を明らかにすることで「カ」国でも「バ」国の Unicef 等介入による Arsenicosis 症例の増加傾向が同様に発生していると仮説した。この仮説に基づき本研究は、①「カ」国におけるUnicef等による管井戸建設等介入の経緯、WBDs症例の減少確認及びArsenicosis症例数の増加予測、②「カ」国における地下水砒素問題に対し、援助機関等が今後取るべき効果的な介入手法を検討整理しこの介入によるArsenicosis症例数の低減予測、③以って、我が国地下水砒素汚染問題の国際協力の援助手法の提言、これらを行うことを目的とする。

2. ドナー介入と地下水砒素問題に関する変遷のレビュー

2.1 バングラデシュ国の変遷

「バ」国は1970年代Unicefによる安全な水供給のための管井戸の建設が開始され1980年代には民間業者が同建設に参入するようになった。この間、下痢症等水系性疾患(WBDs: Water Boren Diseases)症例数の低減が見られたが、1983年にカルカッタで慢性砒素中毒による皮膚疾患症例(Arsenic-induced skin lesion)が報告され、1987年までに西ベンガル州で「バ」国からの患者数名を含め最初の慢性砒素患者(Arsenicosis)が確認された(WHO)。さらに1993年「バ」国 Nawabganj 県(District) [1]の管井戸から始めて砒素が検出され、1997年には砒素汚染の影響があるとされた18郡で行われた調査で1,630人の57.5%が、同様に砒素汚染が確認された200村落で実施された調査では469,424人の内1,802が砒素中毒による皮膚病変(Skin Lesions)を示していることが確認された(WHO)。その後類似の調査から地下水砒素汚染及びArsenicosis症例の確認数は増加傾向を示しこれら問題に対する国際機関等ドナーによる調査等介入が行われている。2009年現在270(全国469)郡(Upazila)[1]が砒素汚染地域とされ約3,000万人がその影響を受けている (JICA)。この状況に対し「バ」国政府は2004

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[1] 「バ」国の地方行政区分は、県（District）＞郡(Upazila)＞ユニオン(Union)＞ワード(Ward)

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年「国家砒素緩和政策」及び「実行計画」を採択し、2005年策定のPRSPにおいても砒素対策を含む安全な水の供給を重要な課題の一つとして位置づけている。我が国は砒素汚染対策を対「バ」国援助重点分野に位置づけ「砒素汚染対策プログラム」として JICA による包括的な協力(専門家派遣、技プロ事業等)を2004年以降展開している(JICA)。

2.2 カンボジア国の変遷

「カ」国はUnicef支援により1983年から安全な水供給のための井戸(管井戸、掘削井戸等)の建設が本格的に開始され1990年代後半になると同国政府、国際機関、NGOや民間業者の井戸建設が活発化し始めた。その結果1995年現在計12,267の井戸が建設され（JICA調べ,2002)、1998年～2003年に農村開発省(MRD)は40,500の井戸を建設した。一方2000年WHOの調査から地下水砒素汚染が始めて発見され、Arsenicosis症例やその広がりも次第に調査・報告されるようになった(WHO、Unicef他)。2009年現在、主要河川であるメコンとその支流のバッサク及びトンレサップ河の流域7州の沖積層で国家飲料水基準(CDWQS)である50ppb以上の砒素濃度を示す地下水が確認され、2005年現在これら7州の1,607村落と各村落の人口に基づきリスク地帯に居住する一般住民は224万人と予測されている(Frederick)(表2.1)。この問題に対し「カ」政府は2002年、MRDを座長とした関連5省からなるAISC(Arsenic Inter Ministerial Sub-Committee)を組織し調査やIEC活動等を実施、特にUnicefカンボジアはMRDに簡易砒素テストキット供与や訓練、砒素センター(Arsenic Center)を設立し全国の砒素データ収集やIEC教材開発等の支援をしているが小規模である。またAISCはUnicefとWSP(Water and Sanitation Program)/世銀の支援を受け、2006年砒素5ヵ年戦略的アクションプランを作成し何度かの修正が行われたが2009年3月時点で政府の承認待ちの状態であり、具体的な事業等は無い。「カ」国政府の対応及びドナーの介入は黎明期にあると評価できる(JICWELS、2009)。

表2.1 砒素リスク地帯に居住する一般住民予測

州	リスク人口(人)*	州人口(人)	%
Kandal	983,000	1,215,000	81
Kampong Cham	496,000	1,754,000	28
Phnom Penh	239,000	998,000	24
Kracheh	164,000	291,000	56
Prey Veng	156,000	1,076,000	14
Kampong Thom	120,000	635,000	19
Kampong Chhnang	82,000	455,000	18
	2,240,000	6,424,000	35

出展 *Dr. David Fredericks (Situation and Response Analysis 2006)*
*安全な低濃度砒素汚染水、改善されていない比較的安全でない砒素汚染水及び砒素汚染水を利用している住民を含む

2.3 類似点

2.1と2.2に記したとおり文献レビュー及び現地調査(2008、2009年)で確認した両国のドナー等の介入と砒素問題の変遷に対する類似点は、以下の時間的連続性及び並行性である。

2.3.1 時間的連続性

時間的連続性とは、図2.1に示す①地方都市の水不足(BHN)及び表流水の生物汚染→②管井戸等建設による安全な水供給へのドナーの介入→③WBDs症例数の減少(正の健康影響)→④地下水砒素汚染の拡大と砒素慢性疾患(Arsenicosis)症例の増加(負の健康影響)→⑤地下水砒素問題へ国際機関等ドナーによる介入、とした変遷である。

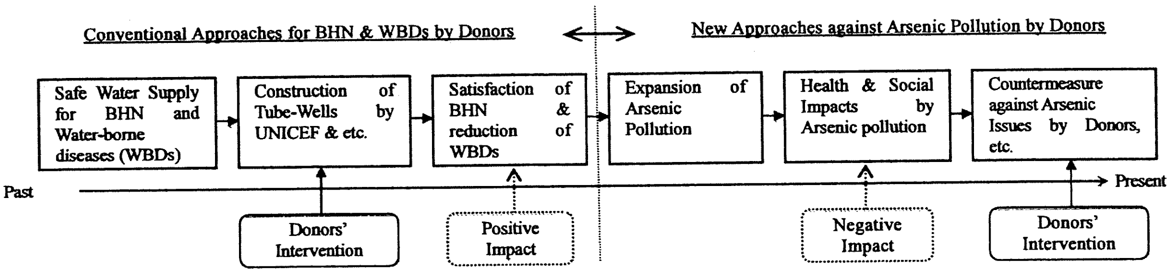

図2.1 地下水砒素汚染に関する時間的連続性

2.3.2 時間的並行性

時間的並行性とは図2.2に示す時間的連続性の中で観測される両国における各事象の発生の時間的変位（位相）である。

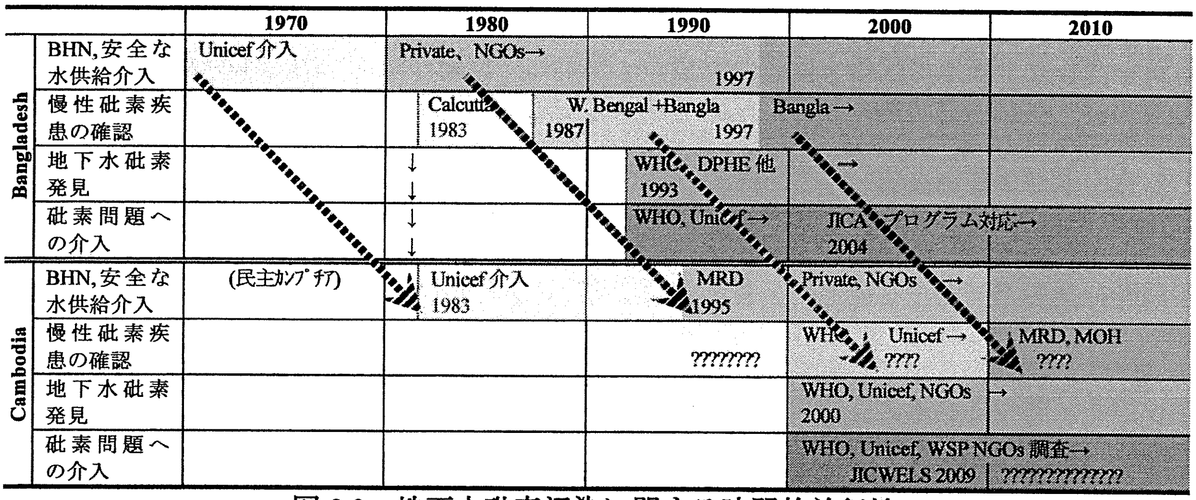

図 2.2　地下水砒素汚染に関する時間的並行性

特に興味深いのはUnicef介入による井戸掘削による安全な水供給から約10年位経過するとArsenicosis症例と地下水の砒素汚染が確認され始めた点である。これは砒素(毒性を示す3価、5価)汚染水飲用によるArsenicosis発症に約10年の曝露とした報告(WHO)と符合する。但し、砒素が地下水中で3価、5価となり溶出するメカニズム及びそれに要する時間も考慮する必要がある。次に、両国政府および国際機関やドナー等の対応は事実確認に約10年位の時間を要している点である。「カ」国で井戸建設のUnicef介入が新政府樹立後の1983年で、この年はカルカッタで最初のArsenicosis症例の確認された年である。即ち1983年以降に隣接したベンガル地方を含め「バ」国で発見されたArsenicosis症例や地下水砒素汚染の同様の経緯等を「カ」国でも辿っていることが理解される。

3. カンボジア国砒素汚染現地調査結果概要

研究グループは「カ」国で計2回の現地調査(2008年9月、2009年3月)を実施しAISC各省、Unicef、WHO等国際機関やNGO訪問による情報収集、地下水実測や聴取り調査等を行った。

3.1 井戸水実測調査

(1) 実測目的:文献等で報告されている砒素汚染の実態の検証
(2) 分析項目：砒素(As)及び鉄(Fe)[2]
(3) 分析方法:各分析項目の濃度レベルの計測のためフィールドキット(砒素(As) ;HACH As Test Kit, 0-500ppb、鉄(Fe) ; HACH Iron Test Cube, 0-10 mg/l)を使用

3.1.1 カンダール州Prek Russey村(2008年調査)

Prek Russey村はプノンペン南約40Kmのカンダール州のバッサク河の東約2kmに位置し、「カ」国で最も砒素濃度の高い(MRD)カンダール州の一村である。村(人口約2千)の実測した30井戸の水質結果を表3.1に示す。表から国家基準の50ppbを超える砒素濃度を示した井戸は計28、500ppbの井戸が最も多く13、砒素汚染の無い井戸は2との測定結果を得た。即ち97%の井戸水が基準(50ppb)以上の砒素濃度を示しており、カンダール州が最も砒素濃度が高いとするこれまでの結果(MRD、WHO等)と一致する。一方、鉄濃度は1～10mg/lを示し、傾向として高い濃度の井戸が多数であるが、2mg/lと10mg/lの井戸がそれぞれ7つと最も多い結果となった。即ち、砒素濃度と鉄濃度との相関は観測されなかった。また、同村のArsenicosis症例数は当初15で、2009年現在124世帯260名の同症例数が確認されている。

表3.1 実測結果 1 (2008年)

As(ppb)	井戸数
0	2
100	6
250	9
500	13
計	30

村内実測 30 井戸の内、管井戸が 28、掘削井戸が 2

Fe(mg/l)	井戸数
1	2
2	7
4	3
6	5
8	6
10	7
計	30

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[2] 鉄の実測は、研究グループらが「バ」国で行った調査結果(2007、2008年8月他)等から水中の砒素は鉄と1:40の比で共沈し、鉄が砒素を除去できることから両パラメータの濃度レベルを計測し砒素除去に関する適正技術等を考案する際に必要と考えているため。

3.1.2 カンダール州、プレイベン州、コンポンチャム州及びタケオ州各村落（2009年調査）

2009年調査は砒素汚染の広がりを検証するため「カ」国内4州(表3.2)6村の計12井戸水質を実測した。結果は砒素汚染7州の内リスクの高いと報告されている州の順に従い表3.2に整理した。タケオ州は砒素汚染確認外の州である。表からカンダール州、プレイベン州、コンポンチャム州の順に砒素濃度が高くタケオでは1井戸で確認された。この結果は既存の文献等(MRD、WHO他)の情報と一致する。また、砒素濃度が高いプレイベン州の村では井戸の位置により低濃度(10ppb)を観測、地下水砒素汚染が一様ではないことを裏付ける結果である。鉄については砒素濃度が高い井戸から高い濃度を示す傾向があるが表3.1と同様必ずしも正の相関を取っていないことが分かった。

表3.2 実測結果2(2009年)

州	管井戸	As(ppb)	Fe(mg/l)
Kandal	村落1-1	400	10
	村落1-2	500	4
Prey Veng	村落2-1	350	2
	村落2-2	500	2
	村落3-1	250	2
	村落3-2	10	6
Kampong Cham	村落4-1	250	6
	村落4-2	500	10
Takeo	村落5-1	75	0
	村落5-2	0	10
	村落6-1	0	0
	村落6-2	0	10

3.2 質問表調査及びWBDs等医療統計

質問表によるインタビュー調査は砒素問題認識、飲料水確保習慣、砒素除去に対する支払意思額(WTP)等の住民意識を把握する目的で実施した。ここでは紙面の都合で結果を割愛するが、習慣として雨季は雨水及び表流水を、乾季は表流水のみを飲用している点、IEC等の衛生教育等が実施されている村落ほど砒素問題の認識やWTPが高い傾向があることが判明した。なお、WBDsやArsenicosis症例等の統計は「カ」国では入手できなかった。

4. 結論

本研究は「バ」国、「カ」国の安全な水供給、ドナー介入と砒素汚染問題に関する時間的連続性と平行性を明らかにした。また現地調査は「カ」国の砒素汚染の実態について文献等の結果を検証した。「カ」国は医療統計が不十分なためUSAID Country Health Statistical Report(2008)の乳児死亡率等をWBDsの代替データとし、同データとUnicef等井戸建設介入、健康影響との関連を表4.1であると予測した。また「カ」国は雨水を飲用するため砒素汚染水の通年での曝露が相対的に少ないと評価でき、Arsenicosis症例数にも影響すると推測される。即ち社会経済、住民意識、砒素濃度レベル、栄養状態等多様な背景を考慮した介入方法や医療面からの介入アプローチも今後検討したい。

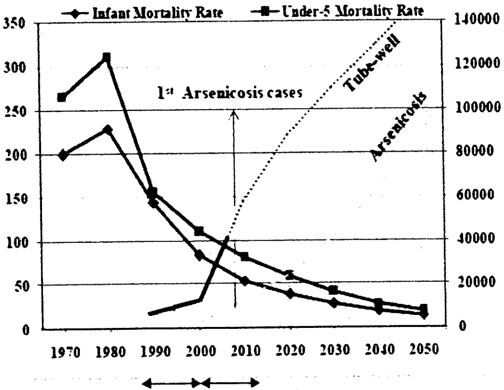

図 4.1WBDs、井戸数(介入)と健康影響(仮説)

5. 謝辞

本研究は各研究メンバーが「バ」国、「カ」国で実施した現地調査等の結果を纏めたものです。特に2009年3月の「カ」国現地調査は国際厚生事業団(JICWELS)の平成20年度水道プロジェクト計画作成指導事業で行われたものであり同事業団ならびに委託元である厚生労働省、また情報提供等の協力をして頂いたMRDを初めAISC関係省、Unicefカンボジア、WHOカンボジア、WSP/世銀の各担当者に対してこの場を借りて御礼申し上げます。

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Dissemination of an Integrated Approach to Arsenic Mitigation in Bangladesh

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Abstract
Arsenic mitigation is a very important issue in Bangladesh where many people still suffer from arsenicosis due to groundwater contamination with arsenic. In this paper, an experience on an integrated approach to arsenic mitigation, and its follow-up and dissemination in Bangladesh is reported for the objective of considering a better way of assistance in rural water supply development. Such an approach, integrating the installation of a safe drinking water supply facility with community development, awareness raising and support to arsenicosis patients, has been developed through two JICA/AAN projects successfully implemented in 2002-2008. The result of the follow-up program clearly shows the importance of continued support for ensuring sustainable safe water supply. In addition, the fact that new safe drinking water supply facilities are being or going to be installed with local initiatives under the support of a dissemination program strongly suggests a new possibility of assistance in safe drinking water supply development in Bangladesh.

Keywords
Arsenic mitigation; Bangladesh; drinking water supply, integrated approach

INTRODUCTION

Groundwater contamination with arsenic is a very serious issue in Bangladesh where many people still suffer from arsenicosis. Most of people in Bangladesh are living in rural areas. They usually use groundwater as drinking water sources because the risk of its microbial contamination is less than that of surface water. Therefore, the supply of arsenic-free drinking water is a big challenge in Bangladesh, and many projects have been implemented for this purpose in the past two decades. Nevertheless, the situation has not remarkably been improved. One of the reasons seems the lack of sustainability. There exist many instances where water supply facilities newly installed by an arsenic mitigation project are not used any more due to technical or managerial difficulties.

Community participation is essential to rural water supply development in developing countries. The efficacy and sustainability of a water supply development project may be increased combing it with other programs for the improvement of environmental health and living conditions. In this paper, an experience on an integrated approach to arsenic mitigation, and its follow-up and dissemination in Bangladesh is reported for the objective of considering a better way of assistance in water supply development.

METHODS

This paper focuses two arsenic mitigation projects, AM Project (JICA and AAN, 2004) and SAM-ILGS Project (LGD and JICA, 2008), consecutively implemented by a NGO, Asia Arsenic Network (AAN), in Jessore District, Bangladesh, in 2002 through 2008 under the funding of Japan International Cooperation Agency (JICA), and their follow-up and dissemination program, Follow-up and Dissemination Program of the SAM-ILGS Project, currently being undertaken. The outlines of the two JICA/AAN projects are shown in Table 1. The follow-up and dissemination program is carried out under the funding of JICA and the supervision by a JICA expert.

Necessary information was collected through literature review, interviews of AAN members engaged in the JICA/AAN projects, and the field survey of the LGD-JICA Follow-up and Dissemination Program. Some of the authors are directly involved in both of the JICA/AAN projects and the follow-up/dissemination program.

Table 1. JICA/AAN projects for arsenic mitigation in Bangladesh (JICA and AAN, 2004; LGD and JICA, 2008).

Item	AM Project	SAM-ILGS Project
Name	Integrated Approach for Mitigation of Arsenic Contamination of Drinking Water in Bangladesh	Sustainable Arsenic Mitigation under Integrated Local Government System in Jessore
Duration	January 2002-December 2004	December 2005-December 2008
Target area	Sharsha Upazila	Sharsha and Chowgacha Upazilas
Beneficiaries	Approx. 20,000	Approx. 35,250
Safe water supply facilities installed	63	151

RESULTS AND DISCUSSION

JICA/AAN arsenic mitigation projects

The main purpose of both these projects was to provide safe, i.e. not only arsenic free but also bacteria free, drinking water supply facilities. During the course of implementation of the two projects, many “red” wells with arsenic concentration of more than 50 micrograms per litre were newly found in Chowgacha and Sharsha Upazilas (LGD-JICA and SAM-ILGS, 2008a). In total, 63 and 151 safe water supply facilities were newly installed in each project as shown in Table 1. They included deep tube wells, pond sand filters, dug well sand filters, arsenic iron removal plants (AIRPs) and piped water supply systems. Beneficiaries living in the project areas were involved throughout all the steps of project implementation. The beneficiaries deposited the amount of money corresponding to ten percent of the initial cost to a bank account, like in many other projects. Each household also pay 5 to 15 Tk (Taka: Bangladesh’s unit of currency) a month, in principle, according to the type of safe drinking water supply facility for the operation and maintenance of the facility.

The feature of these projects was the fact that they were implemented under an integrated approach together with such activities as community development, awareness raising, support to arsenicosis patients, and training of community residents, doctors/health assistants and other stakeholders as shown in Table 2. This is the reason why these projects could attain a high sustainability and, consequently, they were highly evaluated (JICA, 2004; JICA 2008).

Table 2. Main activities in JICA/AAN projects (JICA and AAN, 2004; LGD and JICA, 2008).

Activity	AM Project Jan 2002-Dec 2004	SAM-ILGS Project Dec 2005-Dec 2008
Awareness raising	Yes	Yes
Community development	Yes	Yes
Installation of safe water supply facilities	Yes	Yes
Support of arsenicosis patient	Yes	Yes
Involvement and training of DPHE staffs	No	Yes
Involvement and training of Upazila Health Complex staffs	No	Yes
Organization and support of AMCs	No	Yes

Note) DPHE: Department of Public Health Engineering, AMC: Arsenic Mitigation Committee

Additionally in the SAM-ILGS Project, Arsenic Mitigation Committees (AMCs) were organized at each administration level of Upazila, Union, Ward and Village, and a monthly reporting system from User Committees (UCs) to Union AMCs was established. Involvement and training of DPHE (Department of Public Health Engineering, Local Government Division, Ministry of Local Government, Rural Development & Coopratives) staffs and Upazila Health Complex staffs were also undertaken in the SAM-ILGS Project. The importance of involving local government institutions and DPHE as well as communities in arsenic mitigation in Bangladesh is strongly suggested by M. Nuruzzaman and M. F. Ahmed (2007). Figure 1 shows the framework of maintenance and monitoring of community-based water sources adopted in the SAM-ILGS Project.

In the SAM-ILGS Project, a system for the surveillance and registration of arsenicosis patients using a referral slip under the collaboration of health assistants and doctors of the Upazila Health Complex was established based on the framework created by the Ministry of Health and Family Welfare. The result of arsenicosis patient identification up to 30 September 2008 in Chowgacha and Sharsha Upazilas is shown in Table 3, and, as the result of the following activities for the health management of arsenicosis patients in the SAM-ILGS Project, the condition of nearly a half of the patients improved than before as shown in Table 4. The project also contributed to the establishment of a new way of using the ADP (Annual Development Programme) budget for purchasing medicines for arsenicosis patients.

As described above, the SAM-ILGS Project was unique because it was so intensive under an integrated and multi-sector approach in order to ensure the sustainability of operation and maintenance of each safe drinking water supply facility. For the purpose of sharing lessons learnt in the SAM-ILGS Project, a handbook with a title of "Practice of Sustainable Arsenic Mitigation" (SAM-ILGS, 2008) has been published.

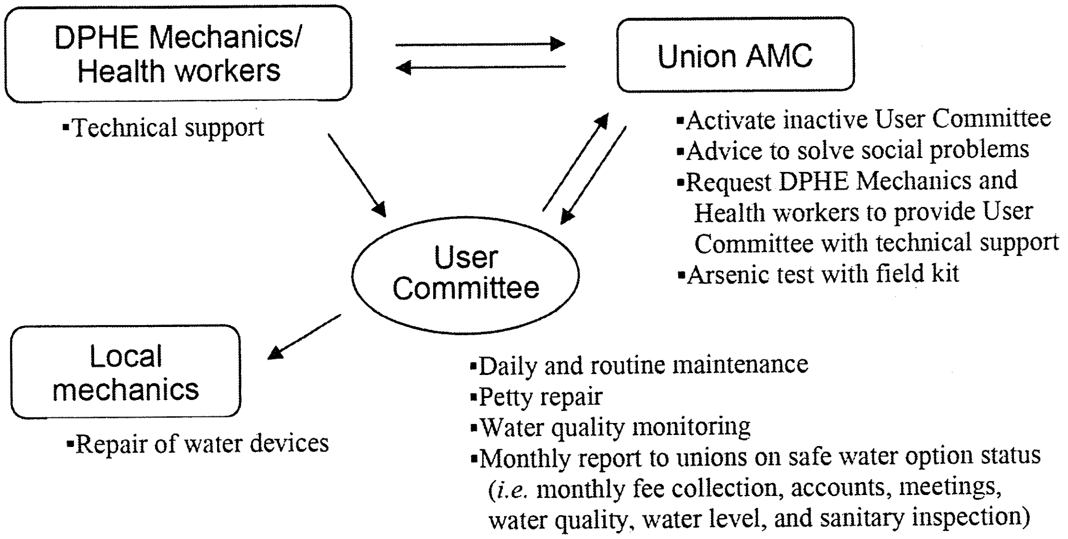


Figure 1. Framework of maintenance and monitoring of community based water sources (LGD and JICA, 2008).

Table 3. The result of arsenicosis patient identification in Chowgacha and Sharsha Upazilas (LGD and JICA, 2008).

Upazila	Suspected Patients (A)	Confirmed Patients (B)	Non-arsenicosis Patients (C)	A – B – C
Chowgacha	1,300	687	571	42
Sharsha	843	478	356	9
Total	2,143	1,165	927	51

Table 4. The condition of patients' health at the end of the SAM-ILGS Project (LGD and JICA, 2008).

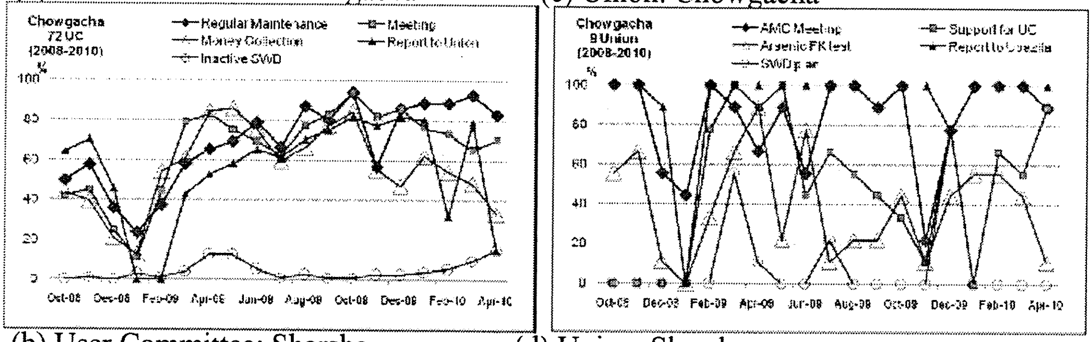
Upazila	Patient	Improved	Not changed	Deteriorated
Chowgacha	687 (100%)	335 (49%)	332 (48%)	20 (3%)
Sharsha	478 (100%)	185 (39%)	254 (53%)	39 (8%)
Total	1,165 (100%)	520 (45%)	586 (50%)	59 (5%)

Follow-up and dissemination of the SAM-ILGS Project

After the finish of the SAM-ILGS Project, its follow-up along with the dissemination of an integrated approach developed in it is being undertaken for the period from January 2009 to March 2011. The target areas of dissemination include Sharsha and Chowgacha Upazilas as well as six other Upazilas, i.e. Abhaynagar, Bagherpara, Jhikargacha, Keshabpur, Manirampur and Sadar Upazilas, in Jessore District.

The progress of follow-up. The purpose of the follow-up program is to continue the support of the activities of UCs and Union AMCs through monitoring and giving advices, if necessary. The activities of UCs and AMCs in Sharsha and Chowgacha Upazilas are shown in Figure 2. They dropped down in the period of the end of the project in 2008 through the beginning of its follow-up in 2009. Although UCs' activities once recovered up to a satisfactory level owing to the support of the follow-up program, they are gradually declining again in general in recent months. The activities of Union AMCs remain rather unstable.

(a) User Committee: Chowgacha (c) Union: Chowgacha



(b) User Committee: Sharsha (d) Union: Sharsha

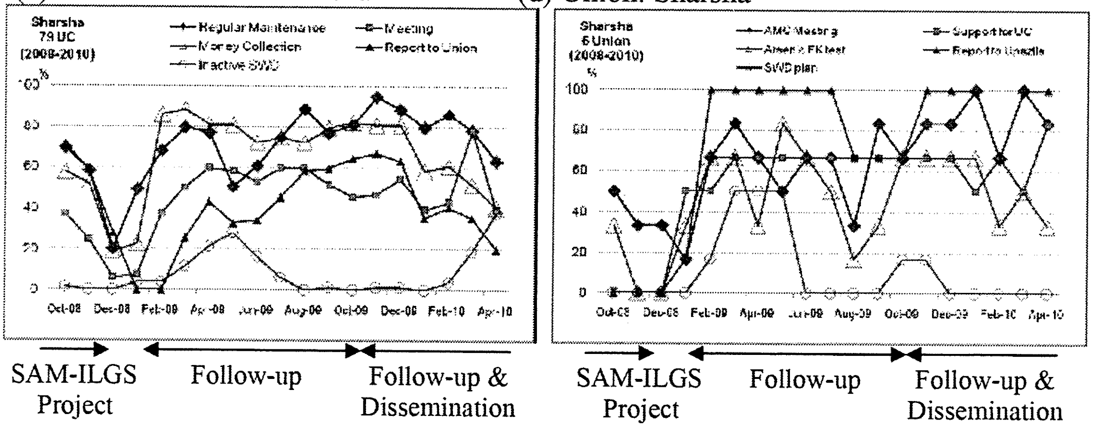


Figure 2. Progress of the follow-up program in Chowgacha and Sharsha Upazilas.

The result of the follow-up shows that it is not easy to maintain the activities of UCs and Union AMCs at high levels. The reason of such a recent decline in UCs' activities is not well clear. However, some UCs were obliged to stop water supply operation due to the lowering of groundwater levels, presumably caused by excessive groundwater abstraction for irrigation. The lowering in groundwater levels in the dry season of this year is remarkable. Another reason may be the limitation of manpower for the follow-up/dissemination program.

Dissemination of an integrated approach. The purpose of the dissemination program is the dissemination of an integrated approach to arsenic mitigation which has been developed through the two JICA/AAN projects. For example, the procedure of dissemination of an integrated approach in Jhikargacha Upazila includes:

1) Communication with Upazila administration
2) Meeting with Union Chairmen
3) Organization of an Upazila orientation program, inviting such guests as written below, and the development of Union AMCs and Ward AMCs
    - DPHE Sub-Assistant Engineer
    - Upazila Health and Family Planning Officer
    - Sharsha UNO (Upazila Nirbahi (=Executive) Officer)

  - Sharsha UP (Union Parishad (=Council)) Chairman
  - Jhikargacha UNO
4) Organization of a Union orientation program
5) Purchase of one arsenic field test kit for each Union by Upazila's own budget (Tk 5,500 for each)
6) Exchange-visit program (3 times)
7) Capacity building, awareness raising, doctors/health assistants training, technical training of DPHE staffs, and arsenic test training at Union level
8) Development of a safe water supply facility (if any budget is available)

One of the successes of the dissemination program in Jhikargacha Upazila is the capacity development of doctors and health assistants, and, in consequence, the identification of new arsenicosis patients. The cases of arsenicosis increased from 144 before training to 253 after training. It was found that there are 288 suspected cases in addition although they still remain suspected because of the limitation of medicines and health cards in the Upazila Health Complex. The cost of the dissemination program for one Upazila is shown in Table 5.

Table 5. Unit cost of dissemination program.

Item	Cost
AMC organization and its orientation	Tk 100,000
Training medical doctors and health assistants	Tk 50,000
Training of DPHE staffs	Tk 15,000
Exchange visits	Tk 50,000
Awareness raising (rally, fair, etc.)	Tk 50,000
Total	Tk 265,000

Note) The cost is per one Upazila.

Installation of a new safe drinking water supply facility under the support of the dissemination program. As written above, the dissemination program is being carried out in Chowgacha and Sharsha Upazilas as well as six other Upazilas. It is encouraging that a safe water supply facility has newly been installed in a village in Chowgacha Upazila, with a strong initiative of a female villager utilizing a LGSP (Local Government Support Program) budget under the support of the dissemination program. The LGSP, a 5-year program for building the capacity of Unions started in 2006, is supported by the World Bank (LGD-JICA and SAM-ILGS, 2008b). Details until the completion of the new water supply facility are as follows:

1) Tube-well screening in 2008 and a lot of arsenic contaminated wells found
2) Villagers' arrangement of a meeting to discuss how to solve the problem and agreement on requesting the Union for installing a safe water supply facility
3) Union Chaiman's acceptance of the female villager's appeal
4) Decision of Union Parishad to provide budget
5) The organization of Para (local community) by the female villager, including:
  - Para map preparation
  - Para meeting arrangement
  - User list preparation
  - UC formation

- User share fixation, money collection, bank account opening and money depositing
- Application to Union Parishad for the construction of a safe water supply facility

6) Issue of a letter from Union Chairman to DPHE asking for a suitability test
7) Conduct of a suitability test by DPHE and DPHE's certification on installing an AIRP (arsenic iron removal plant)
8) Provision of a construction cost estimate and facility design by DPHE
9) The allocation of a budget for construction by Union Parishad
10) Organization of PIC (Project Implementation Committee) chaired by the female villager
11) Purchase of construction materials by the chairperson (the female villager) with technical support (quality assurance, etc.) by DPHE
12) Construction of a safe water supply facility
13) Water quality test by Union Parishad followed by UP's permission to use the facility

This is a very good example showing that a close collaboration among all stakeholders can lead to the installation of a new safe water supply facility with a minimum external support. Some other safe water supply facilities have already been completed or are under planning in a way similar to this in Sharsha and Chowgacha Upazilas.

CONCLUSIONS

Among many arsenic mitigation measures taken so far in Bangladesh, the follow-up and dissemination program as reported here is unique. This example clearly shows the importance of continued support for ensuring sustainable safe water supply although it is not always easy to be realized. However, the fact that new safe drinking water supply facilities are being installed with local initiatives under the support of the dissemination program strongly suggests a new possibility of assistance in safe drinking water supply development in Bangladesh.

ACKNOWLEGEMENT

The authors express their gratitude to DPHE, LGD and the local government of Jossore District, residents in the target areas of the AM and SAM-ILGS Projects, JICA, all the staffs of the JICA/AAN projects, all the staffs of LGD-JICA Follow-up and Dissemination Program of SAM-ILGS Project, and all other people concerned.

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バングラデシュ国とカンボジア国における地下水ヒ素汚染の現状と対策における比較研究

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キーワード：地下水ヒ素汚染、カンボジア、バングラデシュ、水使用形態、持続的対策

1．研究の目的

近年カンボジア王国（以下「カ」国）において、地下水ヒ素汚染対策の先行事例のあるバングラデシュ国(以下「バ」国)と同様なヒ素汚染が確認され、地下水を多飲する村落部でヒ素汚染による慢性ヒ素中毒(Arsenicosis)の健康被害が報告されている。即ち、先行研究や文献レビュー等から「バ」国おける国際機関等ドナー組織による管井戸（チューブウェル）建設による安全な水供給の支援（介入）、地下水ヒ素汚染の拡大及び健康への影響（水系性疾患(WBDs)症例の減少と Arsenicosis 症例の増加）、その後の地下水ヒ素問題へ国際機関等による介入経緯と「カ」国のヒ素問題発生の経緯及びその後の対応には類似点が認められる。しかしながら、両国の自然条件、社会条件及び行政的対応などヒ素汚染とその対応を廻り両国では多くの相違点も確認される。このため、両国においてこの類似点と相違点を明らかにするための現地調査や先行事例等のレビューを実施した。本研究は両国の現地調査やレビュー結果を比較分析し、両国で取るべき介入アプローチの違いや持続可能で内発的発展を促すような代替水源の普及方策の検討に必要な条件を明らかにすることを目的とした。

2．研究の方法

研究グループは 2008 年「バ」国、2009 年「カ」国、そして 2010 年 8 月に両国において現地調査を以下の研究体制の下、実施した。

（1）調査体制及び現地調査

① 「バ」国：BUET(Bangladesh University of Engineering and Technology)をカウンターパートとし、対象地は Manikganj, Ghior, Baikunthapur village

② 「カ」国：ITC(Institute of Technology of Cambodia)をカウンターパートとし、対象村落はカンダール州，キンスバイ，バンフェイデック，クソン村及びカンダールレウ村

（2）先行研究と文献レビュー

Unicef、WHO 等国際機関、JICA や GTZ 等バイドナーや両国政府関連機関（「バ」国 DPHE、BUET 等、「カ」国農村開発省（MRD）、ITC 等）等が実施した先行研究・報告書等のレビューにより、ヒ素汚染や Arsenicosis 症例の広がりや介入アプローチ等を中心にレビューを実施。

（3）質問票によるヒアリング調査

2010 年調査は両国の村落部で比較検討を可能とするため各対象村落の実情を評価した類似の質問票を作成しヒアリング調査を行った。同調査は、両国の各対象村落の用途別水源を明らかにすること、

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村落部に水使用習慣に適正なヒ素対策のアプローチ検討等を主眼に置いた質問項目を設定した。

（4）地下水質調査

① 実測目的：文献等で報告されているヒ素汚染の実態の検証すための簡易検査

② 分析項目：ヒ素(As)及び鉄(Fe)

③ 分析方法：各分析項目の濃度レベルの計測のため以下のフィールドキット（ヒ素(As)；HACK As Test Kit, 0-500ppb、鉄(Fe)；HACH Iron Test Kit, 0-50 mg/l)を使用

3．現地調査結果

（1）水質検査結果

「カ」国の対象村落において計 25 井戸からサンプルを採取し水質検査を行った。結果、72%の井戸水が「カ」国家飲料水基準(CDWQS)のヒ素濃度(50ppb)以上を示し、最大値は 500ppb と高濃度であった。

表3.1 実測結果

Cambodia

As(ppb)	井戸数
0	4
5	2
15	1
25	3
50	3
75	2
100	2
250	2
450	1
500	5
計	25

表3.2 実測結果

Bangladesh

As(ppb)	井戸数
0	3
5	2
10	4
25	1
50	1
75	1
計	12

*全て管井戸

一方、「バ」国の対象村落では、計 12 井戸からサンプルを採取し水質調査を行った。結果、「バ」国家飲料水基準であるヒ素濃度(50ppb)以上の井戸は僅か 16.7%であった。この結果に対し、我国等先進国が採用している WHO ヒ素飲料水質基準(10ppb)を適応した場合、それを超えた「バ」国の井戸は 58%と半部以上となる。なお、「バ」国の比較的ヒ素濃度が低めであったのは調査時期が雨期であることが間がられるが、調査村落の土質はシルト質で透水率が一般土壌に比べて低いこと、地域差等が考えられるが詳細は不明である。（表 3.1、表 3.2 参照）。同時に測定した地下水の鉄濃度はスペース都合で割愛するが、「カ」国調査対象井戸の 88%が 10mg/l 以下であった。一方、研究メンバーが 2008 年、2009 年に「カ」国の他村落で実施した調査結果からも同様に比較的低い鉄濃度を観測した。但しヒ素と鉄が 1:40 の割合で共沈するとした両者の相関性は今回も確認されなかった。これは、調査の精度、調査時期が雨期で地下水への影響（希釈）や溶存酸素による酸化等が考えられるが、本研究グループは、地域差はあると考えられるが、「バ」国に比べて「カ」国の鉄濃度が一般的に低いとした先行研究[1)]や調査事例結果を支持する。

表3.3 用途別水源の使用率(%)

Purpose and Water source		Bangladesh				Cambodia			
		TW	Rain	River	Water bender	TW	Rain	River	Water bender
Dry season	Drinking	91.7	0.0	8.3	0.0	30.8	50.0	3.8	53.8
	Cooking	83.3	50.0	25.0	0.0	34.6	46.2	3.8	53.8
	Cook rice	91.7	41.7	33.3	0.0	34.6	42.3	3.8	53.8
	Washing plates	83.3	8.3	8.3	0.0	96.2	0.0	0.0	3.8
	Washing clothes	58.3	8.3	25.0	0.0	96.2	0.0	0.0	3.8
	Washing hands	91.7	0.0	0.0	0.0	96.2	0.0	0.0	3.8
	In the toilet	83.3	0.0	16.7	0.0	96.2	0.0	0.0	3.8
	Cleaning house	75.0	0.0	16.7	0.0	96.2	0.0	0.0	3.8
	Domestic animals' drinking water	50.0	0.0	8.3	0.0	100.0	0.0	0.0	0.0
	Bathing (Women)	50.0	8.3	41.7	0.0	100.0	0.0	3.8	3.8
	(Men)	50.0	0.0	50.0	0.0	69.2	0.0	0.0	0.0
Rain season	Drinking	91.7	8.3	8.3	0.0	15.4	88.5	0.0	15.4
	Cooking	91.7	50.0	33.3	0.0	23.1	88.5	0.0	15.4
	Cook rice	91.7	50.0	33.3	0.0	23.1	88.5	0.0	15.4
	Washing plates	83.3	8.3	8.3	0.0	92.3	3.8	0.0	3.8
	Washing clothes	58.3	8.3	33.3	0.0	92.3	3.8	0.0	3.8
	Washing hands	83.3	0.0	0.0	0.0	92.3	3.8	0.0	3.8
	In the toilet	75.0	0.0	16.7	0.0	88.5	3.8	0.0	3.8
	Cleaning house	66.7	0.0	16.7	0.0	88.5	3.8	0.0	3.8
	Domestic animals' drinking water	41.7	0.0	16.7	0.0	92.3	3.8	0.0	3.8
	Bathing (Women)	41.7	0.0	41.7	0.0	96.2	3.8	3.8	0.0
	(Men)	50.0	0.0	50.0	0.0	80.8	3.8	0.0	0.0

（2）住民の水使用形態

両国の調査対象地域における村落住民の用途別水源使用率を表 3.3 に示す。「バ」国では、雨季乾季とも管井戸を飲料(91%)として使用している。「バ」国では水の購入する世帯は確認できなかった。また、調理や炊事に雨水や河川水を利用することも確認でき、生活用水に河川水を利用する背景は、鉄による繊維着色等を忌避することをヒアリングで明らかにした。一方「カ」国は、30.3%が管井戸を飲料水源として使用し、雨季乾季とも雨水や水の購入が主な代替水源として利用している。さらに水売りから近隣河川水を購入・飲料しておりその世帯は 57.7%であることが分った。従って、ヒアリング調査により、両国の村落部における水の使用形態は明確に異なると結論付けることができる。

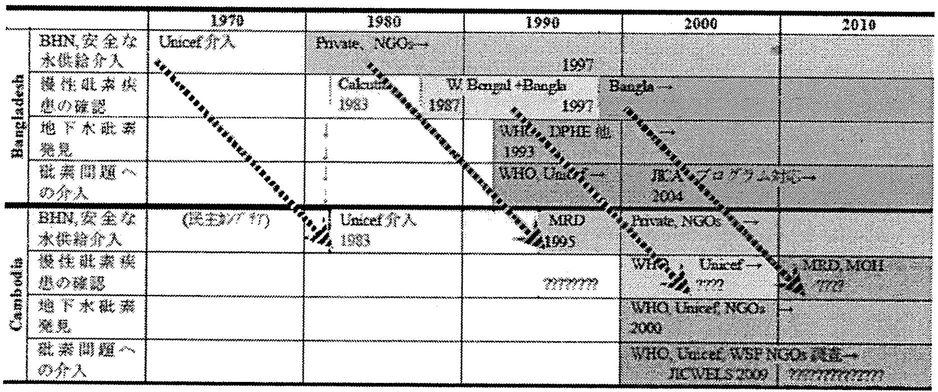
（3）類似点と相違点

①類似性

2008 年、2009 年に両国で実施した現地調査及び文献レビューから両国のドナー等の介入とヒ素問題対応の変遷に関し、以下の時間的連続性及び並行性の類似点を明らかにした。

a）時間的連続性

時間的連続性とは両国における、①村落部の水不足(BHN)及び表流水の生物汚染 → ②管井戸等建設による安全な水供給へのドナーの介入 → ③WBDs症例数の減少(正の健康影響) → ④地下水ヒ素汚染の拡大と Arsenicosis 症例の増加(負の健康影響) → ⑤地下水ヒ素問題へ国際機関等ドナーによる介入、とした変遷。



出所：「カンボジア国村落部における地下水ヒ素汚染に関する研究」五十嵐、Sophak 他 2009 国際開発学会研究発表会論文集

図 3.1　地下水ヒ素汚染に関する時間的並行性 2)

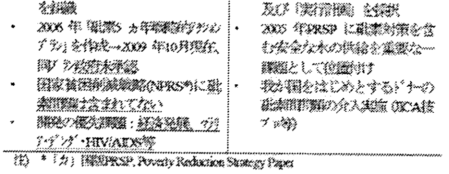
b）時間的並行性

時間的並行性とは図 3.1 に示す時間的連続性の中で観測される両国における各事象の発生の時間的変位 2)（位相）である。即ち Unicef 介入による井戸掘削による安全な水供給を開始後の約 10 年位から Arsenicosis 症例と地下水のヒ素汚染が確認され始めた。次に、両国政府および国際機関やドナー等の対応は事実確認に約 10 年位の時間を要している点である。「カ」国で井戸建設の Unicef 介入が新政府樹立後の 1983 年で、この年はカルカッタで最初の Arsenicosis 症例の確認された年である。即ち 1983 年以降に隣接したベンガル地方を含め「バ」国で発見された Arsenicosis 症例や地下水ヒ素汚染の同様の経緯等を「カ」国でも辿っている。

c）管井戸の普及と利便性

両国のヒ素汚染に対する Unicef の介入により建設開始された管井戸は現在民間企業が参入し Unicef 介入中止後も引き続き安価に井戸掘削が行われている。また、現地調査から「バ」国の管井戸平均利用率が乾期 73.5%、雨期 70.5%であり、「カ」国では乾期 77.3%、雨期 71.3%である(表 3.3)。これらから両国村落部における管井戸の利便性が非常に高いことが判る。即ち、両国とも Unicef 介入以前はあまり存在しなかった管井戸が介入後 10 年以上も利用してことからその利便性が住民に定着していると考察され、ここに介入結果としての類似性が認められる。

表 3.4 地下水ヒ素汚染問題に対する両政府の対応比較 2)



カンボジア政府	バングラデシュ政府
• 2002 年、[illegible] からなる AISC を組織 • 2006 年「[illegible] ヵ年[illegible]アクションプラン」を作成→2009 年10月現在、[illegible] • 国家貧困削減戦略(NPRS*)に[illegible]含まれていない • 開発の優先課題：経済発展、[illegible]・HIV/AIDS 等	• 2004 年「[illegible]」及び「[illegible]」を採択 • 2005 年PRSP に[illegible]対策を含む安全な水の供給を重要な一課題として位置付け • 我が国をはじめとするドナーの[illegible]の介入実施 (JICA 技プロ等)

注）*「カ」国PRSP, Poverty Reduction Strategy Paper

②相違点

図 3.1 により両国のヒ素汚染対応の連続性、平行性においての類似点を示したが、表 3.4 は両国政府のヒ素汚染問題に対する対応(2010 年現在)2)を示したもので、表から明らかに両政府の対応には 180 度の違いがあることがわかる。

また、表 3.4 からヒ素濃度、雨水等飲用慣習や水購入習慣の違いが理解される。特に「バ」国では、最大ヒ素濃度 75ppb で、一方、「カ」国のそれは 500ppb と非常に高いヒ素濃度が検出された。また、

表 3.5 相違点

比較		バングラデシュ	カンボジア
ヒ素濃度(Max)	雨期	75ppb	500ppb
管井戸 (飲料使用率)	乾期	91.7%	30.8%
	雨期	91.7%	15.4%
雨水 (飲料使用率)	乾期	0.0%	50.0%
	雨期	8.3%	88.5%
表流水 (炊飯時使用率)	乾期	33.3%	3.8%
	雨期	33.3%	0.0%
水購入(表流水) (飲料使用率)	乾期	0.0%	53.8%
	雨期	0.0%	15.4%

「バ」国では鉄の吸着剤を必要としないヒ素・鉄除去装置(AIRP)を On-Site な適正技術としてその可能性を評価いている [3](BUET、東洋大他)が、「カ」国では鉄釘を吸着剤に用いるカンチャンフィルター(適正技術の一つ)の導入が試みられている(ITC)。これは両国の鉄濃度の相違がある。即ち、3.(1)で考察したとおり、「バ」国の方が「カ」国より鉄濃度が高いとする相違性があることが推察される。次に、地下水の使用状況・水汲み習慣は両国において大きな相違がみられる。即ち、「バ」国では主に管井戸を飲料として使用しており、1 日 1 時間程度を浪費し表流水汲みを行っている。他方、「カ」国では雨水や河川水を購入（1$:1000ℓ）し飲料等している点である(表 3.5)。これは、「カ」国は伝統的に約 1m^3 の水瓶(タイ東北部やラオスでも使用されている)を使用し雨水を利用する習慣がある、一方「バ」国にそのような水瓶は無く、雨水を飲用しない。即ち雨水利用において両国の社会習慣・文化的背景に大きな違いがあることが分った。

以上、両国の相違点を概説したが、地下水による安全な水供給を断念した Unicef 等ドナーや両政府は、Rainwater harvest による安全な水の供給の可能性の検討を開始し始めている（Unicef カンボジア, IUCN バングラデシュ聞き取り調査による)。このため今後、雨水利用に関する啓発活動や適正技術導入等が拡大していく可能性もあることが推察される。しかしながら、雨水の利用は生物汚染問題に回帰する恐れがあることが予想される点が新たな問題として検討されている。

4．結論

本研究から両国の政策、社会習慣・文化的背景、水質(ヒ素、鉄濃度)、雨水利用、水使用形態の相違点は点が明らかになった。これら諸点はヒ素対策アプローチ(ソフト・ハード両面)を検討する際に明確する必要がある最低限の評価項目であることが本比較調査結果から判明した。即ち本研究から両国の類似点と相違点を明らかにしたが、今後は、現在両国以外の特にヒマラヤ山系諸国でみられるヒ素汚染対応を検討する際には、こうした先行他国での対応の類似点や当該国や地域の相違点をより精査し明確にすることで、より的確で端的なヒ素対応アプローチを考案する際の手助けになるものと考えられる。ただし今回の研究は両国数村落に限られた調査で得られた結果であり国や地域差については詳細に検討し今後一般化してくことにしたい。

5．謝辞

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