The Chain Reaction

Humanitarian Solutions Worldwide

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CHEMISTS WITHOUT BORDERS

The solution to global warming is hidden in the oceans

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Our planet is heating up and the oceans are getting warmer every year. The National Oceanic and Atmospheric Administration (NOAA) has estimated that the global annual temperature increased at a rate of 0.13 degrees Fahrenheit per decade during the period between 1880 and 1980. However, after 1981 the rate of temperature increase more than doubled to 0.32-degree Fahrenheit per decade. This global warming impacts both the land and oceans.

Global warming is caused by the build-up of greenhouse gases such as water vapor (clouds), carbon dioxide (CO_2), methane (CH_4), ozone (O_3) and nitrous oxide (N_2O) in the atmosphere. These gases come from the combustion of fossil fuels like coal and oil. The drivers for the rise in global temperature may be debatable but the role of human activity in global warming is supported by a significant body of scientific research. Carbon dioxide levels in the atmosphere remained stable for millions of years at 208 parts per million until the beginning of the Industrial Revolution in 1760. Then carbon dioxide levels in the atmosphere almost doubled from 208 ppm in 1760 to 407 ppm in 2018. The rate of change in the carbon dioxide corresponded with the increased use of coal and oil as energy sources. A large number of coal-based power plants were built during the industrial revolution period and fossil fuel usage skyrocketed with the automobile revolution. Both coal and oil combustion contributed enormous amounts of carbon dioxide to the environment: It is estimated that human activities released more than 2,000 billion tons of carbon dioxide into the atmosphere. According to the Environmental Protection Agency (EPA), in 2016 alone, fossil fuel combustion in the USA released about 7 billion tons of carbon dioxide in the atmosphere.

How greenhouse gases cause global warming

Earth's atmosphere encapsulates the planet and protects the earth from harmful rays and particles coming from the space. However, visible light from the sun, and ultraviolet (UV) and infrared (IR) rays easily pass

What's Inside this Issue

Our Mission

Chemists Without Borders solves humanitarian problems by mobilizing the resources and expertise of the global chemistry community and its networks.

Our Vision

A global support network of volunteers providing mentoring, information and advice to ensure every person, everywhere, has affordable, consistent and persistent access to:

- Essential medicines and vaccines
- Sufficient safe water
- A sustainable energy supply
- Education in green chemistry and business which people can apply in their daily lives and teach to others
- Safe processes in work environments where chemical hazards exist
- Emergency support, including essential supplies and technology

Chemists Without Borders is a registered 501(c)(3) with the Internal Revenue Service. EIN: 14-1984379 through the atmosphere. About 30% of the UV light is reflected back to space by clouds, snow, and other reflective objects on the earth. The remaining 70% of UV rays reach the earth. These rays are absorbed by the oceans, earth's surface, plants, and other objects and then slowly released back into space in the form of infrared (IR) rays. However, the atmosphere acts like a gatekeeper for UV rays and IR radiation in both directions -- coming in and going out – so some of this heat is trapped. This maintains an equilibrium to keep earth's temperature stable. Because of this equilibrium, we have life-supporting temperature on the earth. With global warming as carbon dioxide and other greenhouse gases accumulate in the atmosphere, they more readily absorb infrared (IR) radiation that have bounced off the earth's surface and prevent it from escaping back to space, thereby heating up the planet.

Impact of oceans on global warming

The consequences of global warming are dramatic and wide ranging. Polar ice is melting and glaciers are receding worldwide at a rapid pace, and thus ocean levels are rising. Summers are longer and drier while winters are warmer and wetter. Many islands countries are in danger of being submerged and lost permanently under water. We have more severe droughts in already arid parts of the world, leading to severe drinking water scarcity and more violent tropical storms and hurricanes in coastal areas.

One less well understood component of global warming are Earth's ocean ecosystems. Oceans are the lungs of the Earth, as they absorb about 25% (12 billion tons) of atmospheric carbon dioxide per year and produce 70% of our atmospheric oxygen. Oceans produce oxygen through marine plants, such as phytoplankton, kelp and algal planktons or phytoplanktons. These microscopic plants and plankton use carbon dioxide to grow, generate biomass, and produce oxygen as a byproduct of photosyn¬thesis. Without oceans and plankton, there would not be enough oxygen on the earth to support terrestrial life. Healthy oceans are vital for the survival of humanity.

Unfortunately, our oceans are getting sicker and losing one of their most vital resources: plankton. Over the past 60 years, oceans have lost about 50% of their plankton population and continue to lose them at the rate of about 1% per year. When the phytoplankton population declines, there is reduced demand for CO_2 for photosynthesis which results in significantly reduced CO_2 absorption in the ocean and less oxygen produced by oceans. Reduced uptake of CO_2 in the oceans will lead in increased CO_2 levels in terrestrial systems and the atmosphere, which accelerates the process of global warming. Global warming then makes the oceans less hospitable for plankton, creating a positive feedback loop.

Oceanic environment is changing not only because of warmer temperatures but also because they have become a dumping ground for waste: from large debris to microplastic particles to persistent toxic organic chemicals. With increases in pollution levels, there are clear signs of increased stress on oceanic ecosystem. Recent research has indicated that the pollutants such as micro-plastics and persistent organic pollutants (POPs) like polychlorinated biphenyls (PCBs), dioxins, and UV filters chemicals present in sunscreens are primarily responsible for the decline in the plankton population. Research data indicate that the combination of microplastics and POPs is the root cause of plummeting plankton populations in the ocean. POPs especially those commonly found in sunscreen and cosmetics, attach to microplastics and travel with the ocean currents. These pollutant-loaded microplastics act as a toxic pill that kills plankton and accumulate throughout the food chain.

Fixing the problem

Controlling the combustion of fossil fuel alone will not be sufficient to bring down CO_2 levels enough to reverse global warming. We need help from the oceans and plankton to actually remove the CO_2 from the atmosphere. To meaningfully address the global warming problem, we need to focus on ocean health by preventing plastic and plankton-killing chemical pollutants in sunscreens from reaching the oceans. We need to reformulate sunscreen with environmentally friendly ingredients. We need to improve wastewater treatment systems to remove microplastics and other chemical pollutants from reaching rivers and ultimately our oceans.

By eliminating chemical pollution and microplastics from our rivers and ocean, we can revive the plankton population in the ocean. Increased plankton population will remove more CO_2 from the atmosphere, which in turn can slow down or perhaps even reverse global warming in time, which can allow the oceans to thrive again. Elimination of plankton-killing chemicals from the waterways will allow the planktons to regain its lost population. If we can double the plankton population, ocean can absorb additional 12 billion tons of carbon dioxide annually from the atmosphere enough to tilt the scale in favor of reversing global warming. And as the oceans recover, we may be able to actually reverse global warming. The key to reverse global warming is plankton in the oceans.

If you are interested in learning more about this global challenge or if you would like to be part of the project in the future, please feel free to contact Dr. Achal Garg at achalkgarg@gmail.com.

Improving the Economics of the Biochar Proposition – A Sudoku Problem?

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Methods of "Carbon Capture" are of great importance as our global society veers towards atmospheric carbon concentrations that are bringing us closer to conditions of run-away climate change.

The use of biochar (charcoal made from clean organic matter - preferably wood) as an agricultural soil amendment has significant potential to capture carbon on a large scale. Biochar amended into soils is resilient to decomposition and, turns soils into a "carbon sink". Since this carbon was drawn out of the atmosphere through natural photosynthesis, the biochar proposition provides a potential pathway to maintaining or reducing global atmospheric CO_2 concentrations.

However, the equipment and pyrolysis technology used to make biochar, at a large scale is expensive and current manufacturing costs are in the order of \$800 to \$1000 per tonne of biochar. The carbon content of good quality biochar is in the order of 80%. The material handling costs to harvest the wood and apply the biochar to the soil uses fossil carbons which reduces the effective amount of carbon stored. Since pure carbon has a ratio of 3.67 tonnes of CO_2 per tonne of pure carbon, we can determine how much CO_2 each tonne of biochar represents. Given our example of 80% carbon and 80% efficiency of our conversion technology, this reduces our CO_2 avoidance to the atmosphere to about 2.3 tonnes CO_2 per tonne of biochar amended into soils. It is therefore important for us to find ways to make biochar production and its soil application more efficient.

One way to accomplish this is to fully utilize the synthetic gases and the condensable liquids that are produced from the pyrolysis of wood (let's finish the Sudoku problem). About 2/3 of the feedstock mass is lost in the form of CH_4, CO, H_2, water vapour, and a series of long chain hydrocarbons associated with the feedstock. An inefficient biochar production process loses these "carbon containing" molecules when they are simply burned. Fortunately, we can capture and use these synthetic gases and liquids. The simplest way is to use the syngas as heat to maintain the pyrolytic process and to dry the incoming feedstock - most biochar production plants take advantage of this. However, a second conservation approach is to condense the longer chain hydrocarbons into synthetic tars and oils and convert them into a renewable "bio-crude".

There needs to be further advances to upgrade wood derived pyrolytic bio-crude into clean biofuels that are drop-in ready to replace fossil derived fuels. We need to find low cost ways of upgrading wood based bio-crude.

One pathway is a bio-crude upgrading process called hydrodeoxygenation (HDO) (let's be sure to use a long history of HDO experience gained by the petroleum industry) which removes oxygen from compounds in the bio-crude. The result is a bio-oil that more closely resembles diesel fuel and can be further refined for use in internal combustion engines. Finding efficient, low cost methods of accomplishing this, would significantly add to the "biochar proposition" by: 1) generating another revenue stream for the biochar production process, offsetting the high cost of biochar production and 2) offsetting the use of fossil carbon derived transportation fuels with renewable bio-fuels.

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Developing a Model for Sharing Safe Drinking Water

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Evaluating arsenic in drinking water in Bangladesh has been ongoing for decades – it's time to implement sustainable solutions

"The largest mass poisoning in history" – that's how arsenic contamination of drinking water in South East Asia is described. As many as 95 million people may be chronically exposed to unsafe levels of arsenic. The long-term effects of arsenic poisoning often take decades of exposure to show up and include cardiovascular disease and cancers of the skin, lung, and bladder.

In 2018, nearly two thirds of the 300 drinking water wells Chemists Without Borders tested for arsenic using a Hach EZ field test kit exceeded the Bangladesh standard of 50 parts per billion. The Bangladesh standard is five times higher than both the USEPA and WHO standards. Earlier this year, Chemists Without Borders re-tested 200 of the community wells using two test methods to evaluate the arsenic concentrations and to compare the results of the two test methods. The Hach field test method was used as well as a novel technique developed by Marya Lieberman's lab at the Chemistry Department at the University of Notre Dame (UND).

The UND method involves a typical 2-liter plastic bottle and cap. Water is collected in the bottle and the cap with a filter is secured. The bottle is then turned over, so that the water passes through the activated carbon filter in the cap. The filter, prepared by UND, absorbs arsenic that is dissolved in the water. The filters are then shipped to UND for analysis with X-ray fluorescence, which has been demonstrated to closely correlate with inductively coupled plasma optical emission spectroscopy analysis.

We discovered that the results of the Hach field test and the UND laboratory poorly correlated. Approximately 80 percent of the Hach results were higher than the lab results, with some results more than 3-fold higher. This led us to research the Hach field kit more closely. We found a study by the University of Michigan that tested eight arsenic field kits and compared the results to hydride generation atomic absorption spectroscopy analyses. They concluded that the Hach EZ test kit is neither accurate nor precise.

Collecting water samples from a private well in the community of Teriail.

Once we resolve the arsenic testing issues, we will identify wells with acceptable levels of arsenic (i.e., <50 ppb). We will then evaluate other chemical characteristics, as well as the hydrogeology of the aquifer where the well is screened to assess whether the well can support the estimated water demand for well sharing.

Chemists Without Borders intends to develop and introduce a Well Sharing Program (WSP), which will allow those whose wells are contaminated with arsenic to take water from a neighbor's safe well. Well sharing presents its own difficulties such as social, cultural, and economic considerations, which we hope to overcome in part through stakeholder outreach and education. With the development of logistics and policies that make the program acceptable to the community, we believe that the model may then be replicated across Bangladesh.

Chemists Without Borders and the water sampling volunteers

The WSP has the potential to be the most cost-effective, sustainable solution for drinking water in Bangladesh compared to other options such as installing treatment systems or drilling deep wells. For example, a water treatment system can cost more than $20,000 and require frequent operation and maintenance and specialized parts, which if not properly maintained make them susceptible to break down, which is often the case, and why many water projects fail after about one year.

If we demonstrate success of the WSP, the model may be implemented across Bangladesh, and to other countries that are experiencing similar problems. The solution isn't limited to arsenic – we can use this method to address other types of contaminants.

Chemists Without Borders is seeking technical and program management support to assist with the WSP. If you have experience with water quality and quantity evaluation and project management, please contact me at robert@environmentalstrategies.org.

The Formation and Importance of Soil Organic Matter in Ecosystem Health

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Carbon (C) is the fourth most abundant element in the universe and is the foundation of all life. All living tissues contain C in forms of organic compounds made of C rings or chains with other essential nutrients. The recycling of these tissues (e.g. plant litterfall, decomposition) is a fundamental process involved in global C cycling and the formation of soil organic matter. For thousands of years, humans have appreciated the fact that 'dark soils' are commonly productive soils and the dark color is often associated the amount of organic matter incorporated into the mineral soil. As world population increased, the demand for agricultural production increased resulting in increased land exploitation. Under intensive agricultural production even the most productive soils may gradually become less productive - a consequence driven in part by the degradation of soil organic matter quantity and/or quality. Land clearing for row crop agricultural production encouraged net mineralization of organic matter, soil erosion, increased acidity, (or accumulation of alkali in arid lands), leading to a decline in soil productivity over time.

Soil organic matter is a complex and dynamic component of the soil ecosystem and one of the key soil attributes that is directly influenced by management decisions. Soil organic matter primarily consists of residual compounds from the decomposition of plant, fauna, and microbial input, and it exerts a major influence on soil structure and function. For example, soil organic matter provides much of the cation exchange and water holding capacity of surface soils; it increases soil aggregate stability and reduces the potential for surface runoff and soil erosion; it also acts as the primary energy source and nutrient source for soil organisms thereby influencing soil microbial diversity and activity. It is also important to note that globally, soil organic matter contains about twice as much C as all terrestrial vegetation (yes, including trees!) and the atmosphere combined. Therefore, it is essential to understand how to effectively manage soil organic matter to ensure a healthy and productive ecosystem.

Soil organic matter slowly accumulates over time in natural ecosystems and the rate at which soil organic matter either increases or decreases depends on the balance between gains and losses of C. The C gains mainly are on-site plant residues (root and shoot production and turnover); applied organic materials (natural or anthropogenic). The C losses commonly come from soil respiration (mineralization or conversion of reduced C to CO_2), plant biomass removals, and/or processes that directly remove soil, such as erosion. Temperature and moisture constraints dictate decomposition rates, with anaerobic conditions associated with wetlands (commonly also in a depositional position in the landscape) resulting in exceptionally slow C loss rates and high C accumulation rates. Management practices need to maximize C gains while minimizing C losses in order to conserve or build soil organic matter. Healthy soil ecosystems contain a diversity of organic compounds and classes of compounds that make up fast, slow and passive pools of soil organic matter.

For agroecosystems, there are a multitude of practices that can help build soil organic matter including: 1) Seeking to maintain continuous vegetative cover; 2) returning all plant residues rather than harvesting straw or stover; 3) Applying composts, manures, and/or biochar to promote C gains; 4) Minimizing intensive tillage and synthetic fertilizer applications; 5) avoiding whole plant harvest and overgrazing to reduce C losses. For natural ecosystems such as forest or prairie, the rates of soil organic matter turnover are lower than that in croplands. In forests, the secondary metabolites in tree and understory litter can slow the decomposition of soil organic matter and the absence of tillage or intensive physical disturbance greatly reduces C losses to increased soil respiration. Large disturbance such as a forest fire may have the capacity to rapidly remove a significant amount of soil organic matter depending on the fire regime. As a legacy of fire and a passive form of C, charcoal or pyrogenic organic matter (Fig 1) can directly contribute to the passive component of the soil organic matter pool, although the low density may facilitate lateral transportation and a redistribution of C across a landscape. Nevertheless, careful management to promote soil organic matter accumulation is essential to improve soil health and productivity across ecosystems. Elimination of fire from forest or grassland ecosystems reduces the inputs of pyrogenic C. Rebuilding soil organic matter pools to pre-Anthropocene levels will best be accomplished by reducing soil disturbance, increasing biomass returns to soil and incorporating pyrogenic C into management systems.

Figure 1. Soil organic matter formation and the "short-cut" for charcoal or pyrogenic C as a passive form of soil carbon (DeLuca and Aplet. 2008. Frontiers in Ecology and the Environment 6, 18–24. http://dx.doi.org/10.1890/070070).

Below are some additional resources to learn about soil organic matter:

- Soil organic matter in agricultural ecosystem (Cornell University): http://franklin.cce.cornell.edu/resources/soil-organic-matter-fact-sheet
- Soil organic matter helps maintain a healthy forest ecosystem (Michigan State University): https://www.canr.msu.edu/news/organic_matter_in_soils_helps_maintain_a_healthy_forest_ecosystem
- Interpretation of soil organic matter testing result (Oregon State University): https://catalog.extension.oregonstate.edu/em9251
- Soil organic C reservoir, dynamic, and response to global change (1997 article): https://doi.org/10.1073/pnas.94.16.8284
- Persistence of soil organic matter as an ecosystem property (2011 article): https://doi.org/10.1038/nature10386
- Land use, management, and global change on soil organic matter dynamics (2011 article): https://doi.org/10.1007/s11104-010-0617-6
- A updated view on the components and persistence of soil organic matter (2015 article): https://doi.org/10.1038/nature16069

Inclusive Water and Sanitation - Leaving No One Behind

BY HEIDI DOAK
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UN Sustainable Development Goal 6 is to "ensure access to water and sanitation for all", but it takes more than clever chemistry to make sure everyone benefits.

Innovative science and engineering are at the heart of many novel water and sanitation solutions, particularly when infrastructure is limited. The January 2019 edition of The Chain Reaction (Newsletter 29), covered the Reinvented Toilet Challenge. (https://www.chemistswithoutborders.org/Newsletters/Newsletter%20029.pdf) Participating organizations had developed a number of new toilet systems that could work without large quantities of water or connection to sewer infrastructure. These systems employed varied methods – thermal, chemical, biological – to ensure safe, sustainable, decentralized disposal of waste.

Newsletter 32, June 2020, described the challenges of providing hand washing facilities in refugee camps. (www.chemistswithoutborders.org/Newsletters/Newsletter%20032.pdf) These systems cater to large numbers of people with limited water supplies, in sometimes harsh conditions and they need to be low cost and easy to maintain. But can everyone use these facilities? Are they accessible to each person they are designed for? Are they inclusive?

WaterAid has some detailed resources to help people working in water and sanitation answer these questions. In their toolkit: Understanding and addressing equality, non-discrimination and inclusion in water, sanitation and hygiene (WASH) work, they define the key concepts to understand inclusion. (https://washmatters.wateraid.org/publications/equality-non-discrimination-and-inclusion-toolkit) They explain that inclusion requires a shift in thinking from a "needs-based, individual approach" to a "rights-based, inclusive approach" to bring about systemic change.

WaterAid identifies four risk factors for potential exclusion that exist in all communities: gender, age, disability and health status. Within individual communities there can be additional factors that also lead to exclusion, for example economic situation and migration status.

One important aspect of inclusive WASH programmes is menstrual hygiene management. The team at the Duke University Center for Water, Sanitation, Hygiene and Infectious Disease (WaSH-AID) is working on technologies in this area. As well as developing wastewater treatment technology for the Reinvented Toilet Challenge, the team has designed the S.H.E. (Safe Hygiene for Everyone). (http://washaid.pratt.duke.edu/work/hygiene)

The S.H.E. gives women and girls a safe and discreet way to dispose of sanitary pads. It treats waste thermally, producing limited emissions. The current fuel source is LPG, but there are plans to test wood pellets and dried faeces as alternatives. As well as facilitating women's participation in work and school, solutions like the S.H.E. can deliver environmental benefits by providing improved waste disposal and treatment methods.
For more information on features to look for in inclusive WASH programmes, see this checklist, Inclusive WASH – What does it look like?, from WaterAid and WEDC, on the Essential Reading list on this page: https://wedc-knowledge.lboro.ac.uk/collections/equity-inclusion/.

To learn more about menstrual hygiene management and waste disposal, see this open access literature review, Menstrual Hygiene Management and Waste Disposal in Low and Middle Income Countries—A Review of the Literature (https://www.mdpi.com/1660-4601/15/11/2562).

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