ENVIRONMENTAL CONTAMINATION OF AQUATIC RESOURCES: IMPLICATIONS ON HEALTH

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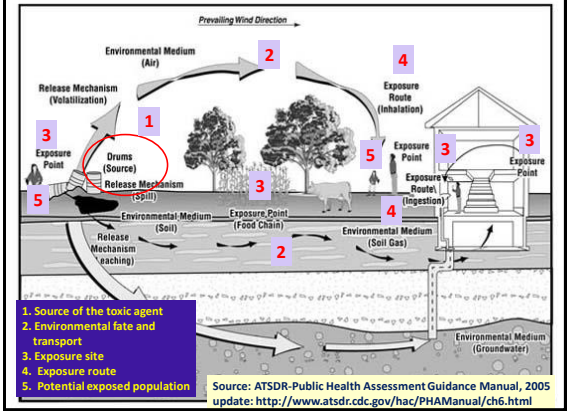
Objectives

- Review the conceptual model of exposure pathway
- Enumerate common environmental pollutant issues affecting aquatic resources
- Discuss the health implications of aquatic contaminations
- Outline preventive strategies to address environmental issues involving food and water

Conceptual Model of Exposure Pathway: Five Essential Elements

- Source of the toxic agent
- Environmental fate and transport
- Exposure site
- Exposure route
- Potential exposed population

Source: ATSDR-Public Health Assessment Guidance Manual, 2005 update: http://www.atsdr.cdc.gov/hac/PHAManual/ch6.html)



Source: ATSDR-Public Health Assessment Guidance Manual, 2005 update: http://www.atsdr.cdc.gov/hac/PHAManual/ch6.html

Environmental Issues: CONTAMINATION

Arsenic in drinking water....

The magnitude of this problem is severe in Bangladesh and West Bengal, India[42,43]. In West Bengal alone more than 6 million people[44] living in almost 50 % of the districts[45] are exposed to arsenic through drinking water. In recent years the evidence of groundwater contamination by arsenic has emerged in many other Asian countries including Cambodia, the Lao People's Democratic Republic, Myanmar, Pakistan[43], Nepal[46], Cambodia, Vietnam[47], a province in Iran[48]. The higher level of arsenic concentration in drinking water has been reported in Ghana where *ca.* 45 % of the total drinking water is produced from groundwater[49]. Barbu *et al.*[50] reported that along with other metals arsenic is also present in high concentration in the Jiu River, Romania.

Source: Moonis Ali-Khan and Yuh-Shan Ho.
Asian Journal of Chemistry,23(5), 1889-1901 (2011)

Environmental Issues: CONTAMINATION

Domestic, agricultural and industrial wastes are major contributions to environmental contamination.

Laguna Lake Pollution

- **The Millennium Ecosystem Assessment, sub global assessment done in 2005 states that heavy metals such as lead (Pb), chromium (Cr), cadmium (Cd), copper (Cu), arsenic (As), and mercury (Hg) have all been found in the Laguna Lake**

***Source**: LASCO, Rodel D. and ESPALDON, Ma. Victoria (eds.). 2005. Ecosystem and People: The Philippine Millennium Ecosystem Assessment (MA) Sub-global Assessment, pp. 4, 16, 18-19, 31-34.*

Clean the Marilao, Meycauayan and Obando [Bulacan, Philippines] River system project [2006]

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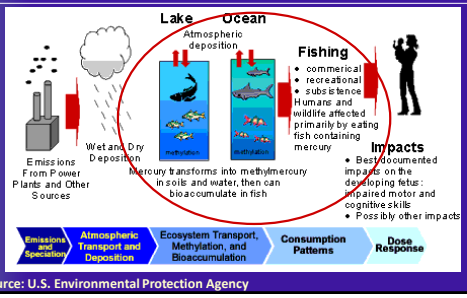
Abstract

The Marilao, Meycauayan and Obando river system in the province of Bulacan is the focus of a clean-up project being spearheaded by a stakeholder group composed of government agencies, LGUs, industries, and socio-civic organizations. The river system is considered to be a 'hot spot' of water quality. Pollution from upstream feed into thousands of hectares of active fishponds where the produce is consumed by the local populace and shipped to adjoining areas primarily Metro Manila. Certain parameters of water quality exceed environmental standards, thus contaminating the fishes and shell fishes in the area. This has negative health implications not only to the local population but to those in Metro Manila where most of the fishes are sold. The major causes of pollution are effluents that contain heavy metals, organic wastes and other hazardous materials from industries. Some of the heavy metals detected in the Marilao-Meycauayan-Obando river system are lead(Pb), mercury(Hg), chromium(Cr), arsenic(As), cadmium(Cd), and some synthetic organic compounds. If these metals are taken unknowingly, it can reach levels endangering the health of human beings. The final recipient of the contaminated water is the Manila Bay, already known to be heavily polluted and posing a serious environmental problem. Being located on the fringes of Metro Manila, the municipalities of Marilao and Meycauayan are hosts to a multitude of industries and urban-related activities.

Environmental Issues: BIOACCUMULATION & BIOMAGNIFICATION: Mercury in Fish



Source: U.S. Environmental Protection Agency

Mercury in Fish in Palawan

- Mercury deposits are found in several places in the Philippines and the first viable mercury deposit was discovered in 1938 at Barrio Tagburos, Puerto Princesa, Palawan. The PQMI was in operation from 1955-1976 producing 140,000 kg of mercury yearly. Most of the mine tailings were dumped into the nearby sea until an artificial peninsula 600 meters long and 50 meters wide was created. Contamination of the bodies of water prompted the monitoring of fish for the presence of mercury and methyl mercury.
- In 2002, the monitoring conducted by the DOH/UP-NPMCC showed the following levels of mercury and methylmercury in different species of fish in Barangay Tagburos

Source: NPCIS/DOHTechnical Report 2002

Mercury in Fish in Palawan

Fish Sample	Total Mercury (ng/g)	Methyl mercury	
		Concentration (ng/g)	Percentage (%)
Torsillo	461.27	440.77	95.56
Islawan	293.14	293.14	100.00
Amurok	247.83	223.43	82.81

The Japanese standards for total mercury is 400 ng/g and methyl mercury is 300 ng/g. The US-FDA and RP-Department of Agriculture standard for total mercury is 500 ng/g.

Source: NPCIS/DOHTechnical Report 2002

Environmental Issues: PERSISTENCE Persistent Organic Pollutants (POPs)

- **Dirty Dozen: Aldrin, Chlordane, DDT, Dieldrin, Endrin, HCB, Heptachlor, Mirex, Toxaphene; PCBs, Dioxins, Furans**
- **Also bioaccumulate and are prone to transboundary atmospheric transport & deposition**

Monitoring POPs in Selected Biota in the Philippines (Santiago EC, Kwan CS)

- Pesticides monitored in freshwater shrimps (2006), fish (2007), squid (2008)
- FINDINGS: SHRIMP SAMPLES

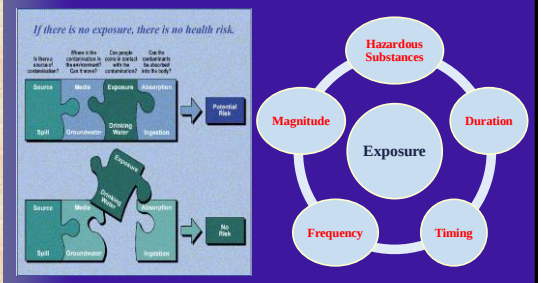
- Shrimp muscle sample from one site in Chico River showed concentrations of transchlordane and p,p' DDT (dry season)
- Shrimp muscle samples showed concentration of transchlordane and endosulfan 1(rainy season)
- All heads of shrimp samples showed varying concentrations of p,p' DDT, trans nonachlor and methoxychlor; some with p,p'DDD , α BHC, endosulfan

Monitoring POPs in Selected Biota in the Philippines (Santiago EC, Kwan CS)

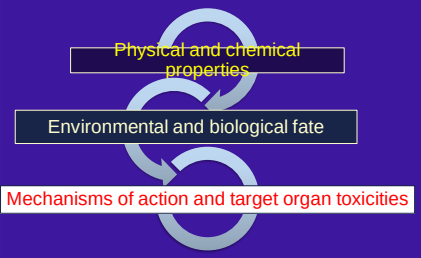
- Pesticides monitored in freshwater shrimps (2006), fish (2007), squid (2008)
- FINDINGS: SQUID SAMPLES

- OCPS were detected in liver and muscle tissues in all samples
- OCPS were detected depending on sample sites
- δ BHC and β BHC, methoxychlor were detected in all liver samples
- p,p' DDD and β BHC were detected in all muscle samples

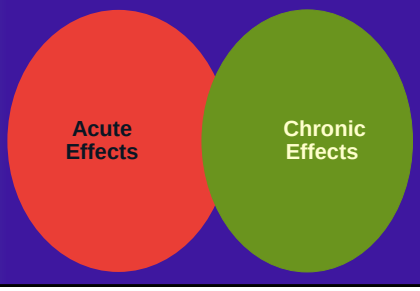
Implications on Health: EXPOSURE



Implications on Health: AGENT



Implications on Health: EFFECTS



Acute Effects
Paralytic Shellfish Poisoning

- **Results from consumption of contaminated mussels, clams, oysters and scallops**
- **Gonyaulax (algae) species: *Protogonyaulux catenella, P. tamarensis* var. *excavata*, *Pyrodinium bahamense* var. *compresa*, *Ptychodiscus brevis, Gambierdiscus toxicus***
- **Toxic principles: saxitoxin, neosaxitoxin, gonyautoxin, and other analogues (a total of 13 PSP toxins)**

Acute Effects
Paralytic Shellfish Poisoning

Algal blooms (red tides) result from excessive growth (bloom) of particular unicellular algae, giving the water a red-brown appearance due to the pigments contained in the algae.

Acute Effects
Paralytic Shellfish Poisoning

- **Nausea, vomiting, abdominal pain**
- **Paresthesia, floating feeling**
- **Muscle weakness, respiratory paralysis**
- **Dysphagia, dysarthria, transient blindness, dysphonia**
- **Vertigo, ataxia, nystagmus, intention tremor**
- **Tachycardia**
- **Headache**

Chronic Effects

Non-carcinogenic endpoints

Carcinogenic endpoints

Chronic Effects: Non-carcinogenic endpoints

A Japanese mother bathes her child, one of many such children born with severe birth defects in the town of Minamata due to the parents eating fish contaminated with mercury dumped into Minamata Bay by the Chisso plastics manufacturing company. Recent reports say that Minamata disease (mercury poisoning) is now showing up among Indian villagers in the Amazon due to gold miners using mercury to separate gold from ore.

Says Tsuginori Hamamoto, who grew up eating fish caught in Minamata Bay and now is confined to a wheelchair because of the ravages of mercury poisoning, "Because we have destroyed the environment, human beings have been destroyed. The cause of Minamata disease is industrial effluent from the (Chisso) factory. What lies behind this is the fact that everyone is seeking an easy life. Are you still going to continue to lead an easy life?"
[Photo by W. Eugene Smith]

Minamata Disease and Methyl mercury

Source: http://oecotextiles.wordpress.com/category/chemicals/mercury/

Chronic Effects: Carcinogenic endpoints

Arsenic and Cancer

Cancers of the skin, lung, liver, bladder, kidney, colon

TABLE 4
Representative Human Epidemiology Studies in Arsenic Drinking Water-Exposed Populations

Study	Population	Dose	Findings
Tseng *et al.* (1968)	Taiwan, >40,000 in survey	0.01–1.82 ppm	Skin cancer (10.6/1000),[a] hyperpigmentation (183.5/1000), keratoses (71/1000), Blackfoot disease (8.9/1000); revalence rate of effects increased with age; Blackfoot disease associated with hyperpigmentation, keratosis, and skin cancer
Chen *et al.* (1988)	Taiwan, ~900,000 person-years	0-30 ppm, 30-59 ppm, ≥ 60 ppm	Significant dose-response relationship between As and age-adjusted mortality for bladder, kidney, skin, prostate, lung and liver cancer
Smith *et al.* (1998)	Chile, >400,000	<100 to 570 μg/l	SMR for bladder cancer: men, 6.0; women, 8.2; lung cancer: men 3.8; women 3.1
Karagas *et al.* (2001)	cases + controls	toenail range: 0.01–2.57 μg/g)	ladder, lung, kidney, and skin cancer evated at toenail As concentrations ratios with toenail As concentration above 97th percentile were 2.07 for SCC and 1.44 for BCC.
Smith *et al.* (2006)	Antofagasta, Chile	~1 ppm for 12 years	*In utero* and early childhood exposure occurred between 1959 and 1971; lung cancer SMR: early childhood, 7.0; *in utero* + early childhood, 6.1; Bronchiectasis SMR: early childhood, 12.4; *in utero* + early childhood, 46.2
Mumford *et al.* (2007)	Inner Mongolia, China; 313 subjects	≤21–690 μg/l	Dose-dependent relationship between prevalence rates of QT prolongation and water As concentrations; measuring QT interval may detect early cardiac As cardiac toxicity
Argos *et al.* (2010)	Bangladesh, >10,000 in survey	0.01–864 ppb	Chronic As exposure via drinking water associated with increased mortality rate. Mortality increased with As concentration in drinking water, As dose, and total As in urine

Note. BCC, basal cell carcinoma; SCC, squamous cell carcinoma; SMR, standardized mortality rate.
[a]*Note.* Prevalence rate.

Skin cancer (10.6/1000)

SMR for bladder cancer: men, 6; women, 8.2
Lung cancer: men 3.8; women 3.1

Source: Hughes MF, et al. Toxicological Sciences 123 (2), 305-332 (2011)

Preventive Strategies…

- Implement health risk assessment activities

Health Protective Guidance Levels

	Human, Non-Cancer	Human, Cancer	Ecological
Convention	Exposure below threshold for adverse effect	Probability of a tumor is acceptably low	Exposure concentration below threshold for adverse effect
Hazard Characterization Input	ADI, TDI, RfD, RfC, BMD, etc.	Cancer slope factor (CSF)	Predicted No Effect Concentration (PNEC)
Exposure Input	Period average daily dose (PADD)	Lifetime average daily dose (LADD)	Predicted environmental concentration (PEC)
Risk Metric	Hazard quotient (HQ)	Excess lifetime cancer risk (ELCR)	Hazard quotient (HQ)
Calculation	HQ = PADD/ADI (or other)	ELCR = LADD x CSF	HQ = PEC/PNEC

From material developed by Dr. David Macintosh for the APEC Introductory level training on risk assessment and risk management

Drinking water monitoring in a community near an active volcano showed the following levels and non-cancer health risks (skin disease):

- **30-year old adult weighing 70 kg drinking 2 liters of water per day**

Site	Water (mg/L)	PADD (mg/kg/day)	HQ
Barangay A	0.4 mg/L	0.011	32
Barangay B	0.6 mg/L	0.017	50
Barangay C	0.3 mg/L	0.008	24

Drinking water monitoring in a community near an active volcano showed the following levels and non-cancer health risks (skin disease):

- **7-year old child weighing 25 kg drinking 1 liter of water per day**

Site	Water (mg/L)	PADD (mg/kg/day)	HQ
Barangay A	0.4 mg/L	0.016	47
Barangay B	0.6 mg/L	0.024	70
Barangay C	0.3 mg/L	0.012	35

Drinking water monitoring in a community near an active volcano showed the following levels and cancer health risks:

- **30-year old adult weighing 70 kg drinking 2 liters of water per day**

Site	Water (mg/L)	LADD (mg/kg/day)	ELCR
Barangay A	0.4 mg/L	0.005	7.5×10^{-3}
Barangay B	0.6 mg/L	0.007	1×10^{-3}
Barangay C	0.3 mg/L	0.004	6×10^{-3}

Drinking water monitoring in a community near an active volcano showed the following levels and cancer health risks:

- **7-year old child weighing 25 kg drinking 1 liter of water per day**

Site	Water (mg/L)	LADD (mg/kg/day)	ELCR
Barangay A	0.4 mg/L	0.0016	2.4×10^{-3}
Barangay B	0.6 mg/L	0.0024	3.6×10^{-3}
Barangay C	0.3 mg/L	0.0012	1.8×10^{-3}

"Safe level" of arsenic in drinking water (non-cancer endpoint)

- If reference dose was set at 3.4×10^{-3} mg/kg/day (US-EPA), then safe level of arsenic in drinking water for a 70 kg man is **0.01 mg/L** which is the Philippine National Standard for Drinking Water for Arsenic.
- For a 25 kg child, the computed safe level is **0.008 mg/L.**
- **SAFE LEVEL FOR AN ADULT MAY NOT BE THE SAME AS THAT FOR A CHILD.**

Preventive Strategies…

- Implement & strengthen international conventions/agreements and national environmental laws
- Decrease dependency on chemicals
- Decrease release of chemicals into the environment

Preventive Strategies…

- Implement environmental and biologic monitoring
- Conduct long-term post marketing surveillance
- Strengthen medical surveillance systems

Principle 15 of the Rio Declaration (1992) states, "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."

Take home points ….

- Environmental issues affecting pollution of aquatic resources are contamination, biomagnification and bioaccumulation, and persistence.
- The health implications of aquatic contamination involve the following factors: exposure, pollutant and clinical effects.
- Important preventive strategies to address environmental contamination of aquatic resources are the conduct of environmental and biologic monitoring, medical surveillance and risk assessment.

"We should be on our guard not to overestimate science and scientific methods when it is a question of human problems; and we should not assume that experts are the only ones who have the right to express themselves on questions affecting the organization of society."

Albert Einstein
May 1949

Thank you and good day !