Chemical Reactions Caused by Pollution - an example integrated STEM initiative for use in an international school secondary setting

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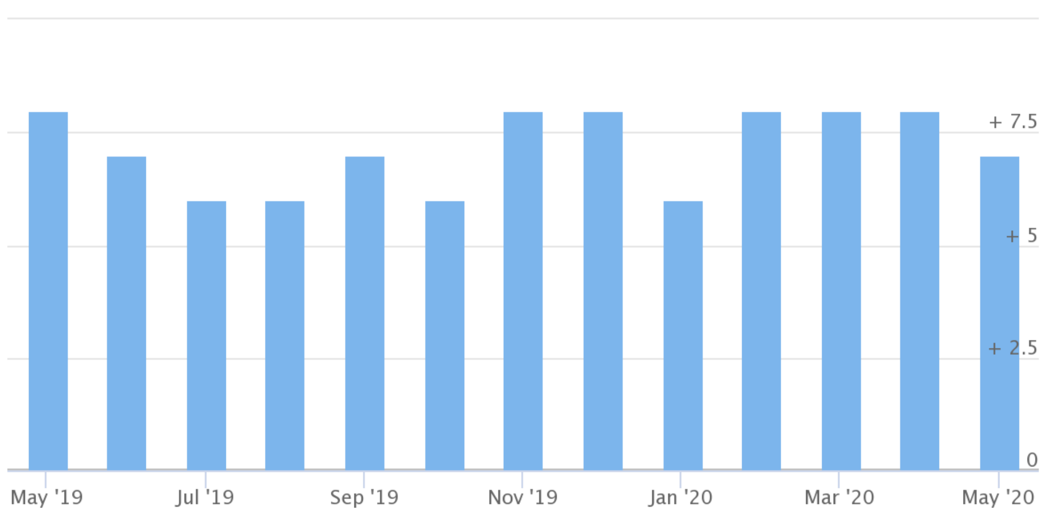
As an Australian growing up in the 1980s, public awareness of the causal link between sun exposure and skin cancer was widespread (Cancer Council Australia, 2019). Despite the success of the Montreal Protocol, an international agreement on stopping the production of ozone depleting substances (Department of the Environment and Energy, 2018), UV levels in Australia and the associated risk of skin cancer continue to rise (Lemus-Deschamps and Makin, 2012). The issue of ozone depletion seems to have been overshadowed by other, more immediately obvious pollution issues in the international schools that I've worked at, with the topic usually relegated to a historical box in the science textbook. However, the locations these schools are in often have high to very high UV index levels for large portions of the year, as exemplified by Figure 1 below.

Figure 1

Average monthly UV index levels in Ho Chi Minh City from May 2019 to May 2020



Note. A UV index level of 8 is considered "very high" (US Environmental Protection Agency, 2019). Adapted from Ho Chi Minh City Monthly Climate Averages (n.d.).

Moreover, I was unable to find any published policies relating to UV index levels or UV protection for students on either our website's safeguarding section (International School Ho Chi Minh City, n.d.) or our parent company Cognita's wellbeing resources page (Cognita Schools, 2020). A conversation with a physical education teacher colleague revealed that we have an internal policy (not publicly available on the web) regarding restriction of outdoor activity due to high heat indices, but not high UV indices. These incongruencies, combined with my own experiences of being caught unprepared and needing to stand outside in scorching sun (see Figure 2 below) for possibly unsafe periods of time, were the inspiration for the integrated STEM initiative described in this paper. After briefly explaining the chemistry of ozone depletion and its connection to UV index levels, I will describe some possible learning experiences in which data collected by secondary science students can be used by those same students to advocate for the creation of much needed sun safety policies in international schools in the region, and possibly the construction of a roof.

Figure 2

The rooftop soccer field at International School Ho Chi Minh City in full sunlight

Note. From Saigoneer.com (2018).

Defining the Problem

In an ozone layer free of ozone depleting compounds, radiation energy in the form of UV radiation is continuously converted into heat energy via the following process (Bylikin, Horner, Murphy and Tarcy, 2014):

$$O_3(g) \rightarrow O_2(g) + O\cdot(g) \tag{1}$$

$$O_2(g) + O\cdot(g) \rightarrow O_3(g) + \text{heat.} \tag{2}$$

Equation 1 requires UV radiation as the energy input, in order to break the weaker single bond in the ozone (O_3) molecule and split it into a stable oxygen (O_2) molecule and a single oxygen free radical (as represented by the dot beside the O). These free radicals then combine with other nearby oxygen molecules, thus converting UV radiation into heat (Bylikin et al., 2014). However, when chlorofluorocarbons (CFCs) such as Freon (CF_2Cl_2) are present in the ozone layer, the UV radiation also breaks the Cl_2 bond as shown in Equation 3 (Bylikin et al., 2014):

$$CF_2Cl_2(g) \rightarrow CF_2Cl\cdot(g) + Cl\cdot(g) \tag{3}$$

The Chlorine (Cl) free radicals then combine with the original ozone and the oxygen free radicals produced in the process described above (see Equation 1) in a series of steps that effectively converts the inputs ozone and UV radiation into oxygen (O_2), rather than heat (Bylikin, Horner, Murphy and Tarcy, 2014).

The net result of the above processes (in an ozone layer with CFCs introduced into it) is a reduction in the total amount of ozone, which results in less UV radiation being converted into heat by the process described in Equations 1 and 2, and thus more UV radiation reaching the Earth's surface. This, in turn, causes the average UV index to rise, since it is a measure of UV intensity (power per unit area) incident on a particular point on the Earth's surface (Australian Government Bureau of Meteorology, 2020). Ozone depletion currently occurs everywhere in the stratosphere except near the equator, but it increases with distance from the equator and is most pronounced at the south pole (Hegglin, Fahey, McFarland, Montzka, and Nash, 2015).

Evaluation of Policies

The Montreal Protocol has been amended six times in order to update the list of substances included (Department of the Environment and Energy, 2018), such as those discovered by Laube et al. in their 2014 study. The latest Kigali Amendment from 2016 has been implemented to varying degrees in the policies and regulations of the countries that have ratified it, and as of 8th June 2020, only 95 of 197 nations have even ratified the amendment to begin with (United Nations environmental programme ozone secretariat, 2020). For example, Australia has already reviewed and updated their relevant legislation to meet new hydrofluorocarbon (HFC) phase-down obligations stipulated by the amendment that began in 2019 (Department of Agriculture, Water and the Environment, n.d.), whereas Vietnam's ratification status is listed as “pending”, and they do not yet have a HFC licensing system in place (United Nations environmental programme ozone secretariat, n.d.).

In the area of policies and procedures for reducing sun exposure of school-aged children, Australian organisations such as SunSmart support schools and workplaces in developing sun protection policies (SunSmart, 2020), an example of which can be found on the Victoria State Government Education and Training website (Department of Education and Training Victoria, 2020). In contrast, I was unable to find any equivalent policies in Vietnam (although these may exist only in Vietnamese language versions). That said, there does seem to be some awareness of the potential for extreme UV levels in Vietnam, as evidenced by recent articles in some English language online newspapers (Quy, 2019; Viet Nam News, 2019). The lack of up-to-date regulations on HFC control, together with the apparent lack of sun protection policies for school students in Vietnam, would seem appropriate motivators for an advocacy type service learning project based around the science of ozone depletion and skin cancer.

Designing the Initiative

The inspiration for the initiative came from an article from one of the module readings by Razzouk, Dyehouse, Santone and Carr (2014). They described a model-eliciting activity (MEA) in which students were tasked with making recommendations about which plants to use for bioremediation of a contaminated site based on the data given. In writing their reports, students synthesised knowledge and skills from biology, earth science and mathematics, and had to make engineering design-like trade-offs in choosing their final solution. Based on this example, I imagined a similar approach using chemistry (ozone depletion), skin cancer (biology) and statistics (data presentation and correlation).

In searching for a demonstration that would share the potential consequences of ozone depletion, I consulted the secondary school resources section of the SunSmart website, through which I discovered the smartphone app “seeUV”, an augmented reality app that allows students to visualise UV intensity in their location using UV index and temperature data, and also predict what students’ faces will look like in the future after chronic sun exposure (SunSmart, 2020). Students could also watch time lapse videos of the hole in the ozone layer over their lifetimes, such as those available at NASA Ozone Watch (NASA Goddard Space Flight Center, 2018). Teachers with more time could have students perform a modified version of the sunscreen experiment available at TeachEngineering (Kay, King and Yowell, 2018), perhaps omitting the engineering design aspects of the activity and focusing on the difference in results between protected and unprotected surfaces.

The MEA prompt could be adapted from Exploring the Environment’s “UV Menace” Problem Based Learning (PBL) task (Wheeling Jesuit University, 2005), by updating it to reflect the current Montreal Protocol situation and adding specific expectations regarding advocating for policy creation in local community organisations. Possible products could include letters to heads of schools and education departments of the school’s host city and/or country. Supporting UV index data could be collected experimentally on site, for example using Randall Frost’s UV radiation data collection procedures (2012) available on Education.com. Skin cancer data could be collected by searching online databases (if the school has suitable subscriptions) or directing students to websites such as the World Health Organisation and the US Centers for Disease Control and Prevention.

Conclusion

While ozone depletion is arguably a relatively minor issue these days when compared to global warming, it is still a useful lens through which to engage students in learning about skin cancer risks associated with UV radiation. In this paper, I have outlined a rationale for teaching these topics as an integrated STEM MEA (with additional hands-on experiments if time permits) based on an apparent lack of sun protection policies in international schools in developing countries. It is envisioned that international science education practitioners can adapt these activities to bring about policy change and/or the construction of sun shades in their own schools. In an International Baccalaureate school setting, the initiative could be implemented using either the MYP Community Project or Service as Action (International Baccalaureate Organisation, n.d.) as a vehicle.

References

Australian Government Bureau of Meteorology. (2020). About the UV Index. Retrieved June 20, 2020, from http://www.bom.gov.au/uv/about_uv_index.shtml

Bylikin, S., Horner, G., Murphy, B., & Tarcy, D. (2014). *Oxford IB Diploma Programme: Chemistry Course Companion*. Oxford, United Kingdom: Oxford University Press.

Cancer Council Australia (2019, August 9). Slip Slop Slap Seek Slide. Retrieved June 20, 2020, from https://www.cancer.org.au/preventing-cancer/sun-protection/campaigns-and-events/slip-slop-slap-seek-slide.html

Cognita Schools. (2020, June 03). Resources for Families. Retrieved June 20, 2020, from https://www.cognita.com/cognita-be-well/resources-for-families/

Department of Agriculture, Water and the Environment. (n.d.). Review of the Ozone Protection and Synthetic Greenhouse Gas Management Program. Retrieved June 20, 2020, from https://www.environment.gov.au/protection/ozone/opsgg-program/opsggm-review

Department of Education and Training Victoria. (2020, June 12). Sun and UV Protection. Retrieved June 20, 2020, from https://www.education.vic.gov.au/school/principals/spag/health/Pages/sun.aspx

Department of the Environment and Energy. (2018). Montreal Protocol. Retrieved June 20, 2020, from https://www.environment.gov.au/protection/ozone/publications/montreal-protocol-factsheet

Frost, R. (2012, February 04). Change in UV Radiation: Science project. Retrieved June 20, 2020, from https://www.education.com/science-fair/article/uv-radiation-over-time/

Hegglin, M. I., Fahey, D. W., McFarland, M., Montzka, S. A., & Nash, E. R. (2015). *Twenty Questions and Answers About the Ozone Layer: 2014 Update, Scientific Assessment of*

Ozone Depletion: 2014 (Report No. 55). Retrieved from World Meteorological Organization website: https://www.esrl.noaa.gov/csl/assessments/ozone/2014/twentyquestions2014update.pdf

Ho Chi Minh City Monthly Climate Averages. (n.d.). Retrieved June 20, 2020, from https://www.worldweatheronline.com/ho-chi-minh-city-weather-averages/vn.aspx

International Baccalaureate Organisation. (n.d.). MYP curriculum. Retrieved June 20, 2020, from https://www.ibo.org/programmes/middle-years-programme/curriculum/

International School Ho Chi Minh City. (n.d.). International Standard Safeguarding Policies. Retrieved June 20, 2020, from https://www.ishcmc.com/life-at-ishcmc/safeguarding

Kay, B., King, K., & Yowell, J. (2018, February 09). UV Radiation: Sunscreen SPF Experiment - Activity. Retrieved June 20, 2020, from https://www.teachengineering.org/activities/view/cub_sun_lesson01_activity1

Laube, J. C., Newland, M. J., Hogan, C., Brenninkmeijer, C. A., Fraser, P. J., Martinerie, P., Oram, D. E., Reeves, C. E., Röckmann, T., & Schwander, J. (2014). Newly detected ozone-depleting substances in the atmosphere. *NATURE GEOSCIENCE*, *4*, 266.

Lemus-Deschamps, L., & Makin, J. K. (2012). Fifty years of changes in UV Index and implications for skin cancer in Australia. *International Journal of Biometeorology*, *56*(4), 727–735. https://doi.org/10.1007/s00484-011-0474-x

NASA Goddard Space Flight Center. (2018). NASA Ozone Watch: Multimedia. Retrieved June 20, 2020, from https://ozonewatch.gsfc.nasa.gov/multimedia/index.html

Quy, N. (2019, March 27). Saigon sun poses skin cancer risks - VnExpress International. Retrieved June 20, 2020, from https://e.vnexpress.net/news/news/saigon-sun-poses-skin-cancer-risks-3900209.html

Razzouk, R., Dyehouse, M., Santone, A., & Carr, R. (2014). Plants v. Pollutants: bringing engineering design practices and real-world context to the science classroom. *The Science Teacher*, *9*, 43.

Saigoneer. (2018, December 20). ISHCMC's Innovative New Campus Fosters Bold, Holistic Curriculums. Retrieved June 20, 2020, from https://saigoneer.com/explore/sponsored-listings/243-explore-1/15055-ishcmc%E2%80%99s-innovative-new-campus-fosters-bold%2C-holistic-curriculums

SunSmart. (2020). Schools & early childhood. Retrieved June 20, 2020, from https://www.sunsmart.com.au/communities/early-childhood-schools

SunSmart. (2020). SeeUV: An augmented reality app. Retrieved June 20, 2020, from https://www.sunsmart.com.au/tools/interactive-tools/free-sunsmart-app-campaign

United Nations environment programme ozone secretariat. (2020, June 8). All ratifications. Retrieved June 20, 2020, from https://ozone.unep.org/all-ratifications

United Nations environmental programme ozone secretariat. (n.d.). Status of HFC licensing systems. Retrieved June 20, 2020, from https://ozone.unep.org/additional-reported-information/licensing-systems

US Environmental Protection Agency. (2019, May 21). UV Index Scale. Retrieved June 20, 2020, from https://www.epa.gov/sunsafety/uv-index-scale-0

Viet Nam News. (2019, March 28). UV radiation index reaches high-risk level in HCM City. Retrieved June 20, 2020, from https://vietnamnews.vn/society/507899/uv-radiation-index-reaches-high-risk-level-in-hcm-city.html

Wheeling Jesuit University. (2005). UV Menace. Retrieved June 20, 2020, from http://www.cotf.edu/ete/modules/ozone/ozsituation.html