Ricardo Wurmus

72191 Global Environmental Studies

Assignment 2

Contents

List of Tables

List of Figures

Part I

The national and global impacts of industrial activity

According to the International Energy Agency (2011), coal contributes about 40% to the world electricity generation throughout the last few decades. Approximately 40% of the global electricity consumption is attributed to the industry sector. Industry demands make up more than 77% of the world coal consumption (International Energy Agency, 2011). It hence makes sense to have a closer look at the national and global impacts associated with the extraction, transport, and use of coal.

1 Coal extraction and combustion of fossil fuels

Surface mining procedures to extract coal often result in severe degradation and destruction of ecosystems that exist at and around the mined site. Sites with coal deposits near the surface are stripped of all original vegetation before the overburden is removed. Streams and rivers passing through the site are redirected, affecting aquatic and riparian communities directly and by altering the flow and sedimentation characteristics (Miller & Spoolman, 2009). In some mining methods ablated soil and rock is deposited as spoil banks which are exposed to erosion and recover only very slowly through primary succession. These deposits constitute a long-term source of water contamination as pyrites in the exposed waste piles oxidise, resulting in the production of metal-laden acid solutions that are flushed into streams by rainfall and snow melt (Gray, 1997).

Fossil fuel combustion is one of the top contributors to regional air pollution and global climate change. When coal is burned most of its carbon reacts with oxygen to form the greenhouse gases CO and CO_2. Around 43% of global CO_2 emissions in 2009 were attributed to burning coal (International Energy Agency, 2011). Carbon dioxide is the main driver of anthropogenic climate change (Solomon et al., 2007). Unburned carbon ends up in the air as soot together with a mixture of suspended particulate matter that includes arsenic, lead, mercury, and trace amounts of radioactive materials (US Environmental Protection Agency, 1999b; Lopez-Anton, Yuan, Perry, & Maroto-Valer, 2010; Papastefanou, 2010).

Burning coal leaves behind toxic ash that has to be treated and deposited safely as it contains toxic trace elements, including arsenic, selenium, chromium, cadmium, and mercury, that can leach from landfills and ash basins, pollute groundwater and surface waters, and become biologically magnified in food webs (Cherry & Guthrie, 1977; Wiener, Krabbenhoft, Heinz, & Scheuhammer, 2002; Singh & Kolay, 2009).

The overwhelming majority of anthropogenic emissions of sulphur dioxide is produced when burning sulphur-containing coal (Smith et al., 2011). Fuel-bound nitrogen and nitrogen present in the air combine with oxygen producing nitrogen oxides (NO_x) during coal combustion (US Environmental Protection Agency, 1999a). Secondary pollutants derived from these gases are agents of acid deposition, a regional air pollution problem (Rechcigl & Sparks, 1985). Acid rain increases the acidity of soils and water, and frees aluminium, mercury, and lead from mineral deposits with harmful effects for aquatic animals and humans (Martin, 1994). Acidic water is unsuitable for many fish species (Schofield, 1976; Rechcigl & Sparks, 1985). Acid deposition inhibits plant productivity as the soil acidity increases and nutrients are leached from it (Ulrich, 1983). Nitrogen dioxide contributes to the formation of ozone in the lower atmosphere and is associated with adverse respiratory effects, such as airway inflammation and increased asthma symptoms (US Environmental Protection Agency, 2011b).

The combustion of fossil fuels in trucks, planes and ships used for the transport of goods and materials also contributes significantly to global anthropogenic emissions of carbon dioxide and sulphur dioxide (Solomon et al., 2007; Smith et al., 2011).

2 Metal industry

Similar to the processes involved in extracting coal, mining and processing of metallic ore take their toll on the environment. According to Dudka and Adriano (1997), copper, lead, and zinc are the three metals whose production in the metal industry causes the greatest environmental degradation. The process of metal smelting contributes to *(a)* climate change due to CO_2 emissions; *(b)* air pollution with the emission of gases like NO_x and SO_2, and toxic particulate matter; *(c)* water pollution from the output of toxic sewage and solid wastes (Dudka & Adriano, 1997).

3 Reducing impacts

Current efforts to reduce the environmental impact of industries can be categorised as follows: *(a)* technological fixes to problems caused by the use of coal; *(b)* emissions trading; *(c)* emission reduction and pollution prevention.

Technological fixes are often applied *after* the production of polluting substances. There have been attempts to reduce the impacts of coal use, for example by treating mine waste water to neutralise acid mine drainage and to remove metals (Johnson & Hallberg, 2005), or to reduce the radioactivity of coal ash to make it more suitable for mixing with concrete for construction projects (Baykal & Saygılı, 2011). Another approach is to capture carbon dioxide from emissions and inject it underground for long-term storage (Metz, Davidson, de Coninck, Loos, & Meyer, 2005). While these technological fixes can somewhat alleviate the harmful effects of hazardous waste, many are prohibitively expensive (Metz et al., 2005). In addition, none of the above methods would prevent the obliteration of ecosystems caused by surface mining.

Under the Kyoto Protocol, the signing parties have agreed to reduce greenhouse gas emissions. Overachieving countries with emission units to spare can sell them to countries that are over their targets (United Nations Framework Convention on Climate Change, 2012). Emissions trading schemes have also been established on a national level. According to the US EPA, the national Acid Rain Program has successfully reduced SO_2 emissions to 33% of 1980 levels (US Environmental Protection Agency, 2010). Although trading systems are designed to encourage participants to invest in clean technology, they also enable wealthy polluters to buy their way out unless emissions limits are periodically lowered. The implementation of emissions standards, such as the EPA Mercury and Air Toxics Standard, can further encourage industries to employ and invest in pollution control technologies (US Environmental Protection Agency, 2011a).

To reduce industrial carbon dioxide emissions, the IPCC recommends the integration of renewable energy into present energy systems, materials recovery and recycling (e.g. metals and paper pulp), and reuse of excess heat for sale off-site (Sims et al., 2011). The IPCC report also mentions a pilot plant in Germany that generates steam from solar collectors that can be used to supply industrial heat.

4 References

Baykal, G., & Saygılı, A. (2011). A new technique to reduce the radioactivity of fly ash utilized in the construction industry. *Fuel*, *90*(4), 1612–1617. doi:10.1016/j.fuel.2011.01.006

Cherry, D. S., & Guthrie, R. K. (1977). Toxic metals in surface waters from coal ash. *Journal of the American Water Resources Association*, *13*(6), 1227–1236. doi:10.1111/j.1752-1688.1977.tb02093.x

Dudka, S., & Adriano, D. (1997). Environmental impacts of metal ore mining and processing: a review. *Journal of Environmental Quality*, *26*, 590–602.

Gray, N. F. (1997). Environmental impact and remediation of acid mine drainage: a management problem. *Environmental Geology*, *30*(1), 62–71. doi:10.1007/s002540050133

International Energy Agency. (2011). *2011 Key World Energy Statistics*.

Johnson, D. B., & Hallberg, K. B. (2005). Acid mine drainage remediation options: a review. *Science of The Total Environment*, *338*(1—2), 3–14. doi:10.1016/j.scitotenv.2004.09.002

Lopez-Anton, M. A., Yuan, Y., Perry, R., & Maroto-Valer, M. M. (2010). Analysis of mercury species present during coal combustion by thermal desorption. *Fuel*, *89*(3), 629 –634. doi:10.1016/j.fuel.2009.08.034

Martin, R. B. (1994). Aluminum: a neurotoxic product of acid rain. *Accounts of Chemical Research*, *27*(7), 204–210. doi:10.1021/ar00043a004

Metz, B., Davidson, O., de Coninck, H., Loos, M., & Meyer, L. (Eds.). (2005). *Carbon dioxide capture and storage*. Cambridge University Press.

Miller, G. T., & Spoolman, S. E. (2009). *Living in the environment, 17e* (C. Delgado, Ed.). Brooks/Cole.

Papastefanou, C. (2010). Escaping radioactivity from coal-fired power plants (CPPs) due to coal burning and the associated hazards: a review. *Journal of Environmental Radioactivity*, *101*(3), 191–200. doi:10.1016/j.jenvrad.2009.11.006

Rechcigl, J., & Sparks, D. (1985). Effect of acid rain on the soil environment: a review. *Communications in Soil Science and Plant Analysis*, *16*(7), 653–680. doi:10.1080/00103628509367636

Schofield, C. L. (1976). Acid precipitation: effects on fish. *Ambio*, *5*(5–6), 228–230.

Sims, R., Mercado, P., Krewitt, W., Bhuyan, G., Flynn, D., Holttinen, H., … van Hulle, F. (2011). Integration of renewable energy into preset and future energy systems. In O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, …C. von Stechow (Eds.), *IPCC Special report on renewable energy sources and climate change mitigation* (Chap. 8). Cambridge University Press.

Singh, H., & Kolay, P. (2009). Analysis of coal ash for trace elements and their geo-environmental implications. *Water, Air, & Soil Pollution*, *198*, 87–94. doi:10.1007/s11270-008-9828-3

Smith, S., van Aardenne, J., Klimont, Z., Andres, R., Volke, A., & Arias, S. D. (2011). Anthropogenic sulfur dioxide emissions: 1850–2005. *Astropheric Chemistry and Physics*, *11*, 629–634. doi:10.5194/acp-11-1101-2011

Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K., … Miller, H. (Eds.). (2007). *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007*. Cambridge University Press. Retrieved January 4, 2012, from http://www.ipcc.ch/publications_and_data/ar4/wg1/en/contents.html

Ulrich, B. (1983). Soil acidity and its relations to acid deposition. In B. Ulrich & J. Pankrath (Eds.), *Effects of accumulation of air pollutants in forest ecosystems*. D. Reidel Publishing Company.

United Nations Framework Convention on Climate Change. (2012). Emissions trading. Retrieved January 14, 2012, from http://unfccc.int/kyoto_protocol/mechanisms/emissions_trading/items/2731.php

US Environmental Protection Agency. (1999a). *Nitrogen oxides (NOx), why and how they are controlled* (tech. rep. No. EPA 456/F-99-006R).

US Environmental Protection Agency. (1999b). *Technical background document for the report to congress on remaining wastes from fossil fuel combustion: waste characterization*.

US Environmental Protection Agency. (2010, December 21). Acid rain and related programs: 2009 highlights. Retrieved January 14, 2012, from http://www.epa.gov/airmarkets/progress/ARP09_4.html

US Environmental Protection Agency. (2011a, December 22). Mercury and air toxics standards: cleaner power plants. Retrieved January 14, 2012, from http://www.epa.gov/mats/powerplants.html

US Environmental Protection Agency. (2011b, July 7). Six common pollutants: nitrogen dioxide. Retrieved January 12, 2012, from http://www.epa.gov/air/nitrogenoxides/health.html

Wiener, J. G., Krabbenhoft, D. P., Heinz, G. H., & Scheuhammer, A. M. (2002). Ecotoxicology of mercury. In D. J. Hoffman, B. A. Rattner, J. G A Burton & J. J Cairns (Eds.), *Handbook of ecotoxicology* (2nd ed., Chap. 16, pp. 407–461). CRC Press. doi:10.1201/9781420032505.ch16

Part II

Global climate change and ozone depletion

Global climate change and ozone depletion are rooted in changes of the chemical composition of the atmosphere: the processes related to global climate change are found mainly in the troposphere (the atmospheric layer closest to the earth's surface), whereas ozone depletion describes the thinning of the ozone layer in the stratosphere, the gaseous sphere that lies above the troposhere.

1 Ozone depletion

The ozone layer protecting life on the earth's surface from much of the harmful solar ultraviolet radiation is an atmospheric zone extending from near the base of the stratosphere to about 26 km above sea level (Miller & Spoolman, 2009). There, under the influence of UV radiation, oxygen and ozone molecules break apart, thereby preventing much of the incoming ultraviolet radiation from reaching the earth's surface (Karoly, 1997; Newman & Morris, 2003). Ozone is continuously replenished through the recombination of molecular and atomic oxygen (Karoly, 1997).

Human activities in recent decades have resulted in the release of substances—such as chlorine, bromine, and nitrogen oxides—into the atmosphere that function as catalysts in ozone destruction cycles (Karoly, 1997; Solomon, 1999). Chlorofluorocarbons (CFCs) which were widely used as propellants in spray cans and as coolants in refrigeration units were recognised as a major source of ozone-destroying chlorine in 1974 (Solomon, 1999). Since the global reduction in CFC production following the adoption of the Montreal Protocol in 1989, the dominant ozone-depleting substance is nitrous oxide (N_2O), which is unregulated by the Protocol (Ravishankara, Daniel, & Portmann, 2009). The largest single source of N_2O is food production, amounting to 60% of total anthropogenic emissions. Agriculture causes direct emissions from animal production and from fertilised soils, as well as indirect emissions through agricultural run-off (Syakila & Kroeze, 2011). (See figure 1 for an overview of major anthropogenic sources of nitrous oxide.)

With the depletion of ozone in the stratosphere the absorption of ultraviolet radiation is reduced, allowing a larger percentage of the harmful solar radiation to reach the earth's surface. In humans, exposure to UV radiation can increase the risk of skin cancers and eye cataracts and trigger the suppression of immune responses (van der Leun, Tang, & Tevini, 1998). UV radiation harms plants and may cause lower crop yields, diminished forest productivity, and

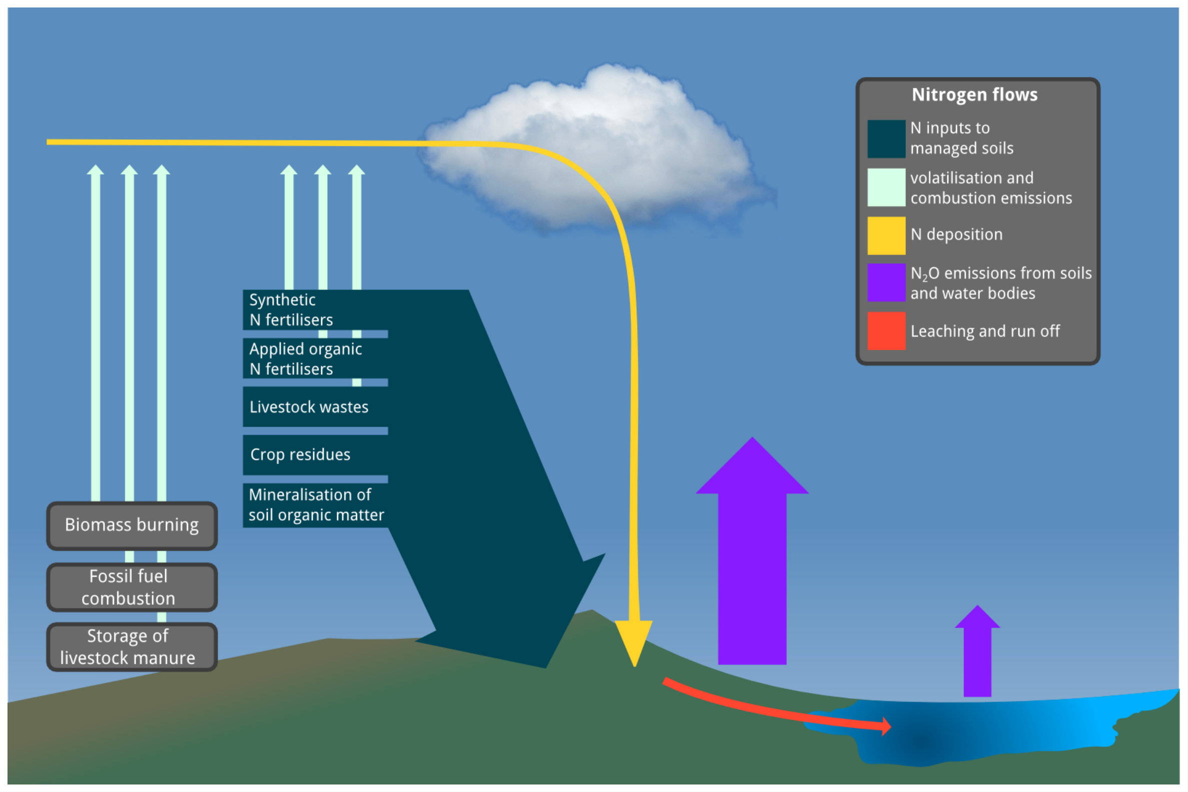

Figure 1: Anthropogenic sources of nitrous oxide. Based on Smith (2010).

reduce phytoplankton populations with cascaded effects on aquatic food webs (van der Leun et al., 1998). Near the ground, UV radiation creates photochemical ozone, an air pollutant.

2 Global climate change

An important process affecting the surface temperature of the earth is the greenhouse effect. Long-lived greenhouse gases in the lower atmosphere, including methane (CH_4), carbon dioxide (CO_2), and nitrous oxide (N_2O), absorb and re-emit heat radiation emanating from the earth's surface, thereby reducing heat loss to outer space (see figure 2). Changes to the chemical composition of the atmosphere result in changes to the earth's temperature due to radiative forcing (Wang, Yung, Lacis, Mo, & Hansen, 1976). (See figure 3 for an overview of important agents of radiative forcing.)

Human activities since the industrial revolution have been implicated in the current warming trend of the troposphere as they either increase the amount of greenhouse and other trace gases in the troposphere or lower the earth's capacity to remove them from the atmosphere through natural cycles (Solomon et al., 2007). According to the IPCC, atmospheric concentrations of the major greenhouse gases CH_4, CO_2, and N_2O have increased by about 150%, 36%, and 18%, respectively, compared to pre-industrial times (Solomon et al., 2007, p. 7.3.1); almost all of the increase is due to human activities, such as food production and combustion of fossil fuels (Solomon et al., 2007, FAQ 7.1). Table 1 shows the major natural and anthro-

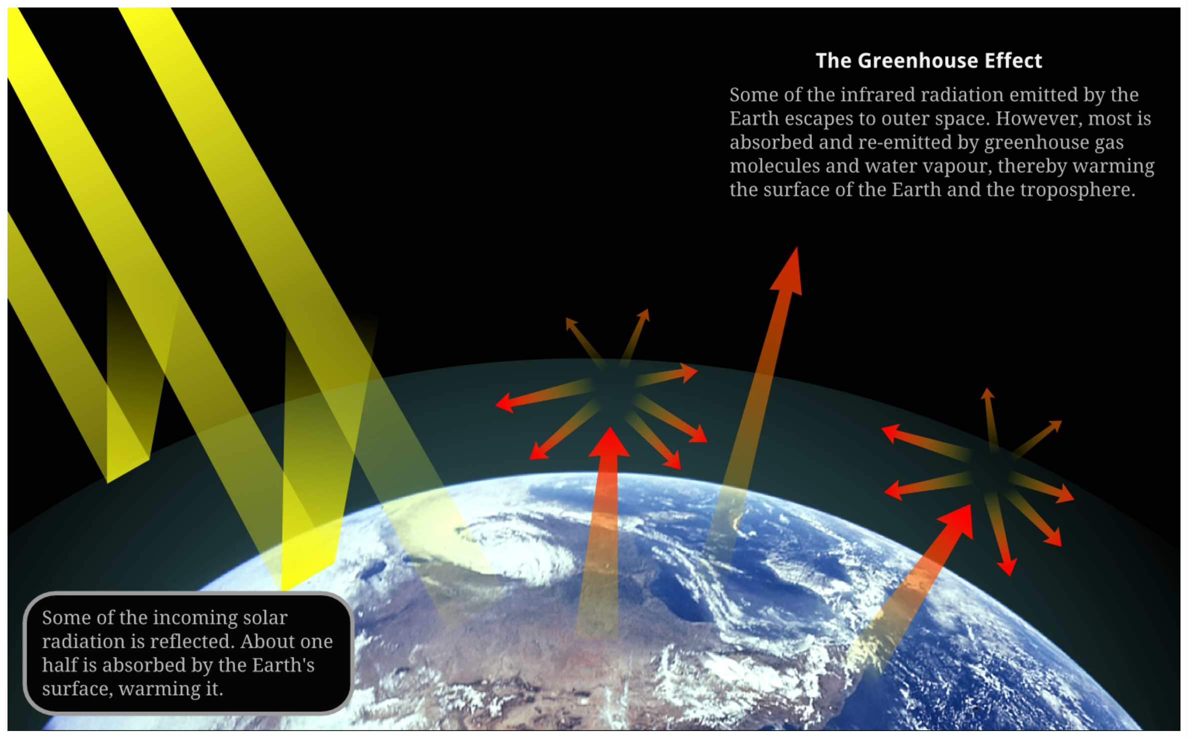

Figure 2: A simplified model of tropospheric warming due to greenhouse gases. Based on Solomon et al. (2007, FAQ 1.3, Figure 1). Photo of the Earth ©1972 by NASA (AS16-118-18873).

pogenic emitters of methane. In addition to increased emissions, clearing of native vegetation for agriculture and urban development has amounted to an overall reduction of the earth's capacity to cycle greenhouse gases (Chambers, Higuchi, Tribuzy, & Trumbore, 2001).

Table 1: Estimated natural and anthropogenic global methane sources in million metric tons per year. Adapted from K. Johnson and D. Johnson (1995).

Natural		Energy/refuse		Agricultural	
Wetlands	115	Gas and Oil	50	Livestock	80
Termites	20	Coal	40	Rice	60
Oceans	15	Landfills	30	Manure	10
Burning	10	Wastewater	25	Burning	5
		Charcoal	10		
	160		155		165

Global climate change is causing a temperature-related shift in animal and plant communities (Root et al., 2003). According to Bergengren, Waliser, and Yung (2011), climate change is likely to trigger plant community changes on half of the earth's land surface area and cause 37% of all terrestrial ecosystems to undergo biome-scale changes by the end of this century. Resulting range losses are expected to lead to global extinctions of endemic species (Malcolm, Liu, Neilson, Hansen, & Hannah, 2006). Migrating animal populations are also at higher risk of extinction during climate fluctuations (Early & Sax, 2011).

Due to the oceans' absorption of CO_2 their surface waters have become more acidic,

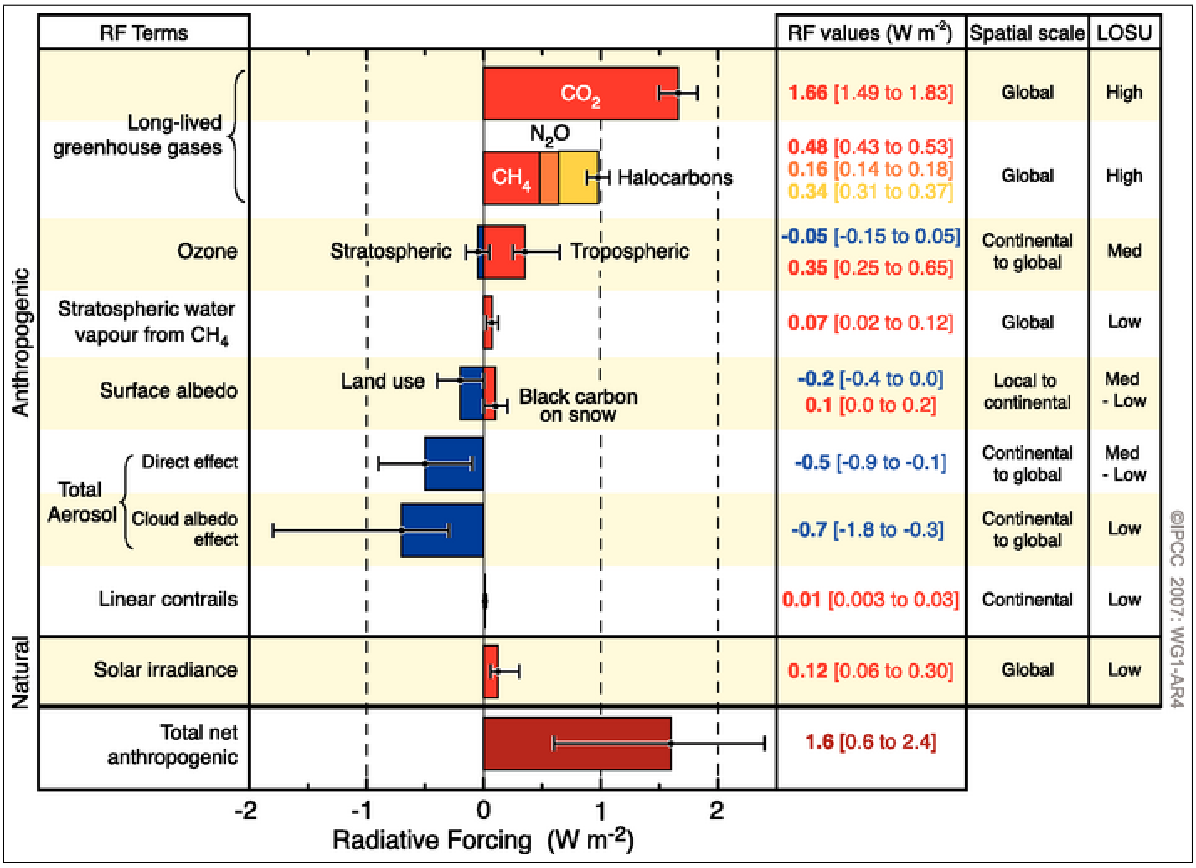

Figure 3: Global radiative forcing estimates for important anthropogenic and natural agents. Positive radiative forcing warms the earth's surface, while negative forcing cools it. Those agents with the stronges global warming potential have increased almost exclusively because of human activities. Figure reproduced from Solomon et al. (2007, SPM.2).

threatening corals and phytoplankton populations with potential cascading effects on aquatic food webs (Solomon et al., 2007, TS.6.2.3). Rising sea levels due to the accelerated loss of land ice and thermal expansion (Solomon et al., 2007, TS.6.2.3) are threatening freshwater supplies (Liu, 2011) and are degrading estuaries, wetlands, and coral reefs (Gornitz, 1991; Hoegh-Guldberg, 1999). Regional food security is challenged not only by possible flooding and soil erosion, but also by rising sea temperatures that affect fisheries with low temperature tolerance (Brander, 2007) and droughts which become more likely as the climate changes (Schmidhuber & Tubiello, 2007).

The effects of climate change on the environment can create positive feedback mechanisms that further accelerate climate change. As ice sheets melt and the area covered by ice shrinks, less sunlight is reflected from the earth's surface, thereby accelerating the melting of remaining ice (Schneider, 1989). As the oceans get warmer their capacity to absorb CO_2 is reduced (Solomon et al., 2007, p. 5.4). The resulting conditions would lead to further warming of the troposphere. Arctic warming could release large quantities of methane stored below the permafrost of the tundra, resulting in a sudden increase of greenhouse effects (Schneider, 1989). Such rapid climate change would degrade terrestrial and aquatic ecosystems at a much faster rate, possibly leading to mass extinctions (Root et al., 2003).

3 References

Bergengren, J., Waliser, D., & Yung, Y. (2011). Ecological sensitivity: a biospheric view of climate change. *Climatic Change*, *107*, 433–457. doi:10.1007/s10584-011-0065-1

Brander, K. (2007). Global fish production and climate change. *PNAS*, *104*(50), 19709—19714. doi:10.1073/pnas.0702059104

Chambers, J., Higuchi, N., Tribuzy, E., & Trumbore, S. (2001). Carbon sink for a century. *Nature*, *410*, 429.

Early, R., & Sax, D. F. (2011). Analysis of climate paths reveals potential limitations on species range shifts. *Ecology Letters*, *14*(11), 1125–1133. doi:10.1111/j.1461-0248.2011.01681.x

Gornitz, V. (1991). Global coastal hazards from future sea level rise. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *89*(4), 379–398. doi:10.1016/0031-0182(91)90173-O

Hoegh-Guldberg, O. (1999). Climate change, coral bleaching and the future of the world's coral reefs. *Marine and Freshwater Research*, *50*, 839–866.

Johnson, K., & Johnson, D. (1995). Methane emissions from cattle. *Journal of Animal Science*, *73*, 2483–2492.

Karoly, D. J. (1997). Physics of stratospheric ozone and UV-B radiation. *Australian Meteorological Magazine*, *46*, 179–184.

Liu, C. (2011, November 27). *Shanghai struggles to save itself from the sea*. Retrieved January 4, 2012, from http://www.eenews.net/public/climatewire/2011/09/27/1

Malcolm, J. R., Liu, C., Neilson, R. P., Hansen, L., & Hannah, L. (2006). Global warming and extinctions of endemic species from biodiversity hotspots. *Conservation Biology*, *20*(2), 538–548. doi:10.1111/j.1523-1739.2006.00364.x

Miller, G. T., & Spoolman, S. E. (2009). *Living in the environment, 17e* (C. Delgado, Ed.). Brooks/Cole.

Newman, P., & Morris, G. (2003). *Stratospheric ozone: an electronic textbook* (R. M. Todaro, Ed.). NASA Goddard Space Flight Center. Retrieved January 1, 2012, from http://www.ccpo.odu.edu/~lizsmith/SEES/ozone/oz_class.htm

Ravishankara, A. R., Daniel, J. S., & Portmann, R. W. (2009). Nitrous oxide (N_2O): the dominant ozone-depleting substance emitted in the 21st century. *Science*, *326*(5949), 123–125. doi:10.1126/science.1176985

Root, T. L., Price, J. T., Hall, K. R., Schneider, S. H., Rosenzweig, C., & Pounds, J. A. (2003). Fingerprints of global warming on wild animals and plants. *Nature*, *421*, 57–60. doi:10.1038/nature01333

Schmidhuber, J., & Tubiello, F. N. (2007). Global food security under climate change. *PNAS*, *104*(50), 19703–19708. doi:10.1073/pnas.0701976104

Schneider, S. H. (1989). Greenhouse effects due to man-made perturbations of trace gases. *Science*, *243*, 771–781.

Smith, K. (2010). *Nitrous oxide and climate change*. Earthscan. Retrieved from http://books.google.com/books?id=gxLjaVwHcPsC

Solomon, S. (1999). Stratospheric ozone depletion: a review of concepts and history. *Reviews of Geophysics*, *37*(3), 275–316.

Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K., … Miller, H. (Eds.). (2007). *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007*. Cambridge University Press. Retrieved January 4, 2012, from http://www.ipcc.ch/publications_and_data/ar4/wg1/en/contents.html

Syakila, A., & Kroeze, C. (2011). The global nitrous oxide budget revisited. *Greenhouse Gas Measurement and Management*, *1*(1), 17–26. doi:10.3763/ghgmm.2010.0007

van der Leun, J. C., Tang, X., & Tevini, M. (1998). *Environmental effects of ozone depletion: 1998 assessment*.

Wang, W., Yung, Y., Lacis, A., Mo, T., & Hansen, J. (1976). Greenhouse effects due to man-made perturbations of trace gases. *Science*, *194*(4266), 685–690.

Part III

The impact of agricultural practises on fresh water quality

1 Eutrophication

Land-use change associated with agricultural practises has affected lakes and rivers long before the appearance of industrial agriculture. In the extreme case of Denmark's lakes, Bradshaw, Nielsen, and Anderson (2006) present evidence for moderate eutrophication from phosphorus throughout the Bronze and Iron Age, as well as a marked increase of nutrient concentrations during the Medieval period. Today, agriculture is the primary contributor to water quality problems in OECD[1] countries, with the majority of pollutants originating from excess nutrients in run-off, soil erosion, and the application of pesticides (OECD, 2003).

Excess nutrients, such as nitrogen and phosphorus, enter surface waters as well as aquifers through run-off from managed agricultural land where manure and inorganic fertilisers were applied (see figure 4) and through the release of organic wastes from fish farms (Carpenter et al., 1998; Talbot & Hole, 1994). Elevated concentrations of nitrates in drinking water can be toxic to livestock and humans (Carpenter et al., 1998). More importantly, though, excessive nutrient inputs are responsible for eutrophication (Carpenter et al., 1998). This leads to explosive growth of algae and aquatic weeds, whose productivity is normally limited by the relatively low concentrations of nutrients in unpolluted rivers and lakes. Algal mats and aquatic weeds block sunlight from entering surface waters and cause loss of habitat for aquatic organisms (Carpenter et al., 1998). The decomposition of dead algae and weeds creates hypoxic or even anoxic water conditions that have been associated with massive fish kill events (Paerl, 2008). In addition to these impacts and their effects on taste and odour, a number of species of cyanobacteria produce toxins that can cause acute poisonings to animals and humans (Paerl, Fulton, Moisander, & Dyble, 2001; Caramichael, 2008).

2 Other sources of pollution

Livestock wastes from animal farms and pastoral agriculture have also been found to contaminate rivers and lakes with faecal bacteria. As Davies-Colley, Nagels, Smith, Young, and Phillips (2004) note, a dairy cow herd crossing a stream causes a very high level of faecal contamination and reduces water clarity. Likewise, failing on-site waste water treatment systems have repeatedly caused public health problems by releasing pathogens into groundwater

---

[1] Organisation for Economic Co-operation and Development

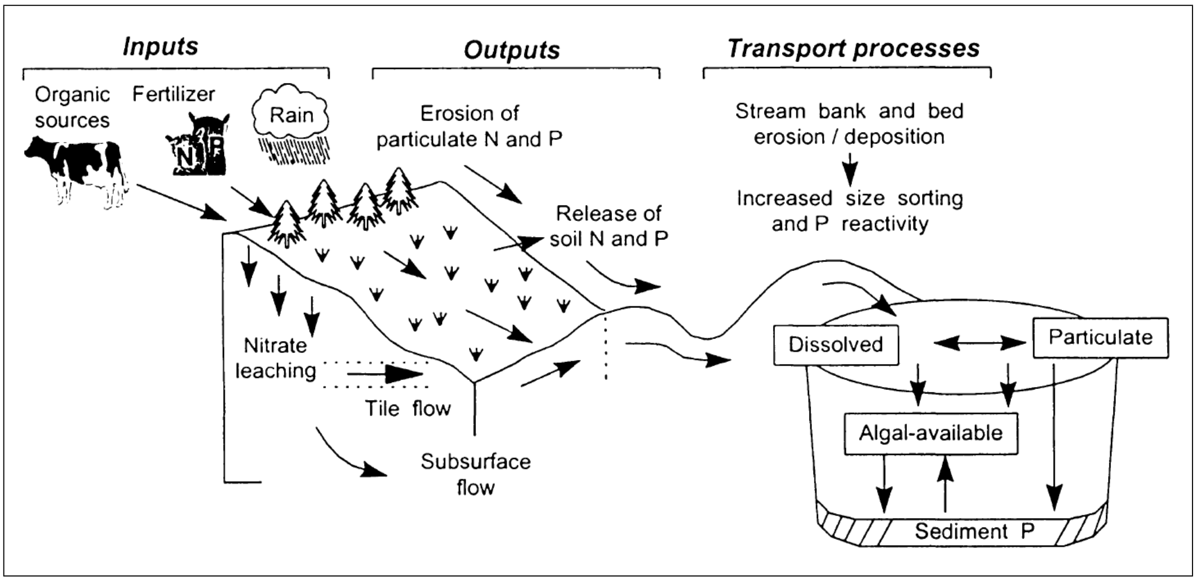

Figure 4: Anthropogenic sources of excess nutrients and their transport from agricultural land to freshwater. Reproduced from Carpenter et al. (1998).

(Gerba & Smith, 2004).

Other pollutants of both groundwater and surface waters include pesticides and herbicides. While they may not pose a direct threat to human health, these contaminants affect phytoplankton and zooplankton (Hanazato, 2000; DeLorenzo, Scott, & Ross, 2001) and can reach harmful concentrations after biological magnification through the aquatic food web (Cheung, Leung, Kong, & Wong, 2007).

Many of the above problems are aggravated by the removal of vegetation for agricultural land-use. With severely reduced vegetation the quantity of run-off water that washes pollutants out of the soil and into nearby surface waters is increased (Mohammad & Adam, 2010). At the same time topsoil is more vulnerable to erosion. As a consequence, rivers and streams suffer from increased sediment loads with negative effects on biodiversity, leading to reduced clarity and a shift in plant communities (Detenbeck, Galatowitsch, Atkinson, & Ball, 1999).

3 Making farming practises more sustainable

While the global human population grows it becomes increasingly important to reduce the impacts of agriculture on freshwater resources. As with other pollution problems, prevention is the easiest and most efficient method to address human impacts on the environment. The root causes of eutrophication are injudicious use of fertilisers and high-density animal farming (Carpenter et al., 1998; Office of the Auditor-General, 2011). Roberts (2007) summarises fertiliser best management practises as matching the fertiliser source, rate, time, and place of application to crop needs in order to find the “sweet spot” in the relation between yield response and nutrient use efficiency. According to the results of a 21-year study comparing conventional farming systems with organic farms in Central Europe, the yields on organic farms were 20% lower although fertiliser inputs were cut in half and pesticide inputs were almost completely eliminated (Maeder et al., 2002). In organic farming experiments in Germany, crop rotation and the planting of catch crops significantly reduced nitrogen leaching (Kayser, Mueller, & Isselstein, 2010).

Excluding cattle from channels by bridging streams intersected by farm raceways and with fences would reduce freshwater contamination with faecal bacteria and minimise direct nutrient inputs from cattle manure (Davies-Colley et al., 2004). The New Zealand *Dairying and Clean Streams Accord*, signed in 2003 by members of the dairy sector, includes this as one of the targets for 2012 (Office of the Auditor-General, 2011). To reduce the impact of aquaculture, Lin and Yang (2003) successfully experimented with optimising feeding regimes and reusing effluents from aquaculture ponds as fertiliser for rice crops and lotus.

A second approach is to filter run-off before it enters surface waters. This can be done by restoring wetlands and riparian vegetation or by planting vegetated filter strips that absorb excess nutrients and remove faecal coliform before they reach waterways (Lim, Edwards, Workman, Larson, & Dunn, 1998; Lee, Isenhart, & Schultz, 2003). This measure has also been effective in reducing soil erosion (Lee et al., 2003). According to Carpenter et al. (1998), wetland restoration may be "the most cost-effective method of decreasing nitrogen pollution."

4 References

Bradshaw, E. G., Nielsen, A. B., & Anderson, N. J. (2006). Using diatoms to assess the impacts of prehistoric, pre-industrial and modern land-use on Danish lakes. *Regional Environmental Change*, *6*(1), 17–24. doi:10.1007/s10113-005-0007-4

Caramichael, W. (2008). A world overview—one-hundred-twenty-seven years of research on toxic cyanobacteria—where do we go from here? In H. K. Hudnell (Ed.), *Cyanobacterial harmful algal blooms: state of the science and research needs* (Chap. 4). Springer Press.

Carpenter, S., Caraco, N., Correll, D., Howarth, R., Sharpley, A., & Smith, V. (1998). Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecological Applications*, *8*(3), 559–568.

Cheung, K., Leung, H., Kong, K., & Wong, M. (2007). Residual levels of DDTs and PAHs in freshwater and marine fish from Hong Kong markets and their health risk assessment. *Chemosphere*, *66*(3), 460–468. doi:10.1016/j.chemosphere.2006.06.008

Davies-Colley, R. J., Nagels, J. W., Smith, R. A., Young, R. G., & Phillips, C. J. (2004). Water quality impact of a dairy cow herd crossing a stream. *New Zealand Journal of Marine and Freshwater Research*, *38*, 569–576. doi:0028-8330/04/3804-0569

DeLorenzo, M. E., Scott, G. I., & Ross, P. E. (2001). Toxicity of pesticides to aquatic microorganisms: a review. *Environmental Toxicology and Chemistry*, *20*(1), 84–98. doi:10.1002/etc.5620200108

Detenbeck, N., Galatowitsch, S., Atkinson, J., & Ball, H. (1999). Evaluating perturbations and developing restoration strategies for inland wetlands in the great lakes basin. *Wetlands*, *19*(4), 789–820. doi:10.1007/BF03161785

Gerba, C. P., & Smith, J. E. (2004). Sources of pathogenic microorganisms and their fate during land application of wastes. *Journal of Environmental Quality*, *34*(1), 42–48. doi:10.2134/jeq2005.0042

Hanazato, T. (2000). Pesticide effects on freshwater zooplankton: an ecological perspective. *Environmental Pollution*, *112*(1), 1–10. doi:10.1016/S0269-7491(00)00110-X

Kayser, M., Mueller, J., & Isselstein, J. (2010). Nitrogen management in organic farming: comparison of crop rotation residual effects on yields, N leaching and soil conditions. *Nutrient Cycling in Agroecosystems*, *87*, 21–31. doi:10.1007/s10705-009-9309-0

Lee, K., Isenhart, T., & Schultz, R. (2003). Sediment and nutrient removal in an established multi-species riparian buffer. *Journal of Soil and Water Conservation*, *58*(1), 1–8.

Lim, T., Edwards, D., Workman, S., Larson, B., & Dunn, L. (1998). Vegetated filter strip removal of cattle manure constituents in runoff. *Transactions of the American Society of Agricultural Engineers*, *41*(5), 1375–1381.

Lin, C. K., & Yang, Y. (2003). Minimizing environmental impacts of freshwater aquaculture and reuse of pond effluents and mud. *Aquaculture*, *226*(1–4), 57–68. doi:10.1016/S0044-8486(03)00467-8

Maeder, P., Fliessbach, A., Dubois, D., Gunst, L., Fried, P., & Niggli, U. (2002). Soil fertility and biodiversity in organic farming. *Science*, *296*(5573), 1694–1697. doi:10.1126/science.1071148

Mohammad, A., & Adam, M. (2010). The impact of vegetative cover type on runoff and soil erosion under different land uses. *CATENA*, *81*(2), 97–103. doi:10.1016/j.catena.2010.01.008

OECD. (2003). *Improving water management: recent OECD experience*. OECD Publishing. Retrieved from http://books.google.com/books?id=gX3T7vNdCEEC

Office of the Auditor-General. (2011). *Managing freshwater quality: challenges for regional councils*.

Paerl, H. (2008). Nutrient and other environmental controls of harmful cyanobacterial blooms along the freshwater-marine continuum. In H. K. Hudnell (Ed.), *Cyanobacterial harmful algal blooms: state of the science and research needs* (Chap. 10). Springer Press.

Paerl, H., Fulton, R., Moisander, P., & Dyble, J. (2001). Harmful freshwater algal blooms, with an emphasis on cyanobacteria. *The Scientific World*, *1*, 76–113. doi:10.1100/tsw.2001.16

Roberts, T. (2007). Right product, right rate, right time and right place … the foundation of best management practices for fertilizer, In *Fertilizer best management practices: general principles, strategies for their adoption and voluntary initiatives vs regulations*. International Fertilizer Industry Association.

Talbot, C., & Hole, R. (1994). Fish diets and the control of eutrophication resulting from aquaculture. *Journal of Applied Ichthyology*, *10*(4), 258–270. doi:10.1111/j.1439-0426.1994.tb00165.x