Christopher Kai Tannock

Challenges of Water in the 21st century: understanding the interrelationship between nature and society from the lens of water management

Water is at the nexus of socioeconomic and environmental challenges we face today. From eutrophication to groundwater depletion, mismanagement of water result in severe sociological and ecological impacts. However, it is also true that from the lens of managing water, we can derive great insights into the interrelationship between nature and humans. This essay analyzes both benefits and impacts derived from fertilizer and pesticide use. It aims to illuminate the interconnectedness humans have to nature and show how damaging the environment will impact human health. Furthermore, the passive stance permeated in environmental management will be criticized, and the importance of the precautionary principle will be emphasized at the end.

The advent of artificial fertilizer forever changed the agricultural capability of the land and allowed the global population to increase dramatically.[1] Haber-Bosch Process developed in the early 20th century converts nitrogen in the atmosphere to reactive forms of fertilizer, and without this invention, scientists estimate that the world population would necessarily remain at half of the population from now, at about 3.5 billion people.[2] Not only nitrogen fertilizer supported the population increase, but more importantly, it granted food security that no other civilization has ever achieved. Today, for the first time in human history, famine exists not by environmental limitations but by political reasons such as armed conflicts and discrimination of marginalized ethnic groups. Although climate change-induced crop failure is rising,[3] it is a lack of political will that causes famine in the 21st century.[4]

However, artificial fertilizers not only offer benefits to humans but also produce detrimental environmental consequences as well. In the famous article "A safe operating space for humanity," published by Johan Rockstrom and his colleagues, they described the nitrogen cycle as exceeding the planetary boundary and destined to cause irrevocable damage

---

[1] Hannah Ritchie, How Many People Does Synthetic Fertilizer Feed (Oxford, Our World in Data, 2017)
[2] Ibid.
[3] Patrick Webb et al., Hunger and malnutrition in the 21st century (Science and Politics of Nutrition, 2018)
[4] Ibid.

to the ecosystem.[5] The consequence of using a massive amount of nitrogen fertilizer has been long documented to damage various forms of aquatic life by the process known as eutrophication. In short, the process takes place when nutrients from agricultural land spill over to rivers, lakes and oceans to cause algae or other microorganisms such as dinoflagellate to bloom, raising Chemical Oxygen Demand (COD) level as a result. Although the depletion of oxygen in the aquatic body takes place by many reasons such as geomorphic processes and increase in water temperature and dimming effect (less light penetrate thereby less photosynthesis to take place), eutrophication-induced hypoxia account for roughly half of all "dead zones" in the world's ocean.[6]

What about the impact on humans? Would an increased level of organic matter in water affect human health in any way? The answer is yes. Along with the Haber-Bach process, water disinfection by chlorine revolutionized public health safety. Evidence shows that water-related diseases such as cholera, typhoid and gastroenteritis dramatically decreased as health authorities around the globe introduced water disinfection measures.[7] However, despite the benefits, disinfection-by-products (DBPs) are produced when chlorine compounds disinfect water. More than 600 types of DBPs are reported today, which some of them are known to be carcinogenic as well as causing reproductive/developmental diseases.[8] To quantitatively assess the toxicity, Richardson et al. reviewed long-term researches on the occurrence, genotoxicity, and carcinogenicity of 85 DBPs.[9] Although the research is extensive and being a critical assessment of many DBPs, for this essay, I want to give special attention to the formation of trihalomethane and the effect on human health because it is produced by the combination of organic matter and chlorine in the water.

Trihalomethane forms when chlorine reacts to the organic matter in water, and it includes chloroform, bromoform, bromodichloromethane, and chlorodibromomethane.[10] According to Richardson et al., all four chemical compounds are tested to be carcinogenic: drinking chlorinated water that includes bromodichloromethane and chloroform produced

[5] Johan Rockstrom et al., A Safe Operating Space for Humanity (Nature, 2009)
[6] Robert J.Diaz and Rutger Rosenburg, Spreading Dead Zones and Consequences for Marine Ecosystems (Science, 2008, p.926)
[7] David Cutler and Grant Miller, The Role of Public Health Improvements in Health Advances: The Twentieth-Century United States
[8] Richardson et al., Occurrence, genotoxicity, and carcinogenicity of regulated and emerging disinfection by-products in drinking water: A review and roadmap for research (Mutation Research, 2007)
[9] Ibid.
[10] Ibid.

renal and liver tumours to exposed rodents in the lab experiments, and two other substances also caused the tumour in one organ or another.[11] More importantly, trihalomethanes are highly volatile compounds, which means the exposure is not constrained to drinking but inhalation and dermal exposures as well. In fact, one study shows that dermal exposure of bromodichloromethane was 25 ~ 130 times higher than oral exposure.[12] Overall, trihalomethane is a by-product of disinfecting the water with chlorine compounds, and the exposure could happen via drinking, showering (touching and inhaling) and many other ordinary usages of water like brushing teeth.

Eutrophication and formation of trihalomethane are connected and have a positive relationship because eutrophication means more organic material in the water, and adding chlorine to the water would inevitably produce more trihalomethane simply by a matter of chemical bonding. Therefore, the more we rely on artificial fertilizers and release them into the environment, the more toxic the water will be, not only for ecosystems but also for humans. If tap water comes from a river used for agricultural purposes, the dynamics become a significant issue – such as in Japan's case.

Three-quarters of all domestic water comes from surface water in Japan: 48% comes from dams, 25% comes from rivers and the remaining 2% coming from lakes, while the rest is supported by underground water. Especially heavily urbanized areas such as Tokyo metropolitan areas rely exclusively on river water. Moreover, Japanese water management is arbitrarily divided by multiple ministries according to varying purposes; nevertheless, it is a river that has to be managed and ensure safety. As a result, coordinated measure to examine the concentration of agricultural chemicals in the aquatic environment is absent nor monitoring DBP contaminants in tap water is possible. The management system is inherently uncoordinated and possible to induce human health hazards.[13] However, eutrophication of the river could take place not only by fertilizers but also by the deposition of nitrogen oxides via rain and wind. Nitrogen oxides are emitted to the atmosphere when we burn fossil fuels. Japan's geographic proximity to China is close enough that westerlies can carry nitrogen oxides produced in China to Japanese water. Therefore, even if we mitigate the amount of

[11] Ibid, p.189.
[12] Leavens et al., Disposition of Bromodichloromethane in Humans Following Oral and Dermal Exposure (Toxicological Science, 2007).
[13] House of Councillors of Japan

fertilizer spilled over to rivers and lakes, we might still experience eutrophication. Scientists speculated that eutrophication in the dam Kurobe, which locates high up in the Japanese alps where no fertilizer could possibly reach, is attributed to these dynamics.

Another example to elucidates the inseparability of the ecosystem and human health is the use of highly contested pesticide – neonicotinoids. Neonicotinoids have become the most widely used insecticides globally since its introduction in the 1980s, representing more than 25% of global pesticide share and having a market value of $3 billion US.[14] Since the first usage, many scientists worldwide reported the ecological impact correlated with the use of neonicotinoids.[15,16,17]Among the reports, Yamamuro et al. found a particularly strong causation factor between the disruption of aquatic food webs and the use of neonicotinoids.[18]

Upon studying the impact of neonicotinoids, they selected a site where the damage to the ecosystem could be attributed to the insecticides maximally. The study site Lake Shinji and its ecosystem have not been affected by invasive species, oligotrophication, surface water chlorinity, nor hypoxia evident by the records of water quality and fish yields between the year 1982 and 2016.[19] However, the use of neonicotinoids begun in the area in 1993 and degraded the aquatic ecosystem tremendously, shown by the decrease in the local fish yield. The average annual yields of Smelt dropped ten-fold (240 tons to 22 tons) between the periods 1981 to 1992 and 1993 to 2004, and the yield declined approximately four times for Eel as well during the period (Fig. 3).[20] In figure 3, we can clearly see the plummet of fish stock between 1992 and 1994 when farmers first used the insecticides.[21]

---

[14] Craddock et al., Trends in neonicotinoid pesticide residues in food and water in the United States, 1999 - 2015 (Environmental Health, 2019)
[15] Hallmann et al., Declines in insectivorous birds are associated with high neonicotinoid concentrations (Nature, 2014)
[16] Williams et al., Neonicotinoid pesticides severely affect honey bee queens (Scientific Reports, 2015)
[17] Woodcock et al., Country-specific effects of neonicotinoid pesticides on honey bees and wild bees (Science, 2017)
[18] Yamamuro et al., Neonicotinoid disrupt aquatic food webs and decrease fishery yields (Science, 2019)
[19] Ibid.
[20] Ibid.
[21] Ibid.

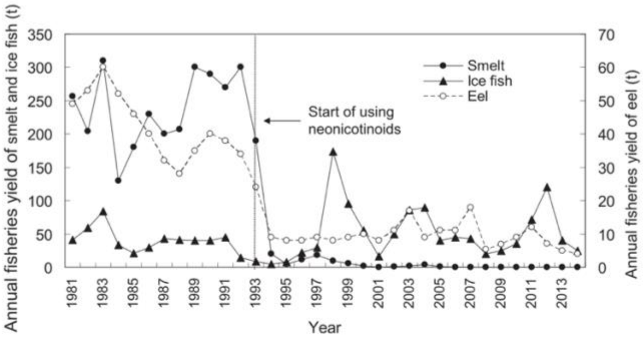

Fig. 3. Annual yield (tons) of smelt, ice fish, and eel in Lake Shinji from 1981 to 2014. The vertical dashed line indicates when neonicotinoid use began in the watershed of the lake.

It is important to note that a decrease in the fish yields signifies the overall degradation of the environment, and the impact is not constrained to the fish species. As Yamamuro et al., denote that "reduction in the abundance of invertebrates, particularly zooplankton, were associated with significantly lower landings of smelt and eel."[22] Therefore, in Lake Shinji, most of the fish depletion happened indirectly by the reduction of invertebrates around the area. However, despite the strong scientific evidence that illuminates the causational relationship between neonicotinoids and the negative impact on aquatic ecosystems, neonicotinoids have not been prohibited nor the usage has declined in Japan. One of the reasons is that neonicotinoids have Japanese origin. Many leading developers of the insecticides are Japanese companies such as Mitsui Chemicals, Nippon Soda, and Sumimoto[23]; short-term economic profits outweighing the long-term implications on ecosystems.

Would neonicotinoids cause any direct human health hazards? We have not yet to know the answer, just as we have not fully grasped the impacts inflicted on humans for many other environmental problems. Despite climate change, biodiversity loss, and chemical pollution could all pose irrecoverable damage to the earth system; the world operates business as usual primarily for economic reasons. Essentially, we are waiting until the impact finally nudges or destroys us. That passive stance permeated in the environmental management could lead to what Donald Wright argues to be a progress trap[24], which is when we introduce problems that we might not be able to solve technologically or politically in the pursuit of short-term economic growth. Much like Mesopotamians who invented irrigation

[22] Yamamuro et al., p.366
[23] Craddock et al., Trends in neonicotinoid pesticide residues in food and water in the united states, 1999–2015 (Environmental Health, 2019)
[24] Wright, R. A short history of progress (University of Cambridge, 2004)

and experienced rapid development of civilization but eventually collapsed due to salinization of soil from the very act of irrigation that made them rich[25], modern society could be triggering their own downfall steadily in the pursuit of short-term gain. Overall, we need to overcome the short-term profit biases and reassess the risk management.

Precautionary principle is the concept often employed in the Environmental Impact Assessment, and according to Noble, it "suggests that when scientific information is incomplete but there is a threat of adverse impacts, the lack of full certainty should not be used as a reason to preclude or to postpone actions to prevent harm."[26] In other words, no justification should be made based on the fact that we have not yet known the entire spectrum of changes a practice could present; lack of certainty should not be the reason to proceed. In terms of the use of nitrogen fertilizer and neonicotinoids, we started to use them imprudently without giving much attention to their side effects partly by being tempted to short-term gains, and we failed to apply the principle. As a result, the environment and human health have been sacrificed. Although abstaining from existing technologies that could benefit us seems paradoxical, it is necessary to avoid the progress trap. This is especially true for water management because all life forms revolve around water, and it dictates their wellness.

Water mediates the relationship human has to nature and resembles the inseparability between them. Therefore, human relation to water implies how well we are managing the environment overall. In the age of Anthropocene, where human presence became the predominant force to determine the planet's future, water management's importance has undeniably enlarged. However, predicament remains especially for the river basins that cross international borders, such as in the Nile. The arbitrarily drawn separation must overcome with greater coordination and partnerships between nations. A large body of water, like rivers and ocean, has been what separated us from neighbours historically, but the notion has become obsolete for confronting the global civilization's challenges in the 21st century. Water has to be what unite us – unite between nation to nation and between nature and humans.

[25] Growth of World Urbanism, Charles Redman (University of Arizona, 1999)
[26] Noble, Introduction to environmental impact assessment: A guide to principles and practice (2015), p.92

References

Craddock, H. A., Huang, D., Turner, P. C., Quirós-Alcalá, L., & Payne-Sturges, D. C. (2019). Trends in neonicotinoid pesticide residues in food and water in the united states, 1999–2015. *Environmental Health, 18*(1), 7-7. doi:10.1186/s12940-018-0441-7

Cutler, D. M., & Miller, G. (2005). The role of public health improvements in health advances: The twentieth-century united states. *Demography, 42*(1), 1-22. doi:10.1353/dem.2005.0002

Diaz, R. J., Rosenberg, R., Naturvetenskapliga fakulteten, Department of Marine Ecology, Institutionen för marin ekologi, Faculty of Sciences, . . . Gothenburg University. (2008). Spreading dead zones and consequences for marine ecosystems.*Science (American Association for the Advancement of Science), 321*(5891), 926-929. doi:10.1126/science.1156401]

Hallmann, C. A., Foppen, R. P. B., van Turnhout, Chris A. M, de Kroon, H., & Jongejans, E. (2014). Declines in insectivorous birds are associated with high neonicotinoid concentrations. *Nature (London), 511*(7509), 341-343. doi:10.1038/nature13531

Leavens, T. L., Blount, B. C., DeMarini, D. M., Madden, M. C., Valentine, J. L., Case, M. W., . . . Pegram, R. A. (2007). Disposition of bromodichloromethane in humans following oral and dermal exposure. *Toxicological Sciences, 99*(2), 432-445. doi:10.1093/toxsci/kfm190

Noble, B. F. (2015). *Introduction to environmental impact assessment: A guide to principles and practice* (Third ed.). Don Mills, Ontario: Oxford University Press.

Redman, C. L. (1999). *Human impact on ancient environments*. Tucson: University of Arizona Press.

Ritchie, H. (2007, November 7). How many people does synthetic fertilizer feed? Retrieved October 24, 2020, from https://ourworldindata.org/how-many-people-does-synthetic-fertilizer-feed

Richardson, S., Plewa, M., Wagner, E., Schoeny, R., & Demarini, D. (2007). Occurrence, genotoxicity, and carcinogenicity of regulated and emerging disinfection by-products in drinking water: A review and roadmap for research. *Mutation Research. Reviews in Mutation Research, 636*(1-3), 178-242. doi:10.1016/j.mrrev.2007.09.001

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E. F., . . . Foley, J. A. (2009). A safe operating space for humanity. *Nature (London), 461*(7263), 472-475. doi:10.1038/461472a

Webb, P., Stordalen, G. A., Singh, S., Wijesinha-Bettoni, R., Shetty, P., & Lartey, A. (2018). Hunger and malnutrition in the 21st century. *Bmj*, *361*, k2238-k2238. doi:10.1136/bmj.k2238

Williams, G. R., Troxler, A., Retschnig, G., Roth, K., Yañez, O., Shutler, D., . . . Gauthier, L. (2015). Neonicotinoid pesticides severely affect honey bee queens.*Scientific Reports*, *5*(1), 14621-14621. doi:10.1038/srep14621

Woodcock, B. A., Bullock, J. M., Shore, R. F., Heard, M. S., Pereira, M. G., Redhead, J., . . . Pywell, R. F. (2017). Country-specific effects of neonicotinoid pesticides on honey bees and wild bees. *Science (American Association for the Advancement of Science), 356*(6345), 1393-1395. doi:10.1126/science.aaa1190

Wright, R. (2004). *A short history of progress*. Cambridge, MA: Da Capo Press.

Yamamuro, M., Komuro, T., Kamiya, H., Kato, T., Hasegawa, H., & Kameda, Y. (2019). Neonicotinoids disrupt aquatic food webs and decrease fishery yields. *Science (American Association for the Advancement of Science), 366*(6465), 620-623. doi:10.1126/science.aax3442

水制度改革に関する請願：請願の要旨：参議院. (n.d.). Retrieved October 24, 2020, from https://www.sangiin.go.jp/japanese/joho1/kousei/seigan/168/yousi/yo1681259.htm