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Water pollution and health determinants

AP Dr Nik Rosmawati Nik Husain

PERSIDANGAN NATIONAL ENVIRONMENTAL HEALTH ACTION PLAN (NEHAP)

Outline

Sustainable development goal

Coverage of drinking water

Sanitation status in Malaysia

Water-borne diseases classifications

Sanitation challenges during emergency in Malaysia

Conceptual framework in disease prevention

Health determinants in water-related diseases

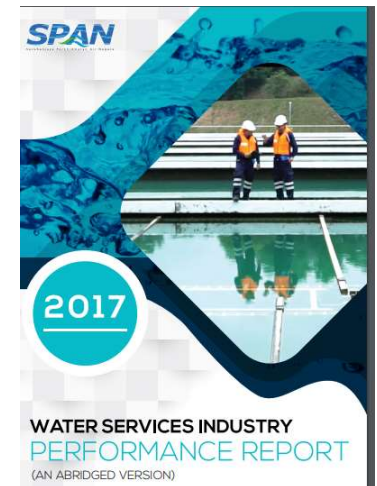
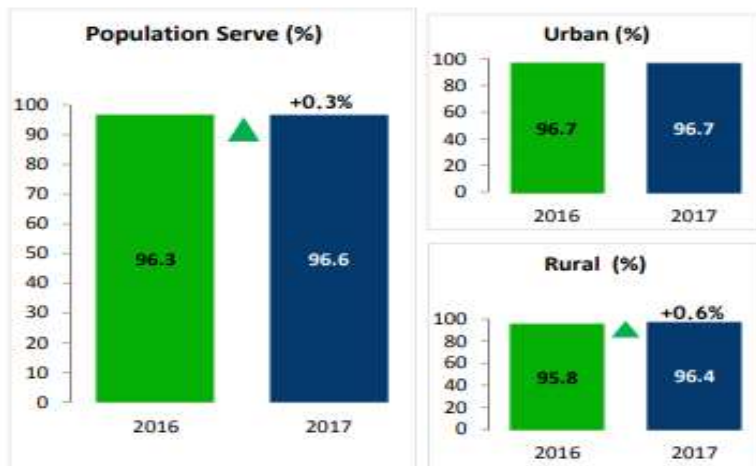
Sustainable development goals

By 2030: achieve access to adequate and equitable sanitation and hygiene for all and end open defaecation, paying special attention to the needs of women and girls and those in vulnerable situations


COVERAGE OF DRINKING WATER

4. Water Supply Coverage

Overall, the water supply services coverage for Peninsular Malaysia and FT Labuan increased slightly by 0.3% from 96.3% in 2016 to 96.6% in 2017. This is primarily due to the increase in water supply services coverage in Kelantan. Water supply coverage in Kelantan showed an upward trend, increasing by 3.3% from 64.7% to 68.0% in 2017.



Malaysia sanitation assessment (by japan sanitation consortium, 2011)



Access to improved sanitation in 2010 was 96% and sewerage diffusion in urban areas covered 70% of the population - significantly high among developing countries of Asia

Malaysia is one of the few developing countries that obtained a certain success in septage management for sanitation improvement



WATER
POLLUTION
AND HEALTH-
DPSIR
FRAMEWORK

DPSIR Framework

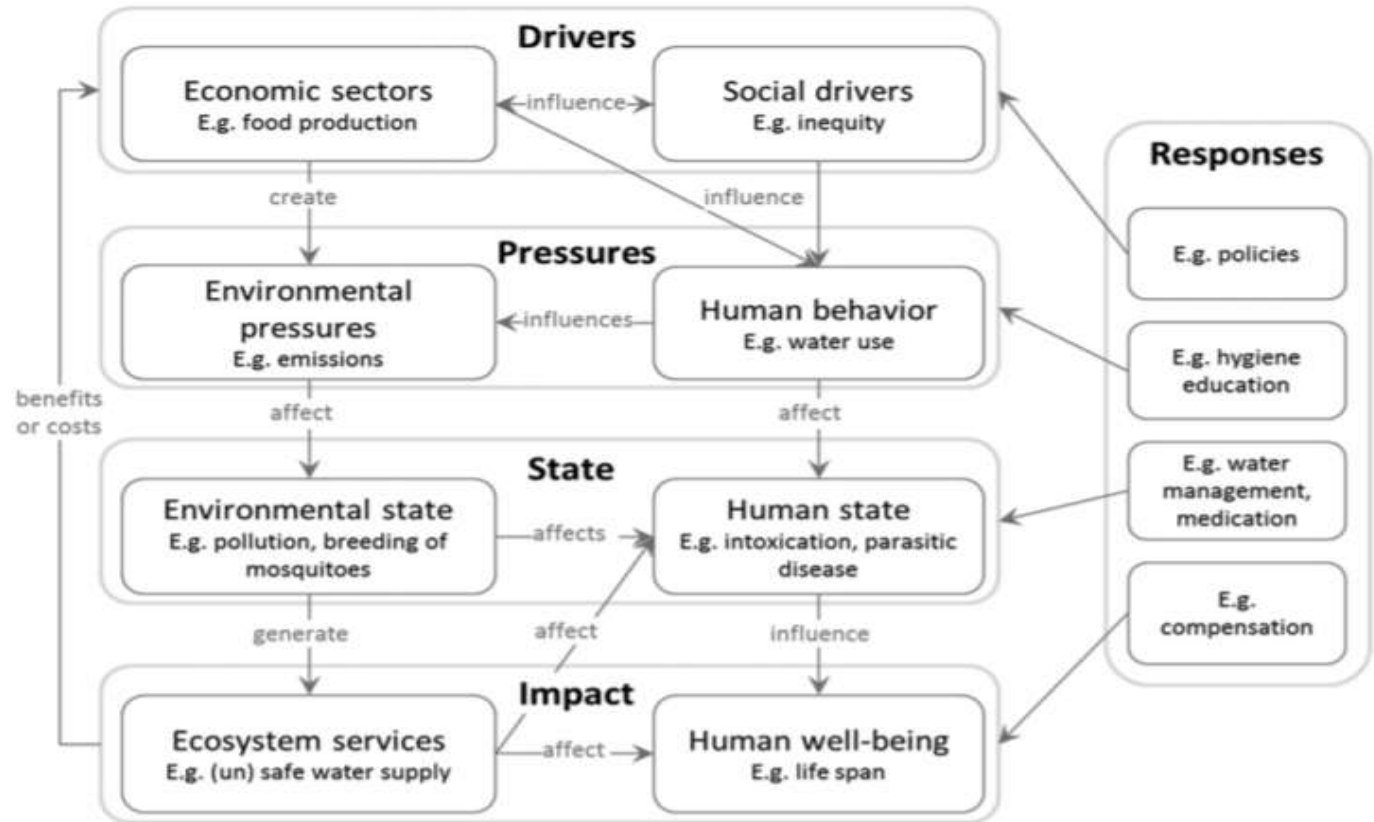


Fig. 1. Conceptual framework, based on [Yee et al. \(2012\)](#), for *Drivers, Pressures, State, Impacts, and Responses* in water and health, with parallel tracks for environmental (left) and human (right) health.

Boelee, E., Geerling, G., van der Zaan, B., Blauw, A. & Vethaak, A.D. 2019, "Water and health: From environmental pressures to integrated responses", *Acta Tropica*, vol. 193, pp. 217-226.

DPSIR Framework – based of type of pollution

Type of pollution	Main pressure	State	Impact
Microbial	<ul style="list-style-type: none"> Poverty Inequalities Poor housing conditions 	<ul style="list-style-type: none"> -Microbiological load -Contamination from open defecation -Dysfunctional latrines / overflows of septic tanks / sewers 	<ul style="list-style-type: none"> WASH related diseases
Chemical	<ul style="list-style-type: none"> -Mining and raw resource manufacturing -Many industries - Leather and textile, electronics, chemical, pharmaceutical -Energy production and transport 	<ul style="list-style-type: none"> Nutrients Heavy metals Pesticides (insecticides, herbicides, fungicides) Pharmaceutical 	<ul style="list-style-type: none"> -Direct -Triggered by flood -Persistent -Bioaccumulate -Food chain

DPSIR Framework – based of type of pollution

Type of pollution	Main pressure	State	impact
Habitat for vector-borne diseases	Intensification of agriculture, dams, reservoirs, and canals for irrigation for livestock, aquaculture, drinking	Suitable habitats for the propagation of (insect) vectors, intermediate hosts, and other carriers	-Water-based diseases -Water-related insect-borne diseases
Cumulative effects of plastic debris	Mismanaged plastic waste	Particle / chemical toxicity (bisphenol-A, brominated flame retardant, phthalates, endocrine disrupting) Vector for breeding habitats	-Chronic effect – cancer -Vector-borne diseases

Water-borne diseases classifications

Water-borne infections

- Diarrhea, intestinal parasitic infection
- Undernutrition(indirect, strong effect)

Water-washed infections (Water-hygiene dz)

- Poor personal and/or domestic hygiene
- Correlated with poverty, Infancy

Water-based infections

- Pathogen must spend a part of its life cycle in the aquatic environment.
- diseases acquired by ingestion of water and by contact with water
- e.g. guinea worm, schistosomiasis, and leptospirosis

Water-related vectors

- Transmitted by insects that breed in water, such as mosquito vectors of malaria, or insects that bite near water
- e.g., malaria, dengue fever, chikungunya, Zika, river blindness, yellow fever, and filariasis

Water aerosol diseases

- *Legionella* spp., *Mycobacterium avium*

Diarrhoeal Diseases

- ▶ Most important of the fecal-oral disease globally
- ▶ 1.6 - 2.5 million death annually, majority children under 5, in developing countries (Lopez 2006)
- ▶ Common pathogens causing diarrhoea in <5 - *Rotavirus*, *Enterotoxigenic Escherichia Coli (ETEC)*, *Enteropathogenic Escheria Coli (EPEC)*, *Shigella spp*, *Campllyobacter Jejuni*
- ▶ Systematic reviews - improving sanitation reduce diarrhoeal illness by 32% - 37% (Waddington and Snilstveit 2009)



Diarrheal prevalence in Malaysia

- ▶ NHMS 2016 - 15,188 children <5 years old
 - Prevalence of diarrhoea <5 yo - 4.4% (95% CI = 3.8–5.2).
 - Using untreated water – 2x higher odds for diarrhoea compared with families using treated water after controlling for other factors (aOR=2.04, 95%CI=1.40, 2.97, p<0.001).
- ▶ Bangladesh & Mongolia -Prevalence of diarrhoea among children <5 = 3.9 and 8.2% respectively

Table 1 Sociodemographic Profile of Respondent

	n	Percentage (%)	95% CI	
			Lower	Upper
Treated Water				
Treated Water	14,914	97.9	97.5	98.3
Untreated Water	272	2.1	1.7	2.5
Waste Disposal				
Sanitary Waste				
Sanitary	11,924	78.6	77.3	79.8
Unsanitary	3160	20.5	19.3	21.8
Latrines				
Sanitary				
Sanitary	14,768	96.8	96.3	97.2
Unsanitary	412	3.2	2.8	3.7

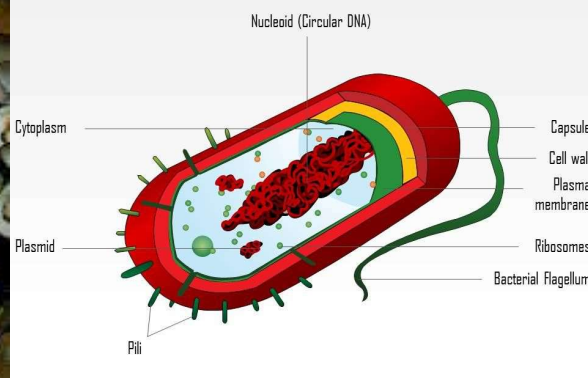
Aziz, F.A.A., Ahmad, N.A., Razak, M.A.A., Omar, M., Kasim, N.M., Yusof, M., Sooryanarayana, R., Jamaludin, R. and Ying, C.Y., 2018. Prevalence of and factors associated with diarrhoeal diseases among children under five in Malaysia: a cross-sectional study 2016. *BMC public health*, 18(1), p.1363.

Diarrhoea in specific locations

- ▶ Kudat Sabah - Outbreak of *Vibrio cholera* O1 Ogawa serotype, in 2014 (78 cases) - **transmitted through contaminated sea foods**



Vibrio Cholerae



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Short Communication

Cholera outbreak by Sea Gypsies in Sabah, Malaysia: A challenge in North Borneo

Muhammad Jikal^a, Tuan Riduan^a, Rosmawati Aarifin^b, Mohammad Saffree Jeffree^c, Kamruddin Ahmed^{d,e,*}

^a Kudat Area Health Office, Kudat, Sabah, Malaysia

^b Ministry of Health Malaysia, Putrajaya, Malaysia

^c Department of Community and Family Medicine, Faculty of Medicine and Health Sciences, Universiti Malaysia Sabah, Kota Kinabalu, Sabah, Malaysia

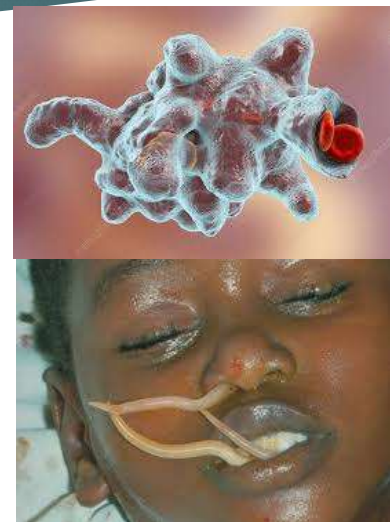
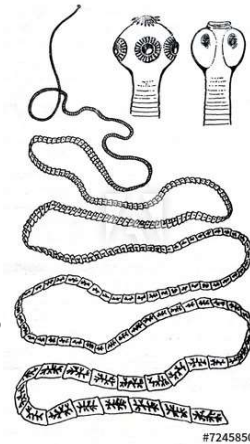
^d Borneo Medical and Health Research Centre, Faculty of Medicine and Health Sciences, Universiti Malaysia Sabah, Kota Kinabalu, Sabah, Malaysia

^e Department of Pathobiology and Medical Diagnostics, Faculty of Medicine and Health Sciences, Universiti Malaysia Sabah

Jikal, M., Riduan, T., Aarifin, R., Jeffree, M.S. and Ahmed, K., 2019. Cholera outbreak by Sea Gypsies in Sabah, Malaysia: A challenge in North Borneo. *International Journal of Infectious Diseases*, 83, pp.83-85.

Intestinal parasitic infection

- ▶ Endemic regions - Sub-Saharan Africa, Southeast Asia, China, South India and South America
- ▶ Highest in indigenous populations - prevalence 52.4 - 98.4%
- ▶ Common IPIs
 - Soil-transmitted helminths (STHs) - *Trichuris trichiura*, *Ascaris lumbricoides*, hookworm, *Strongyloides stercoralis*
 - *Taenia* spp.
 - Enteric protozoan pathogens (i.e. *Giardia duodenalis*, *Entamoeba histolytica*, *Cryptosporidium* spp.)
- ▶ Impact - Nutritional status, consequent growth faltering and stunting in young children, late entry to school, impaired cognitive function, and anaemia (particularly in pregnant women)



Intestinal parasitic infection-Prevalence and factors?

Table 1 Prevalence and distribution of IPIs among the Temuan and Mah M

IPIs	Total (n = 186)	
	n positive (%)	95 % CI
Overall IPIs	145 (78.0)	71.5–83.3
Helminth infections		
<i>Trichuris trichiura</i>	130 (69.9)*	63.0–76.0
<i>Ascaris lumbricoides</i>	25 (13.4)*	10.2–23.6
Hookworm	48 (25.8)*	20.1–32.5
Protozoan infections		
<i>Giardia</i> sp.	21 (11.3)	7.5–16.6
<i>Entamoeba</i> spp.	11 (5.9)	3.3–10.3
Total with three parasites	18 (9.7)	6.2–14.8
Four parasites		
<i>T. trichiura</i> and <i>A. lumbricoides</i> and hookworm and <i>Giardia</i> sp.	1 (0.5)	0.1–3.0
Total with four parasites	1 (0.5)	0.1–3.0
Overall polyparasitism	70 (37.6)	31.0–44.8

- Respondents - Orang Asli, Selangor, 2019
- **Personal hygiene** factors (aOR=6.99-9.94, p<0.05),
- **Not boiling water** before consumption (aOR=5.96, p=0.023)
- **Untreated water source** (aOR=3.66, 95%CI=0.92, 14.53, p=0.007)

Chin, Y.T., Lim, Y.A.L., Chong, C.W., Teh, C.S.J., Yap, I.K.S., Lee, S.C., Tee, M.Z., Siow, V.W.Y. & Chua, K.H. 2016, "Prevalence and risk factors of intestinal parasitism among two indigenous sub-ethnic groups in Peninsular Malaysia", *Infectious Diseases of Poverty*, vol. 5, no. 1.

Intestinal parasitic infection - Prevalence and factors?

Table 2 Prevalence of intestinal parasitic infections by parasite species and number of infections in Terengganu ($n = 340$)

Infections	Orang Asli <i>n</i> (%)	Malay <i>n</i> (%)	Overall <i>n</i> (%)
Overall infections	149 (90.3)	43 (24.6)	192 (56.5)
Parasite species			
<i>Trichuris trichiura</i>	130 (78.8)	17 (9.7)	147 (43.2)
<i>Ascaris lumbricoides</i>	89 (53.9)	6 (3.4)	95 (27.9)
Hookworm	39 (23.6)	1 (0.6)	40 (11.8)
<i>Giardia duodenalis</i>	24 (14.5)	15 (8.6)	39 (11.5)
<i>Entamoeba</i> spp.	24 (14.5)	14 (8.0)	38 (11.2)
<i>Cryptosporidium</i> spp.	7 (4.2)	4 (2.3)	11 (3.2)
<i>Blastocystis</i> sp.	57 (34.5)	31 (17.7)	88 (25.9)
Type of infection ($n = 192$) ^a			
Monoparasitism	35 (23.5)	18 (41.9)	50 (26.6)
Polyparasitism	113 (75.8)	25 (58.1)	138 (71.9)
No. and type of polyparasitism ($n = 138$) ^b			
Two parasite species	39 (34.5)	8 (32.0)	47 (34.1)
Three parasite species	43 (38.1)	14 (56.0)	57 (41.3)
Four parasite species	27 (23.9)	3 (12.0)	30 (21.7)
Five parasite species	4 (3.5)	0 (0)	4 (2.9)

- Respondents - Parasitic infection in 340 participants (165 Orang Asli and 175 Malay) aged ≤ 15 years in Terengganu
- **Unsafe water** aOR= 3.61, $p=0.009$
- **Not washing hands** after playing with soil aOR=4.26, $p=0.004$
- **Not washing vegetables** before eating aOR=3.52, $p=0.008$

Elyana, F.N., Al-Mekhlafi, H.M., Ithoi, I., Abdulsalam, A.M., Dawaki, S., Nasr, N.A., Atroosh, W.M., Abd-Basher, M.H., Al-Areeqi, M.A., Sady, H. and Subramaniam, L.R., 2016. A tale of two communities: intestinal polyparasitism among Orang Asli and Malay communities in rural Terengganu, Malaysia. *Parasites & vectors*, 9(1), p.398.

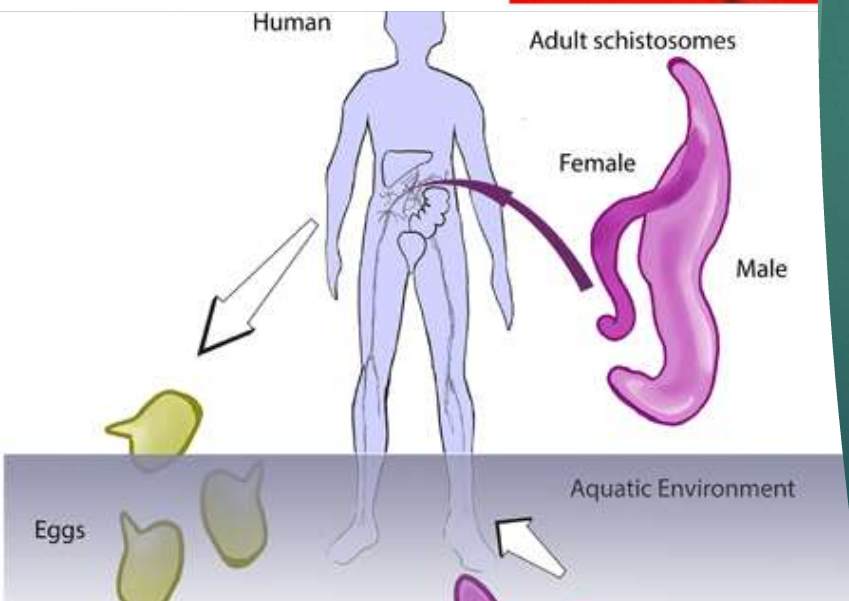
Morphology:

- Adult schistosomes are white greyish worms.
- (6 – 28) mm long & in breadth of (0.25 – 1) mm.
- Schistosomes have separate sexes (**male & female**).
- Both have an oral sucker opening into the alimentary tract, & a posteriorly situated sucker.



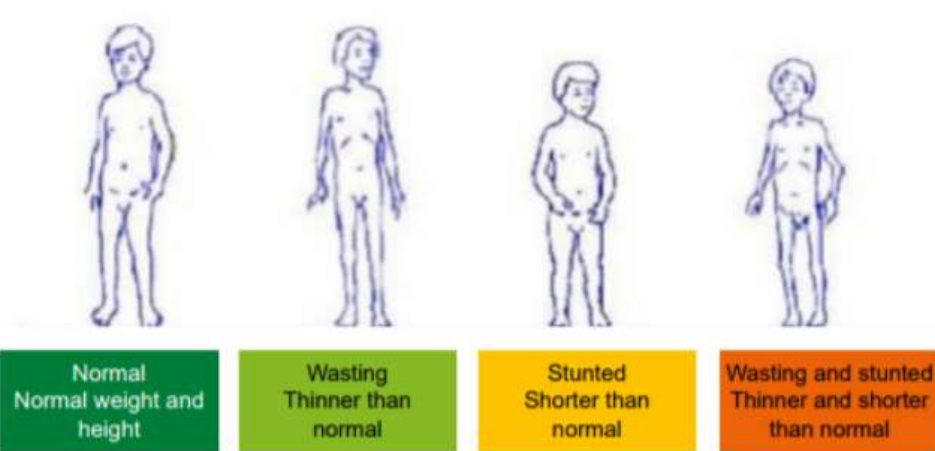
Water-based infections - Schistosomiasis

- ▶ Globally, 190 million infected
- ▶ Vector - aquatic snails
- ▶ Transmission via **urine and faeces contaminate water source**
- ▶ Impact - haematuria, impaired growth, bladder and colorectal cancers, and vital organ malfunction .
- ▶ **Sanitation (and water) interventions** are essential for long-term control and elimination



Indirect effects -

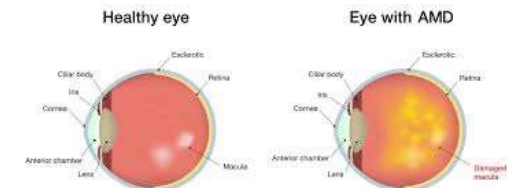
Undernutrition & Stunting



- 3 main underlying causes
 - Poor quality and quantity of food
 - Poor care practices
 - Infectious disease
- Main pathways: Repeated diarrheal episodes, soil-transmitted infections (helminths), and environmental enteropathy
- Poor sanitation, hygiene and water >>> responsible for 50% of the consequences of childhood and maternal underweight
- Synergism between diarrhoeal disease and undernutrition

Chemical water pollution: Nitrates

- ▶ Source - livestock facilities, sewage disposal systems, fertilized cropland
- ▶ Contaminate groundwater – tube well, well
- ▶ Health problems due to high nitrate exposure –
 - ▶ Methemoglobinemia (blue baby syndrome) in infants, thyroid disorders, spontaneous abortions and birth defects and cancer in adults, diabetes, **age related Macular Degeneration (AMD)**, gastric dysfunction
- ▶ 256 wells in Bachok, Kelantan in 2015
 - ▶ Mean nitrate $13.04 \pm 14.39 \text{ mg L}^{-1}$ (agriculture) vs. $6.31 \pm 5.22 \text{ mg L}^{-1}$ (non-agriculture), $p < 0.001$.
 - ▶ Levels $> 10 \text{ mg/L}$ (Malaysia NDWQS) in 52 wells (41.27%) (agricultural area) vs. 35 wells (26.9%) (nonagricultural area) >>> not suitable for drinking
 - ▶ Factors? Near paddy fields, $< 50 \text{ m}$ to the livestock area, $< 20\text{m}$ to septic tank



Nitrates and cancer

- ▶ Systematic reviews from 11 studies - Statistically significant positive association for nitrate exposure and colorectal cancer risk¹
- ▶ Longer-term consumption of water with nitrate-N concentrations > 5 mg/L in ≤5 yo shows RR: 2.6 (95% CI: 1.1–6.2) to develop thyroid cancer²
- ▶ National Standard for Drinking Water Quality = 10mg/L

Data Imported from Peer-reviewed Literature¹

Analysis ID and cancer type	Study author and publication year	% of Total annual cancer cases attributable to nitrate exposure, rounded ^e
A - Colorectal	Espejo-Herrera et al., 2016	8.2%
B - Colorectal	Espejo-Herrera et al., 2016	4.9%
C - Colorectal	Schullehner et al., 2018	3.2%
D - Colorectal	Schullehner et al., 2018	2.1%
E - Colorectal	De Roos et al., 2003	1.0%
F - Ovarian	Inoue-Choi et al., 2015	3.2%
G - Ovarian	Inoue-Choi et al., 2015	0.6%
H - Thyroid	Ward et al., 2010	2.2%
I - Thyroid	Ward et al., 2010	0.8%
J - Kidney	Ward et al., 2007	0.9%
K - Bladder	Jones et al., 2016	0.2%

¹Temkin, A., Evans, S., Manidis, T., Campbell, C. and Naidenko, O.V., 2019. Exposure-based assessment and economic valuation of adverse birth outcomes and cancer risk due to nitrate in United States drinking water. *Environmental research*, 176, p.108442.

²Ward, M.H., Kilfoy, B.A., Weyer, P.J., Anderson, K.E., Folsom, A.R. and Cerhan, J.R., 2010. Nitrate intake and the risk of thyroid cancer and thyroid disease. *Epidemiology (Cambridge, Mass.)*, 21(3), p.389.

Chemical water pollution:

Disinfection by-products (DBPs)



- ▶ Chlorine - water treatment as a disinfectant agent
- ▶ Chlorine reacts with organic matter in water >>> Disinfected By-Products (DBPs) - THMs, haloacetonitriles (HAs), halo ketones (HANs), bromate, chlorate
- ▶ Health effects - Mothers exposed to THMs >>> increased risk of small for gestational age, pregnancy loss.

Mashau, F., Ncube, E.J. and Voyi, K., 2018. Drinking water disinfection by-products exposure and health effects on pregnancy outcomes: a systematic review. *Journal of water and health*, 16(2), pp.181-196.

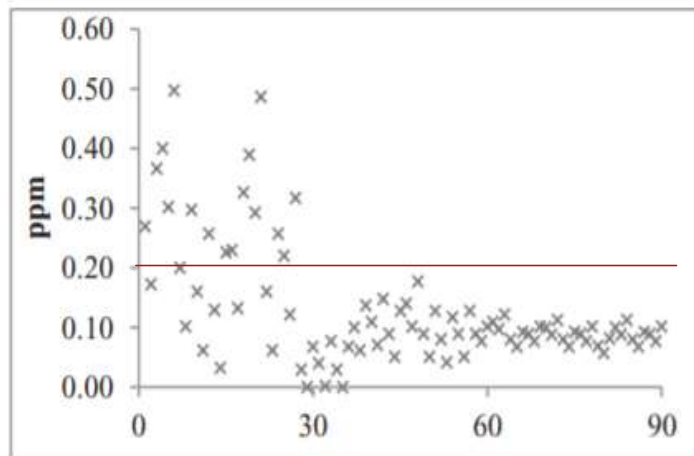


Fig. 4. Chloroform of end-user water samples.

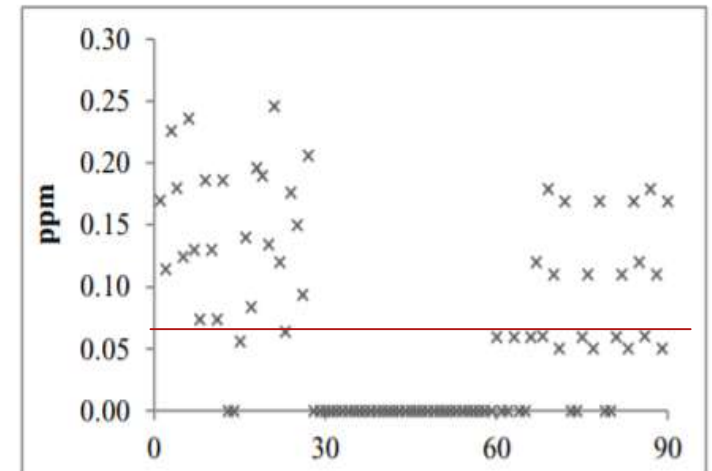


Fig. 5. Bromodichloromethane at end-user water samples.

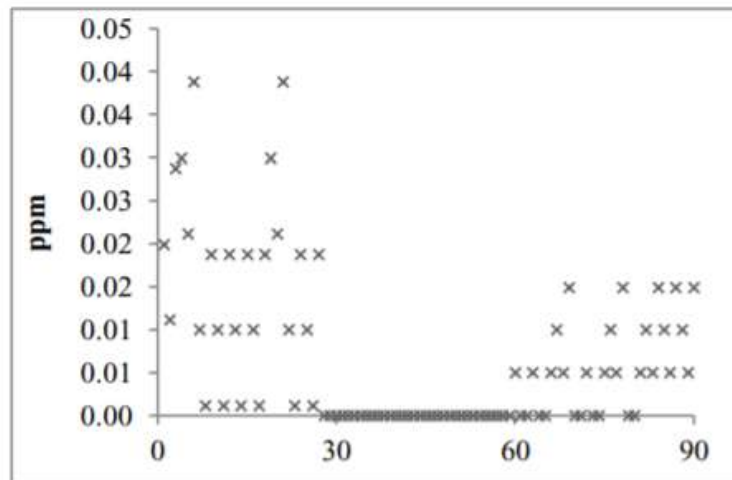


Fig. 6. Dibromochloromethane at end-user water samples.

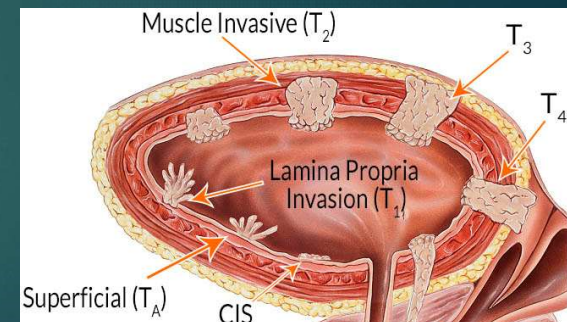
Table 1. WHO guidelines [15].

Parameter	WHO Guidelines value (mg/L)
Chloroform	0.20
Dichlorobromomethane	0.06
Dibromochloromethane	0.10
Bromoform	0.10
Total THM	<0.001

Ab Jalil, M.F., Hamidin, N., Gunny, A.A.N. and Kamarudzaman, A.N., 2018. Identification of Trihalomethanes (THMs) Levels in Water Supply: A Case Study in Perlis, Malaysia. In *E3S Web of Conferences* (Vol. 34, p. 02043). EDP Sciences.

Heavy metal water pollution: Arsenic

- Found in rocks, soil, water, air, or in plants and animals in organic or inorganic forms
- Released into the environment through natural activities such as rock erosion, or human activities such as farming and industry
- Primary route of exposure - drinking water
- Health effects - significantly associated with urothelial cancer¹, malignancies in the integumentary, respiratory, hepatobiliary. Cutaneous lesions are important manifestations after long-term arsenic exposure²



¹Di Giovanni, P., Di Martino, G., Scampoli, P., Cedrone, F., Meo, F., Lucisano, G., Romano, F. and Staniscia, T., 2020. Arsenic Exposure and Risk of Urothelial Cancer: Systematic Review and Meta-Analysis. *International journal of environmental research and public health*, 17(9), p.3105.

²Huang, H.-., Lee, C.-. & Yu, H.-. 2019, "Arsenic-induced carcinogenesis and immune dysregulation", *International Journal of Environmental Research and Public Health*, vol. 16, no. 15.

Heavy metal water pollution: Cadmium

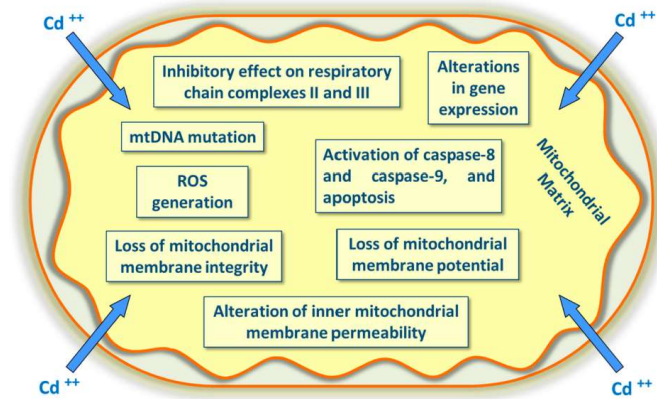


Figure 2. The main target in cadmium intoxication. Cadmium acts on mitochondria by inducing oxidative stress and generating reactive oxygen species (ROS), activating apoptosis, mutating mtDNA, altering gene expression, inhibiting respiratory chain complexes, reducing ATP synthesis, and altering the inner mitochondrial permeability.

● Sources - agricultural and industrial

● Accumulates in plants, animals with long half-life ~ 25–30 yr

● High concentrations in - crustaceans, bivalve mollusks, oysters, cephalopods, and crabs

● Human exposure - ingestion of contaminated food and water, inhalation / cigarette smoking

● Health effects

- ▶ Type 1 carcinogen - various types of cancer, including breast, lung, prostate, nasopharynx, pancreas, and kidney cancers
- ▶ Risk for osteoporosis
- ▶ Renal and hepatic dysfunction, pulmonary edema, testicular damage, osteomalacia, and damage to the adrenals and hemopoietic system
- ▶ Neurodegenerative diseases and age-related disorders, Alzheimer's and Parkinson's diseases, reproduction systems, affects pregnancy or its outcome

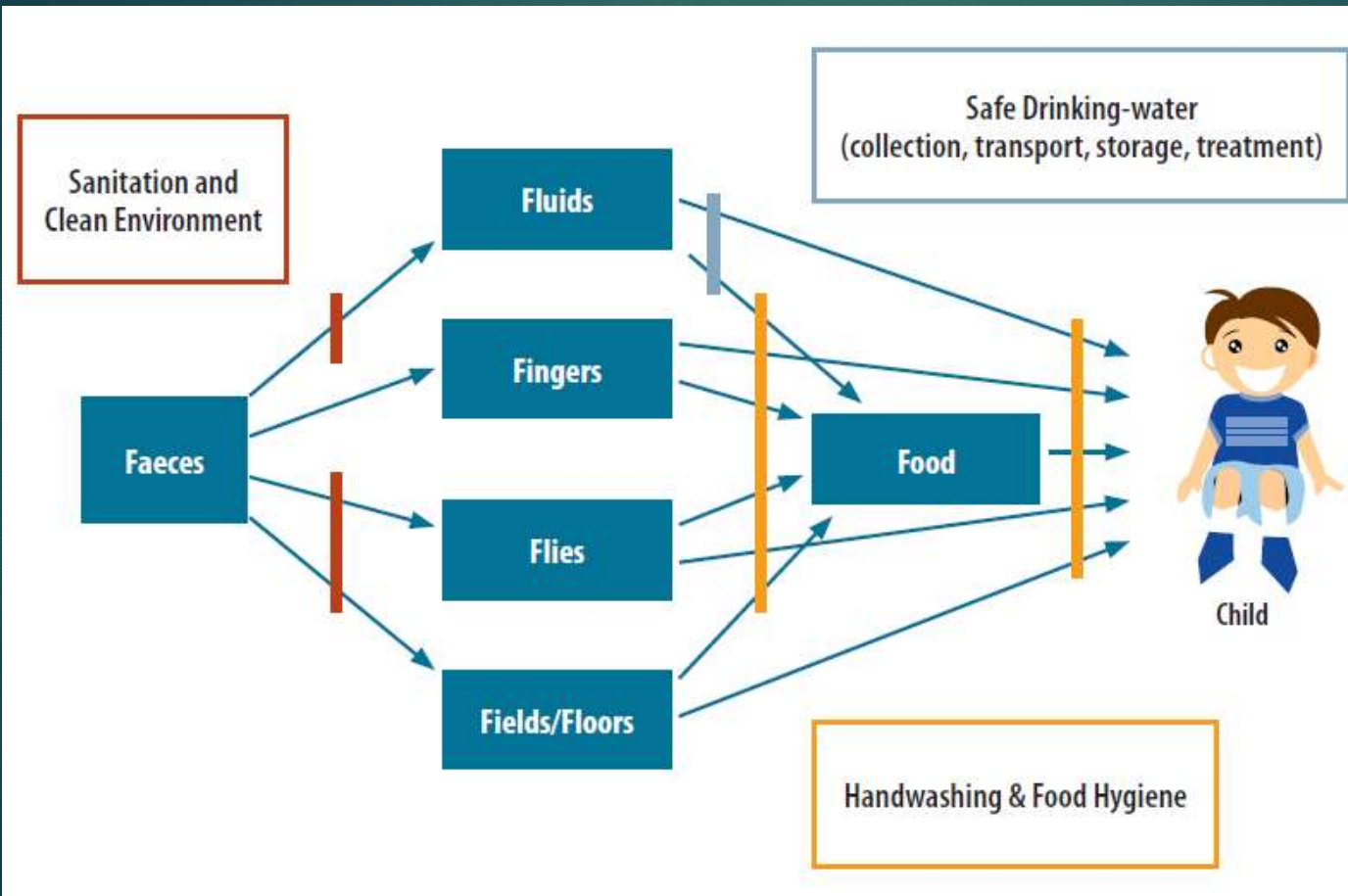
Sanitation challenges during emergency in Malaysia

- ▶ Flood - Malaysia most common natural disasters
- ▶ Flooding cause severe health implications – before, during and after
- ▶ During flood,
 - Limited access to improved sanitation and clean water
 - Shared latrines, limitation to dispose excreta.
 - Crowding, poor hygiene
- ▶ Risk transmission of communicable diseases, particularly fecal oral route
- ▶ 2014 major flood in Kelantan - 162 AGE



Conceptual framework - Prevention of water, sanitation and hygiene related diseases transmission

26



Morbidity
Mortality
Incidence
prevalence

Source: WHO, 2015

Outcome indicators beyond the health indicators

	Indicator
	<ul style="list-style-type: none"> • Proportion of households with access to an improved water source • Proportion of households consistently storing^a their drinking-water safely • Proportion of households consistently treating their drinking-water with recommended^b HWT technologies • Proportion of households with knowledge of at least one HWT method
	<ul style="list-style-type: none"> • Proportion of households using an improved sanitation facility • Proportion of households safely disposing of children's faeces • Number of villages achieving open defecation-free status • Proportion of households with sanitation facilities that are accessible^c by children and disabled members of the household
	<p>Handwashing</p> <ul style="list-style-type: none"> • Proportion of households with handwashing station^d in compound • Proportion of households where primary caregiver can cite critical times for handwashing with soap <p>Food hygiene</p> <ul style="list-style-type: none"> • Proportion of households keeping clean areas where children's food is prepared and served • Proportion of households safely storing children's food • Proportion of households using clean kitchen utensils (to feed children) • Proportion of households that use treated and/or safely stored drinking-water for preparing children's food • Proportion of households washing raw vegetables with treated water before feeding children • Proportion of households reheating children's food thoroughly before feeding them <p>Environmental hygiene</p> <ul style="list-style-type: none"> • Proportion of households with no visible faeces (animal or human) in the compound/yard/children's play area • Proportion of households with no domestic animals in food preparation area

Health determinants in water-related diseases

28



Host

- Vaccination
- Health education
- behavioural modification

Agents

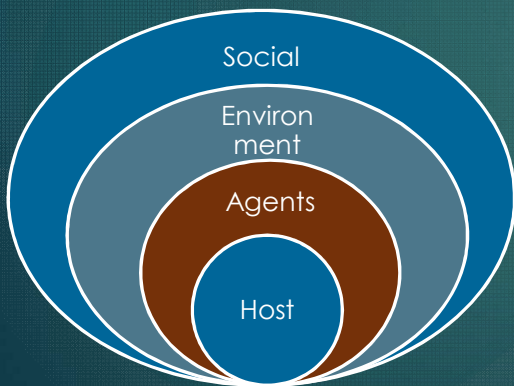
- Drugs - antihelminthes
- Hygiene
- Sanitation
- Water disinfectant

Enviro

- Control of the environment
- Improve sanitation - latrines

Social

- adequate health-care - rapid diagnosis and treatment
- Political will
- Improve water supply and quality



- **Health education and behavioural modification** - breast-feeding, use of narrow neck vessels to store water, good water handling, Hygiene education, household water treatment, keeping animals out of the kitchen, correct disposal of human faeces
- **Control of the environment** - drinking and recreational water, sewage and other wastes, settlement, guidelines
- **Cultivating political will** - cost large-scale water treatment, waste management, legislation
- **Water supply** - Municipal water, household connection, hand-pump, Tube well construction, Well with household or nearby connection

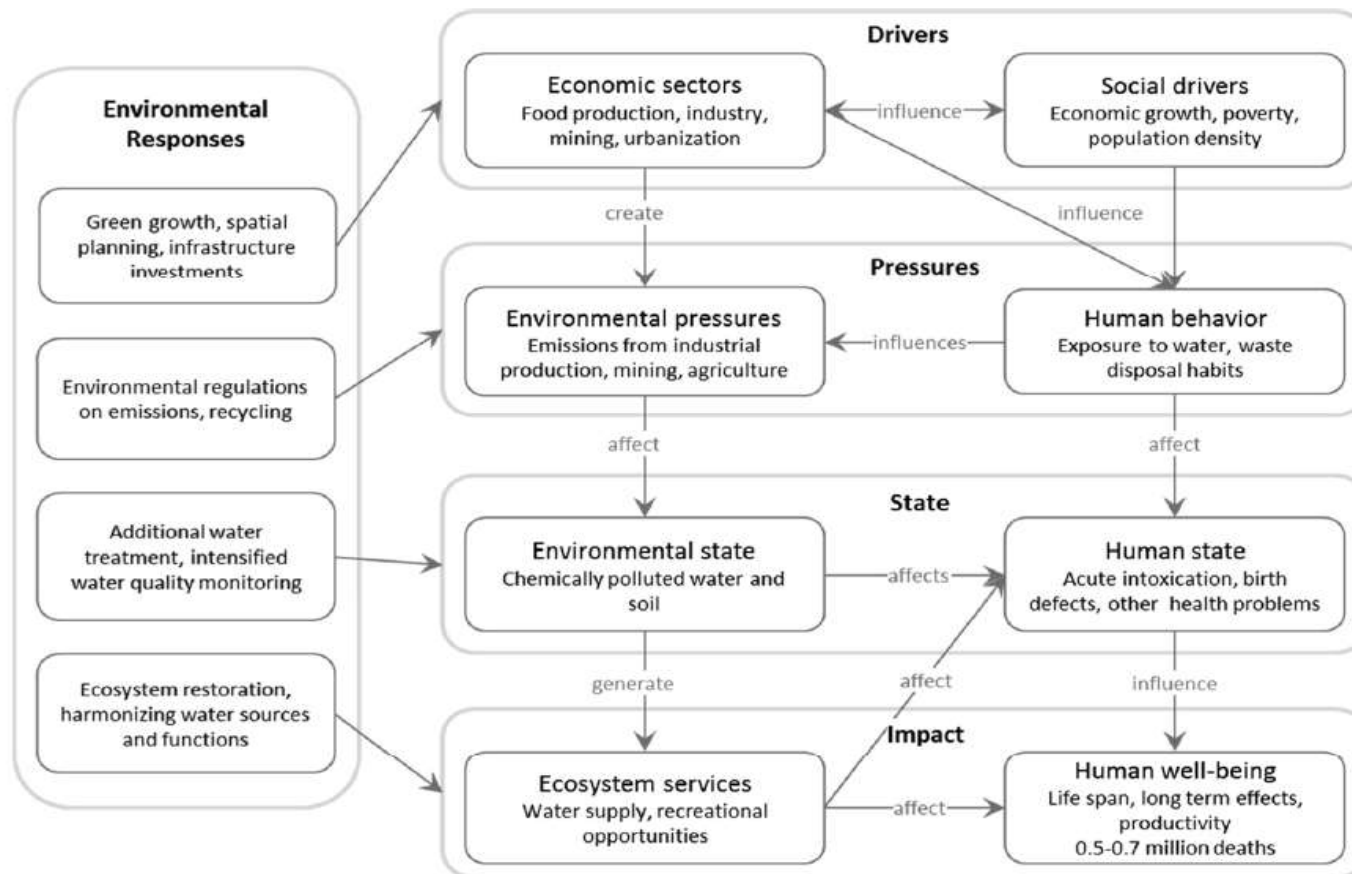


Fig. 2. Drivers, Pressures, Impacts and Responses for the State of chemical water pollution, with parallel tracks for environmental (left) and human (right) health (concept based on Yee et al. (2012); estimated annual deaths based on Landrigan et al. (2017) for 'soil pollution, heavy metals and chemicals').

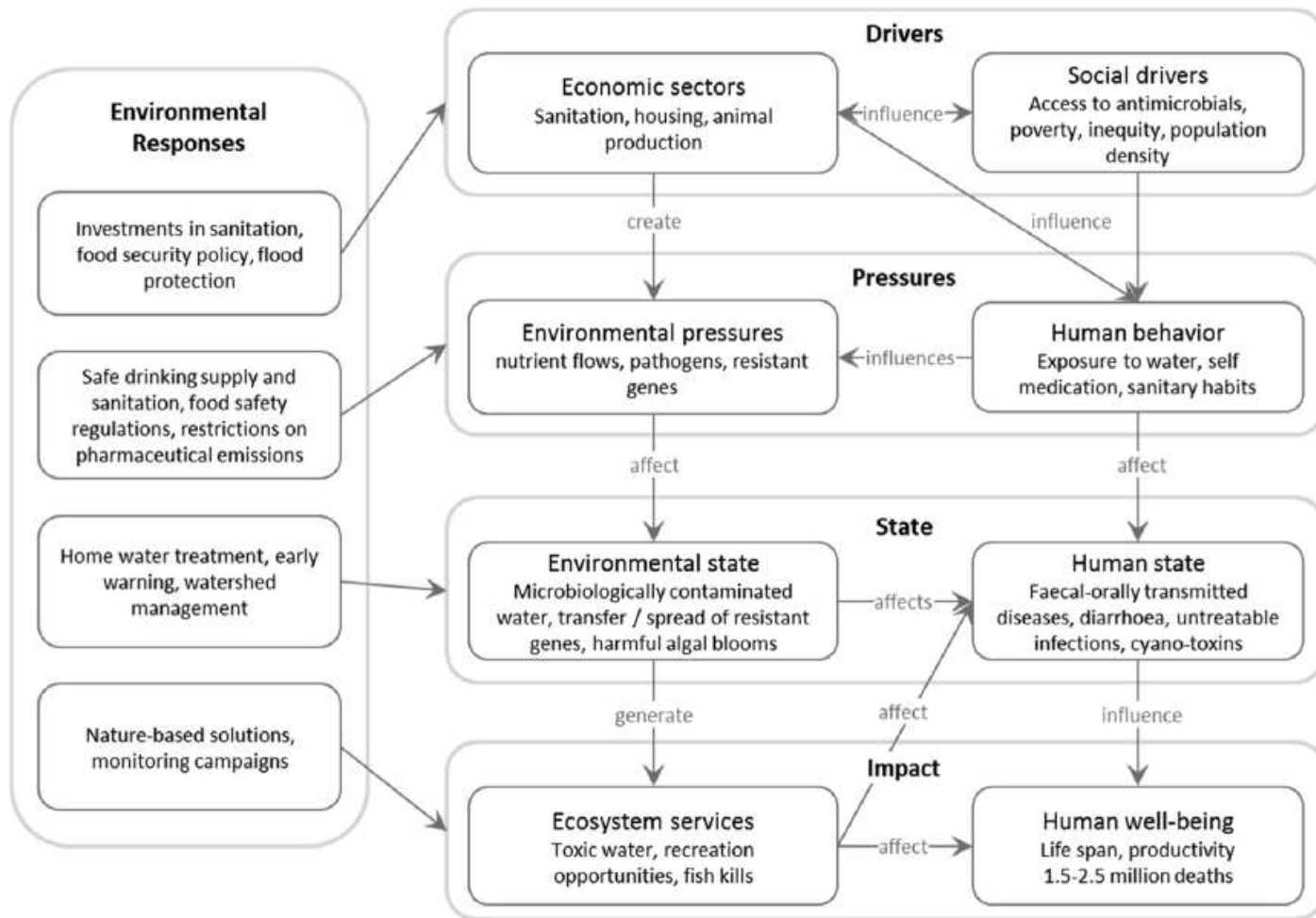


Fig. 3. Drivers, Pressures, Impacts and Responses for a State of microbiologically contaminated water, with parallel tracks for environmental (left) and human (right) health (concept based on Yee et al. (2012); estimated annual deaths based on Landrigan et al. (2017) for (microbiologically contaminated) ‘water’ and O’Neill (2016) for antimicrobial resistance).

Boelee, E., Geerling, G., van der Zaan, B., Blauw, A. & Vethaak, A.D. 2019, "Water and health: From environmental pressures to integrated responses", *Acta Tropica*, vol. 193, pp. 217-226.

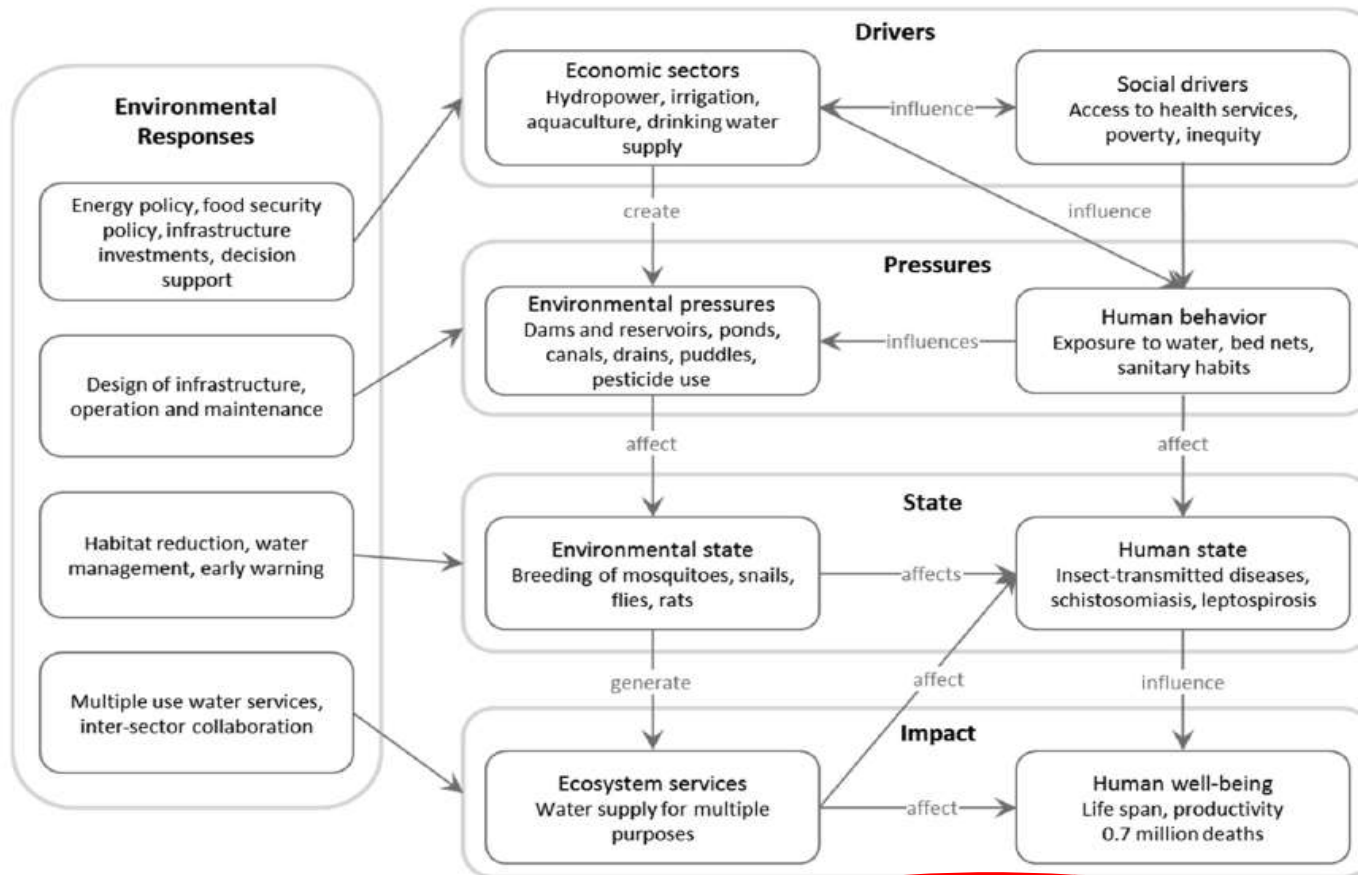
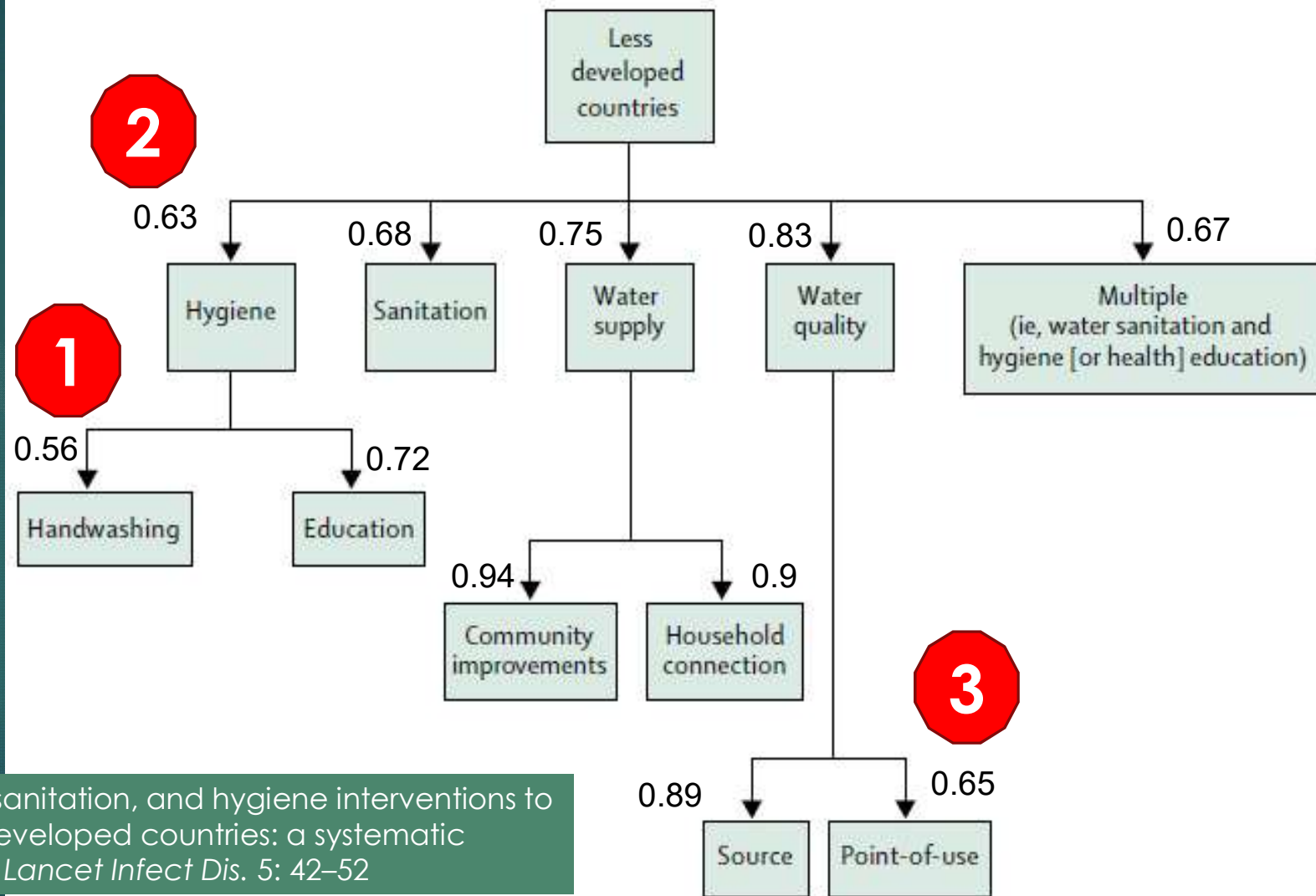


Fig. 4. Drivers, Pressures, Impacts and Responses for the State of water bodies as suitable breeding sites for vectors of disease, with parallel tracks for environmental (left) and human (right) health (concept based on Yee et al. (2012); estimated annual deaths based on WHO (2017)).

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Intervention stratification and the relative risk for diarrheal diseases



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