Impact of global warming on waterborne diseases

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Research Objectives

- Health impact analysis on global warming utilizing statistical model
- Focus on diarrhea, one of the waterborne diseases,
  - Developing a diarrheal incidence estimation model (based on water supply, sanitation coverage, present situation of diarrheal incidence, temparature)
  - Estimating the changes in diarrheal incidence in future worlds under SRES scenario

Present condition and causes of waterborne diseases

- Diarrhea incidence is closely related to drinking water quality and sanitation, about 4 billion cases are reported to occur every year with some 2.2 million deaths (WHO)
  - ✓ Bern et al:
    - Estimated mortality from diarrhea in developing countries at 3.3 million (1.5 to 5.1 million people).
    - Diarrheal incidence of 2.6 times per year per infant (aged 5 years or younger).
  - ✓ WHO:
    - Deaths resulting from diarrhea are mostly seen in infants aged 5 years or younger, with diarrhea accounting for about 15% of infant mortality in developing countries
  - ➢ Necessity of improving water and sanitation condition
- How about is the effect of global warming for cause of diarrheal incidence?

Present access to water supply and sanitation

Access to Water supply and Sanitation in 1990 and 2000

	1990	2000
Water supply	79% (4.1billion)	82% (4.9billion)
Sanitation	55% (2.9billion)	60% (3.6billion)

But…

- As of the year 2000 about 1.1 billion people still had no access to safe water
- About 2.4 billion people were living in poor sanitary environments without access to sanitation,
  - Leading to the incidence of various diseases

Action for reduction of waterborne diseases

- In order to improve the substandard water supply and sanitation environment, VISION 21 was initiated in 2000 under the leadership of the Water Supply and Sanitation Collaborative Council (WSSCC).

SUGGESTED TARGETS FOR 2015 AND 2025

2015	2025
• universal public awareness of hygiene • percentage of people who lack adequate sanitation halved • percentage of people who lack safe water halved • 80% of primary school children educated about hygiene • all schools equipped with facilities for sanitation and hand washing • diarrhoeal disease incidence reduced by 50% • fundamental requirement. Minimum sanitation standards should be established at national level.	• good hygiene practices universally applied • adequate sanitation for everyone • safe water for everyone • all primary school children educated about hygiene, • diarrhoeal disease incidence reduced by 80%.

Impact of global warming on waterborne diseases

- Temperature are also strongly related to waterborne diseases, and global warming is forecast to further increase the incidence of waterborne diseases
  - ✓ Checkley et al. reported that a temperature increase of 1℃ would lead to an 8% rise in the number of diarrhea cases (aged 10 years or younger in Peru)
  - ✓ Singh et al. reported a positive correlation between annual average temperature and diarrheal incidence as well as a negative correlation between water supply accessibility and diarrheal incidence in the Pacific Islands

Estimation method

- ***Region***: Regional categories of the Global Burden of Diseases 2000 project (GBD) conducted by WHO
  - ✓ GBD divides the world into 14 regions based on geographical distribution and mortality rates,
  - ✓ Estimates the incidence, mortality, etc. of various diseases according to these regions
- ***Estimation***: Multiple regression analysis on diarrheal incidence (diarrheal incidence per capita per year) in 2000 (present condition) reported by GBD by region and factors related to incidence, and estimated future diarrheal incidence (2000, 2025, 2055) .
- ***Parameter***: Four factors related to diarrheal incidence: water supply coverage, sanitation coverage, annual average temperature, and per capita GDP.
- ***Scenario***: SRES (A1B, A2, B1, B2)

Regional reporting categories for Global Burden of Disease 2000 project: WHO regions and 14 subregions

Index	WHO region	Mortality strarum	WHO Member States
AFRO_D	AFRO	D	Algeria, Angola, Benin, Burkina Faso, Cameroon, Cape Verde, Chad, Comoros, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Madagascar, Mali, Mauritania, Mauritius, Niger, Nigeria, Sao Tome And Principe, Senegal, Seychelles, Sierra Leone, Togo
AFRO_E	AFRO	E	Botswana, Burundi, Central African Republic, Congo, Côte d'Ivoire, Democratic Republic Of The Congo, Eritrea, Ethiopia, Kenya, Lesotho, Malawi, Mozambique, Namibia, Rwanda, South Africa, Swaziland, Uganda, United Republic of Tanzania, Zambia, Zimbabwe
AMRO_A	AMRO	A	Canada, United States Of America, Cuba
AMRO_B	AMRO	B	Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, El Salvador, Grenada, Guyana, Honduras, Jamaica, Mexico, Panama, Paraguay, Saint Kitts And Nevis, Saint Lucia, Saint Vincent And The Grenadines, Suriname, Trinidad And Tobago, Uruguay, Venezuela
AMRO_D	AMRO	D	Bolivia, Ecuador, Guatemala, Haiti, Nicaragua, Peru
EMRO_B	EMRO	B	Bahrain, Cyprus, Iran (Islamic Republic of), Jordan, Kuwait, Lebanon, Libyan Arab Jamahiriya, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, United Arab Emirates
EMRO_D	EMRO	D	Afghanistan, Djibouti, Egypt, Iraq, Morocco, Pakistan, Somalia, Sudan, Yemen
EURO_A	EURO	A	Andorra, Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Luxembourg, Malta, Monaco, Netherlands, Norway, Portugal, San Marino, Slovenia, Spain, Sweden, Switzerland, United Kingdom
EURO_B	EURO	B	Albania, Armenia, Azerbaijan, Bosnia And Herzegovina, Bulgaria, Georgia, Kyrgyzstan, Poland, Romania, Slovakia, Tajikistan, The Former Yugoslav Republic Of Macedonia, Turkey, Turkmenistan, Uzbekistan, Yugoslavia
EURO_C	EURO	C	Belarus, Estonia, Hungary, Kazakhstan, Latvia, Lithuania, Republic of Moldova, Russian Federation, Ukraine
SEARO_B	SEARO	B	Indonesia, Sri Lanka, Thailand
SEARO_D	SEARO	D	Bangladesh, Bhutan, Democratic People's Republic of Korea, India, Maldives, Myanmar, Nepal
WRPO_A	WPRO	A	Australia, Japan, Brunei Darussalam, New Zealand, Singapore
WPRO_B	WPRO	B	Cambodia, China, Lao People's Democratic Republic, Malaysia, Mongolia, Philippines, Republic Of Korea, Viet Nam, Cook Islands, Fiji, Kiribati, Marshall Islands, Micronesia (Federated States Of), Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu

Selection of Explanatory Variables (Multiple Regression Analysis)

A: SUPPLY, B: SANITATION, C: TEMP, D: LN (GDP/CAP)

		A	B	C	D	AB	*AC*	**AC'**	AD	BC	BD	CD	ABC	ABD	ACD	BCD	ABCD
	Squared multiple correlation coefficient adjusted for the degrees of freedom	0.62	0.64	0.56	0.69	0.72	*0.74*	**0.85**	0.71	0.70	0.71	0.76	0.77	0.73	0.77	0.75	0.76
	Standard error	0.44	0.43	0.47	0.40	0.38	*0.36*	**0.29**	0.38	0.39	0.38	0.35	0.34	0.37	0.34	0.35	0.35
	Number of Determinant	1.00	1.00	1.00	1.00	2.00	*2.00*	**2.00**	2.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	4.00
Coefficient	Intercept (a)	2.63	1.32	-25.74	4.71	2.38	*-13.38*	**-19.05**	4.35	-12.46	3.66	-9.41	-9.13	3.50	-8.50	-7.88	-7.31
	SUPPLY (b)	-3.89				-2.19	*-2.58*	**-2.29**	-1.73				-1.87	-1.48	-1.43		-1.32
	SANITATION		-2.58			-1.55				-1.70	-1.19		-0.98	-1.01		-0.72	-0.59
	TEMP (c)			0.09			*0.05*	**0.07**		0.05		0.04	0.04		0.04	0.04	0.03
	LN(GDP/CAP)				-0.62				-0.41		-0.39	-0.43		-0.25	-0.28	-0.33	-0.20
t-Value	Intercept	3.74	3.20	-4.32	4.79	3.90	*-2.20*	**-3.62**	4.46	-1.75	3.06	-1.41	-1.40	2.99	-1.31	-1.13	-1.07
	SUPPLY	-4.67				-2.16	*-3.07*	**-3.39**	-1.44				-1.97	-1.25	-1.33		-1.19
	SANITAION		-4.86			-2.34				-2.59	-1.44		-1.42	-1.24		-0.88	-0.74
	TEMP			4.22			*2.64*	**4.15**		1.94		2.13	1.76		2.00	1.68	1.60
	LN(GDP/CAP)				-5.44				-2.25		-2.06	-3.27		-1.12	-1.58	-1.80	-0.96

: SUPPLY, B: SANITATION, C: TEMP, D: LN (GDP/CAP)

Procedure for diarrhea incidence estimation

Multiple Regression Analysis

Dependent variable

LN (INC/CAP)

Independent variables

- SUPPLY
- SANITATION
- TEMP
- LN(GDP/CAP)

SRES scenarios

A1B:Moderate environmental preservation (rapid economic growth)	A2:Environmental preservation-neglecting (slow economic growth
B1:Environmental preservation-oriented (rapid economic growth second to that of A1B)	B2:Environmental preservation-oriented (moderate economic growth)

Future scenarios

Annual average temperature

- AO-GCM (NIES/CCSR, IS92a)
- Simplified climate model
- Scaling method

Water supply coverage estimation

$$SUP = \mathrm{Min}(1, c \times (a + b \times \ln(GDP / CAP)))$$

GDP/CAP：per capita GDP (PPP, 1999US$)，*a*, *b*：regression coefficient，*c*：correction coefficient

Diarrhea incidence estimation

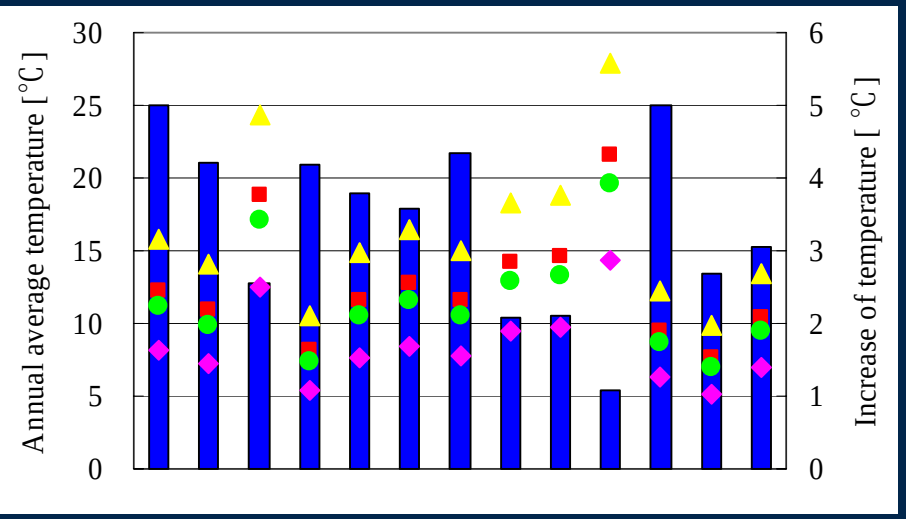
$$\ln(INC / CAP) = d \times e^{a+b \times SUP + c \times TEMP} \quad (1)$$

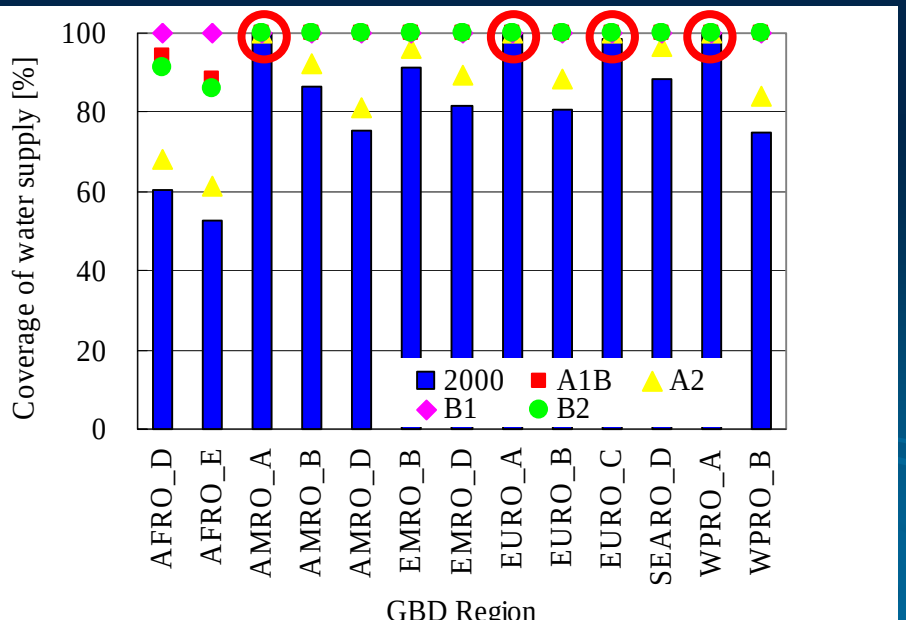
INC/CAP：Diarrheal incidence (incidence per year per capita)，
SUP：Water supply coverage (%/100)，
TEMP：Annual temperature average (K)，
a, *b*, *c*：regression coefficient，*d*：correction coefficient

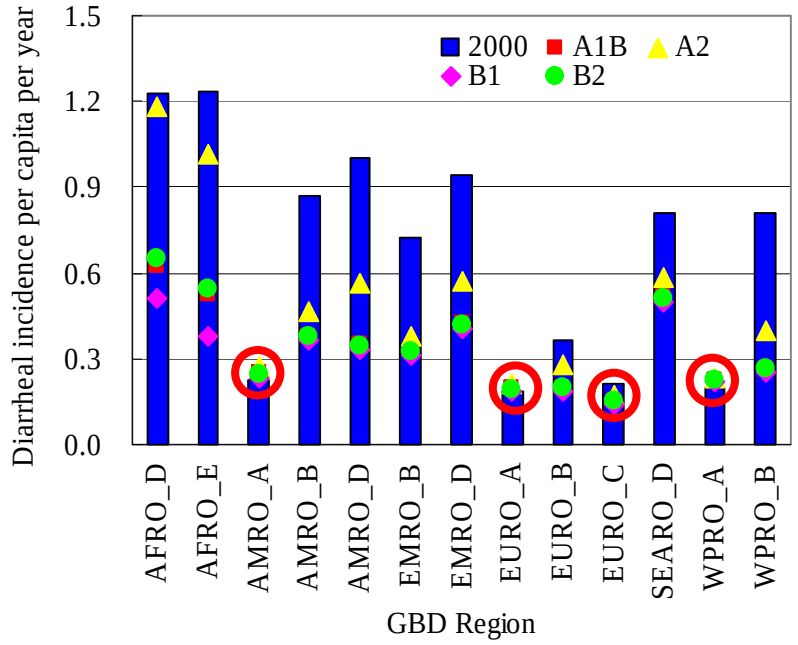
Diarrheal incidence of about 7.3% per 1℃

Changes in diarrheal incidence by region

(Group Ⅰ :AMRO_A, EURO_A, EURO_C, WPRO_A)



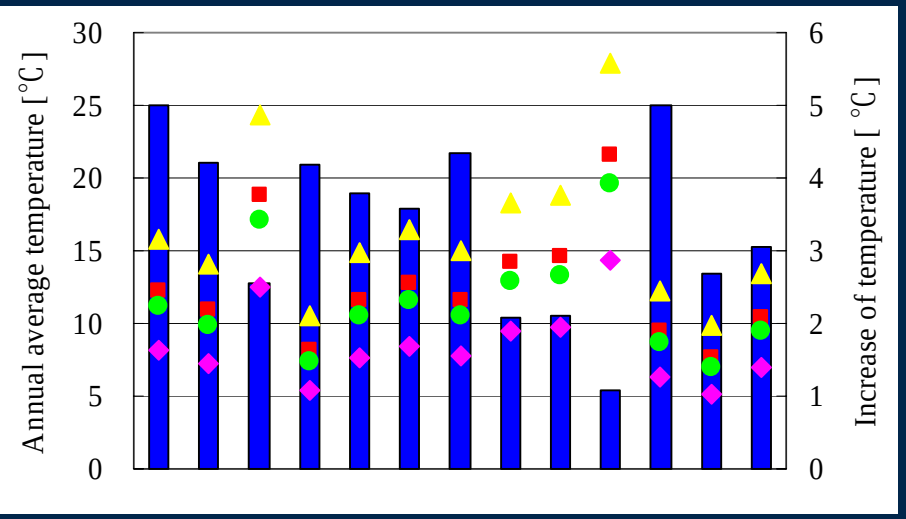


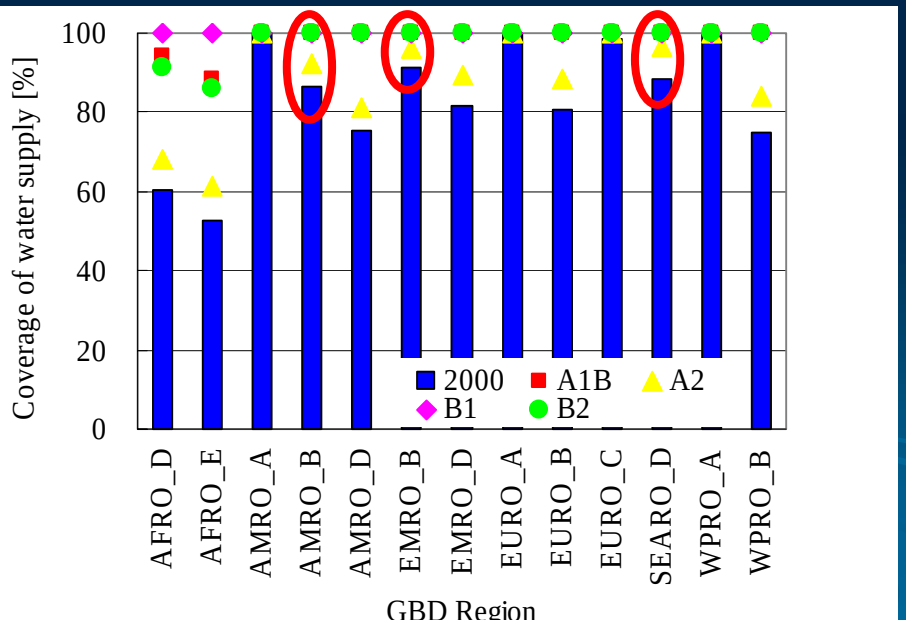


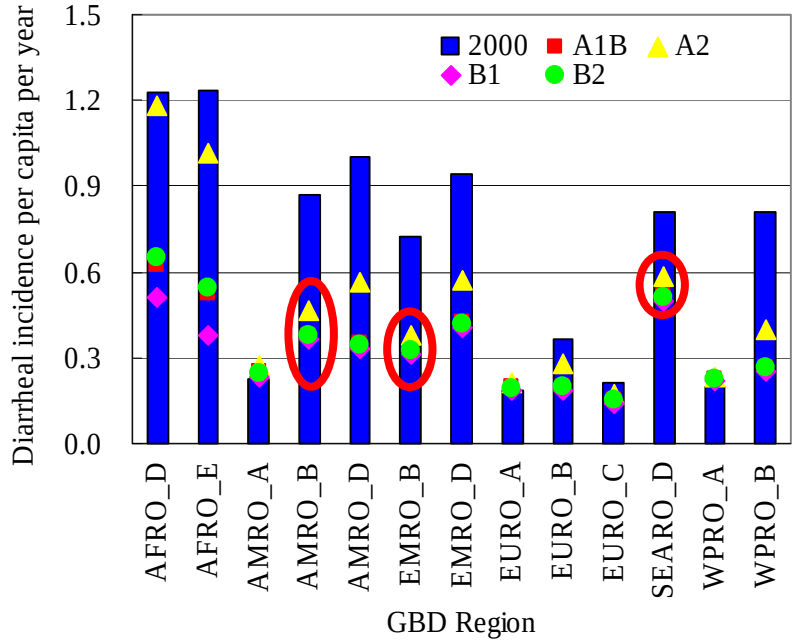
- Present water supply coverage:100%
- Low level (0.2 to 0.25) in 2055
- Almost the same as the present condition, although there are slight differences according to the level of temperature increase among the scenarios

Changes in diarrheal incidence by region

(Group Ⅱ :AMRO_B, EMRO_B, SEARO_D)



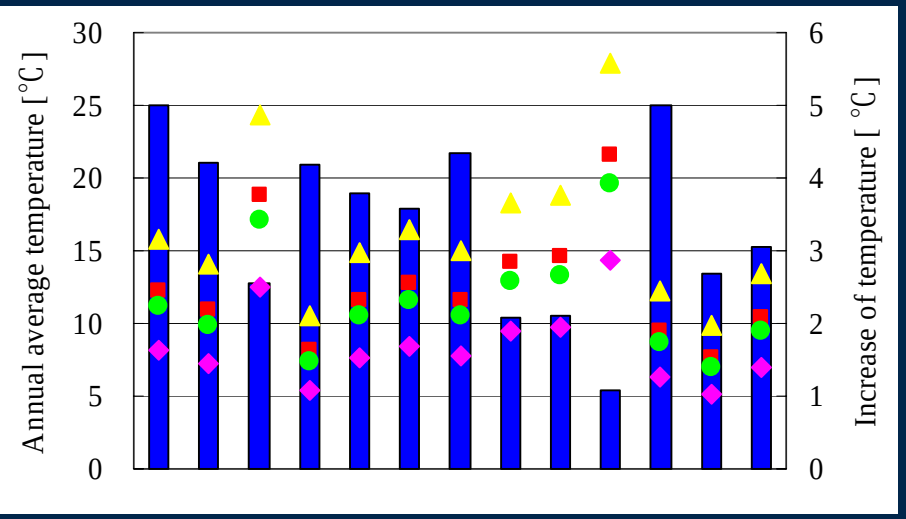


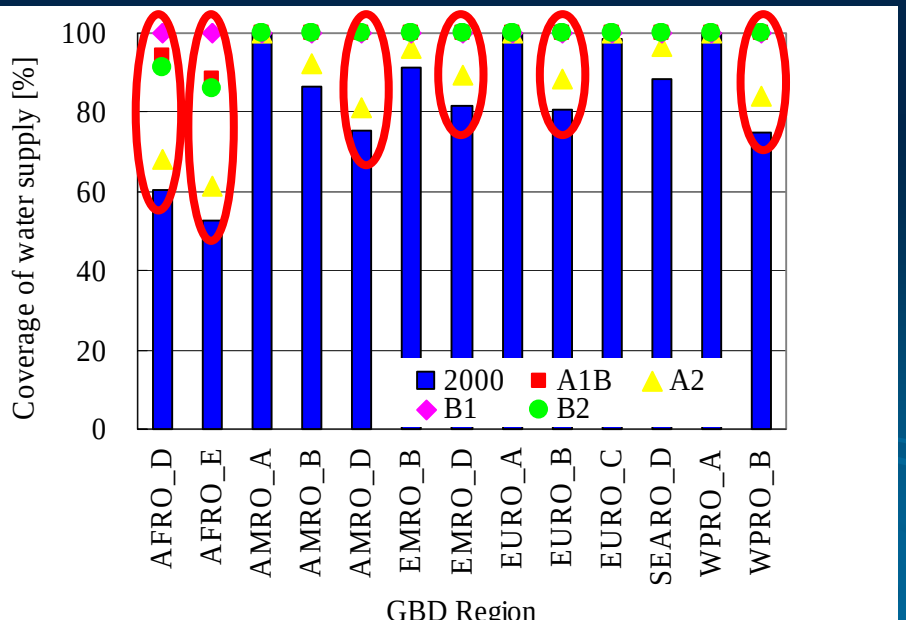


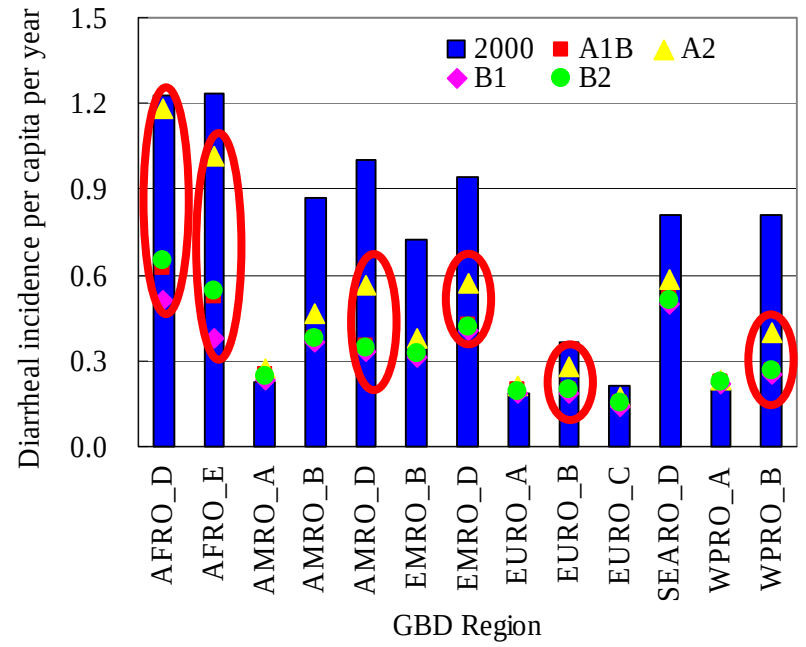
- Present water supply coverage: over 85%
- Water supply coverage reaches 100% in 2055 for all scenarios excluding A2
- Differences in the incidence are seen reflecting the temperature differences among the regions with relatively high average temperatures, so that the incidence does not decrease to the level of Group I

Changes in diarrheal incidence by region

(GroupIII:AFRO_D, AFRO_E, AMRO_D, EMRO_D, EURO_B, WPRO_B)



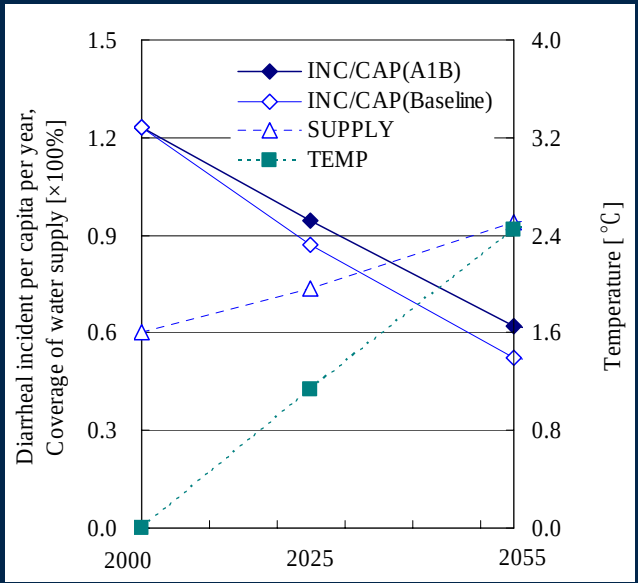




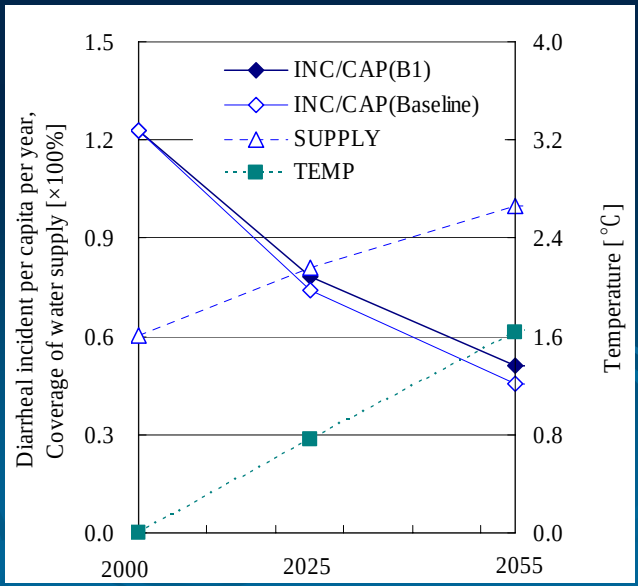
- Present water supply coverage: under 85%
- Large differences among scenarios in the diarrheal incidence in 2055 with the exception of EURO_B
- The highest diarrheal incidence in 2055 is scenario A2 in the AFRO_D region (1.18), showing little improvement from the preser condition.

Changes in diarrheal incidence by scenario (AFRO_D)

- AFRO_D: Highest diarrheal incidence in 2000 (1.23) and exhibited a large difference among the scenarios
- Water supply coverage in 2055 reaches 100% in both scenarios
- Differences in temperature increase (A1B: 2.45℃, B1: 1.63℃)
  - Diarrheal incidence in B1 in 2055 is 11% lower than in A1B
- Baseline: Only water supply coverage changes while the temperature does not change
  - ✓ Differences (2025,2050): A1B(0.07, 0.10), B1(0.04,0.06)
    - Influence of temperature increases is small



A1B

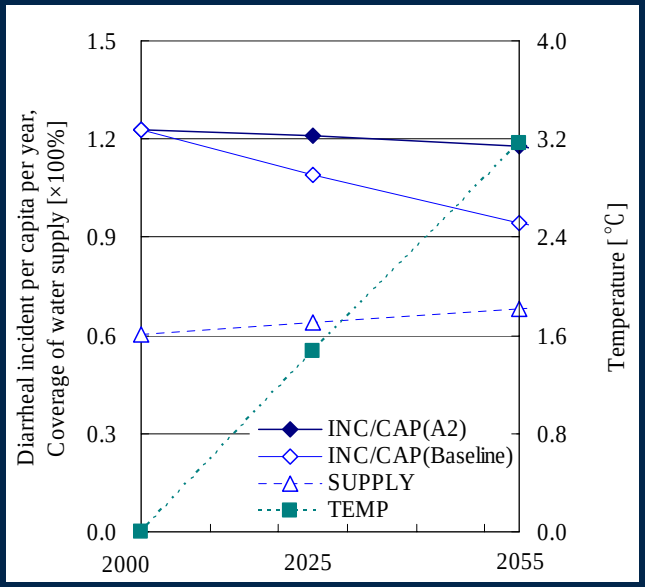


B1

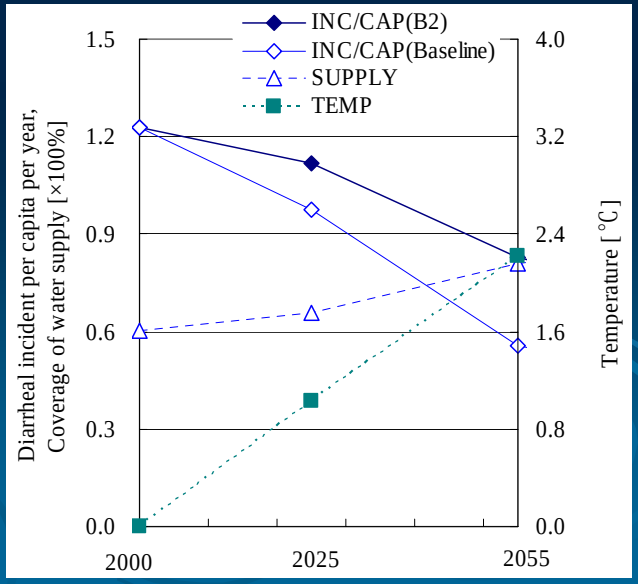
Changes in diarrheal incidence by scenario (AFRO_D)

- A2
  - ✓ Temperature increase is large
  - ✓ Water supply coverage is low
  - ✓ Diarrheal incidence shows insignificant decreases : 1.23(2000), 1.21(2025), 1.18(2055)
- B2
  - ✓ Temperature increase is small
  - ✓ Water supply coverage remains at 81% in 2055
  - ✓ Diarrheal incidence is lower than in A2 and higher than in A1B and B1 and B1
- Differences (2025,2050): A1B(0.12, 0.23), B1(0.14, 0.27)
  - ✓ Temperature increases exert a significant influence

A2

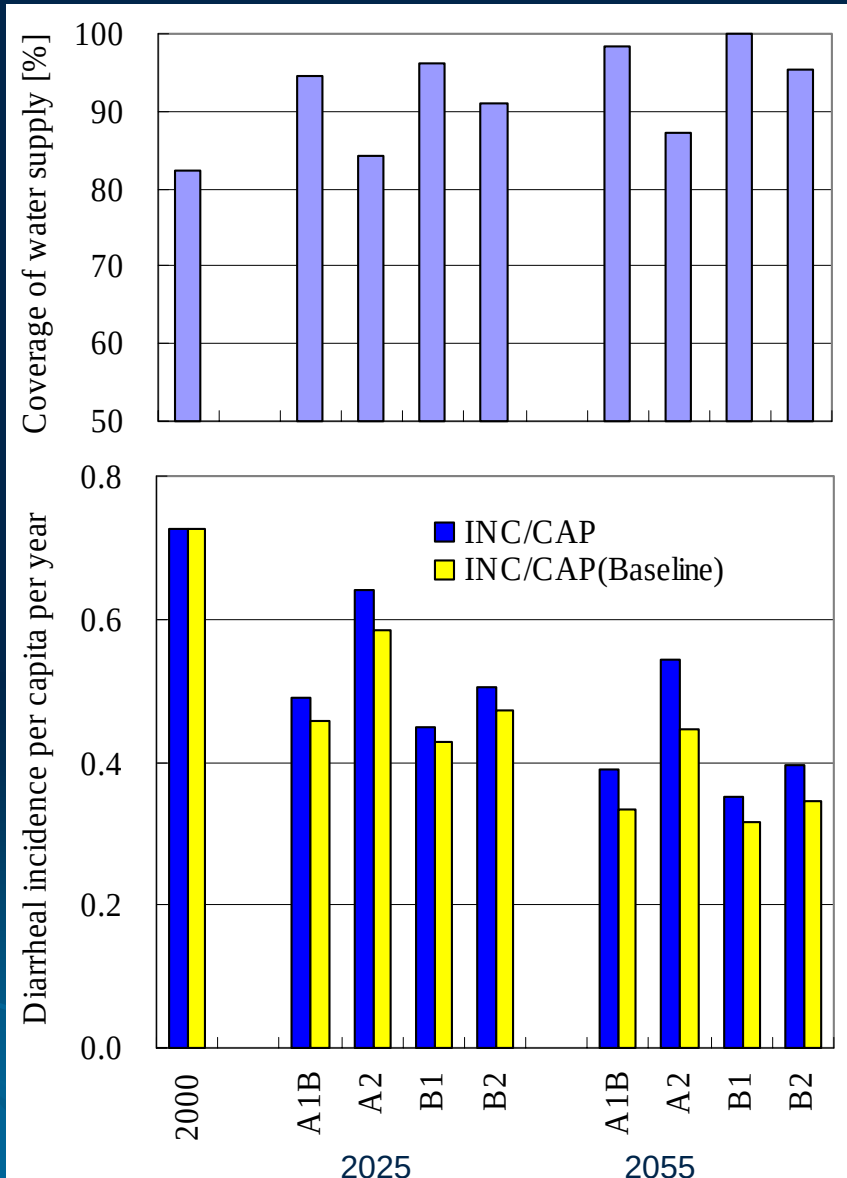


B2



Changes in water supply coverage and diarrheal incidence from a global perspective

- Water Supply Coverage
  - ✓ Under 100% in any scenario in 2025
  - ✓ In 2055, B1(100%), A1B(98%), A2(87%), and B2(95%)
- Diarrheal incidence
  - ✓ 2055：A1B (0.39)，B1 (0.35)，B2 (0.40)，B1, the scenario with the lowest level (about 50% reduction compared with 2000)
  - ✓ A2：Level of 0.54 even in 2055, remaining at the 2025 level of the other scenarios



Conclusion

- From the results of multiple regression analysis, we have proposed a diarrheal incidence estimation equation with temperature and water supply coverage as predictor variables.
- In addition to the regional differences in present temperature and water supply coverage, large differences in the decrease of diarrheal incidence in 2055 are estimated among the regions due to changes in these factors in the future scenarios.

Conclusion *continued*

- The results of our analysis based on four SRES scenarios show that in order to reduce diarrheal incidence, it is important to give consideration to the environment concurrently with socioeconomic growth. Moreover, in order to reduce diarrheal incidence more rapidly, the conventional level of water supply coverage policy is found to be insufficient when considering environmental degradation resulting from climate change, and it is suggested that more progressive policies according to the actual realities of the regions are necessary.