The Chain Reaction

Humanitarian Solutions Worldwide

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CHEMISTS WITHOUT BORDERS

How a small group of people can do big things

BY PATRICE PERILLO
PATRICEMPERILLO@GMAIL.COM

October 3, 2017 was a typical foggy, grey morning in San Francisco when Joan Chang from Chemists Without Borders came to speak to our small Rotary Club, the Rotary Club of San Francisco West, about the arsenic poisoning problem that is wreaking havoc, causing disease and death for people living in the rural villages of Bangladesh. Prior to that morning, we had never heard of Chemists Without Borders and we knew nothing of the 20 million people in Bangladesh who were suffering the effects of arsenic poisoning. This problem was so bad it was deemed by the World Health Organization as the "largest mass poisoning of a population in history."

That day we learned about the 1 million shallow public wells and the 10 million private wells that many NGOs and the government of Bangladesh had dug in the 70's to prevent people from drinking dirty ground water. While these pumps solved one problem, they created another. These shallow wells often tap into earth that contains high levels of naturally occurring arsenic. Millions of people drinking this arsenic contaminated water are being poisoned. The results are a range of health problems from skin lesions and respiratory illness to cancer and early death.

What amazed me most that day was that the well-meaning groups that had dug the shallow wells to provide bacteria-free drinking water were not engaged in providing arsenic-free drinking water for the villagers. Why is this? One reason is that it usually takes years for the effects of arsenic poisoning to show up. The other reason is that replacing all these shallow wells would be extremely costly. When a problem seems so overwhelming and insurmountable, it is often human nature to turn away.

But, lest you think this story has a sad ending, that morning we learned that Chemists Without Borders has a solution! And this solution is simple, cost effective and doable. CWB estimates that if they can implement their solution and replicate it throughout Bangladesh, the arsenic

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

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poisoning problem can be eradicated within approximately 5 years!

"What would it take to implement this model," we wondered. CWB had already started to do some fund raising and had a project manager in Bangladesh organizing youth volunteers from the local high school who were learning how to test wells for dangerous levels of arsenic. They had even started to map an area near Chittagong to show where the contaminated wells were. They had also been working with the local Rotary Club nearby, the Rotary Club of Chittagong, whose members were very concerned about this problem and were contributing some funds.

What Joan Chang of Chemist Without Borders didn't know when she came to speak with our club was that the Rotary Club of San Francisco West's mission is to serve families and children to inspire peace. She also didn't know that our small Rotary club was interested in applying for a global grant from Rotary International. These global grants start at $30,000. The project Joan laid before us could not have been a better fit for our club. First, providing clean water and sanitation is one of the six areas of focus Rotary has chosen to invest its resources in. Second, our club had a desire to make a bigger impact and to serve families and children not just in our own community but across the globe.

Despite the cold, damp fog in the air that morning, a spark was ignited for a very exciting idea. That exciting idea, that small spark, grew into something much bigger than we could have imagined. It eventually became the Bangladesh Water Project Global Grant sponsored by the Rotary Club of San Francisco West!

Fast forward to July 2019. The Rotary Club of San Francisco West and The Rotary Club of Chittagong, Bangladesh, the local host club, along with CWB have been meeting via Skype weekly for over a year while a team of speakers from SF West has been making the rounds to other Rotary clubs to raise funds. To date, along with the RC of Chittagong, we've raised $40,000!

The latest report from Rotary International is that they are reviewing the Rotary Club of SF West's Global Grant proposal. This will not only ensure clean water by installing a deep water well and filtration system at Terial High School, but will repair the toilets and create an educational program for the students and their families on health and hygiene. Menstrual hygiene supplies will also be provided. Additionally, a water sharing program will be created to ensure that all members of the community have access to clean water for drinking and cooking. A sustainability plan will be put in place so the community can take ownership and responsibility to continue to provide clean water and sanitary conditions in the region.

Perhaps you've heard the saying "Timing is everything." Timing certainly was a factor in the creation of this Rotary Global Grant to partner with CWB to implement their solution for the arsenic poisoning problem in Bangladesh. However, I believe Margaret Mead's words are apropos here as well. Mead said "Never doubt that a small group of thoughtful, committed citizens can change the world; indeed, it's the only thing that ever has."

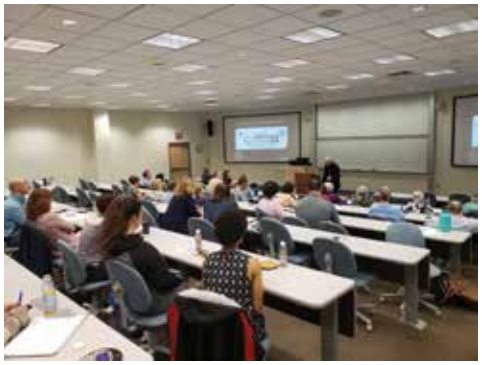
CWB and Rotary plan to continue their partnership to alleviate the arsenic problem in Bangladesh and improve sanitation and health. If you would like to be part of a small group of thoughtful, committed citizens helping provide clean water and a better life for the villagers in Bangladesh, please email me at patricemperillo@gmail.com.

Sierra Leone Chemistry Education Project

BY BAKAAR KANU
KANUABB@WSSU.EDU

Developing undergraduate research through service learning is a high impact practice that can greatly influence student engagement and success. A team of scientists has been working to develop inexpensive microchemistry kits to facilitate Chemistry Education in West Africa. Since 2015, several undergraduate STEM majors have engaged in research with the nonprofit organization, Chemists Without Borders, to enhance chemistry education

in Sierra Leone. The ultimate goal has been to provide chemistry laboratory kits to high school and first-year university students' in Sierra Leone by training teachers to use the kits in their classrooms. In addition to standard labs that will help students understand basic chemical concepts, most of the STEM experiments developed for this project will focus on the application of chemistry towards practical knowledge relevant to the lives of ordinary Sierra Leoneans.



Following our last update, the team is glad to report on the following project progress.

1. On February 21, 2019, Dr. Kanu participated on the monthly conference call with Chemists Without Borders and discussed progress on the Sierra Leone project.
2. The team has set-up a GoFundMe page at https://www.gofundme.com/sierra-leone-chemistry-project. Please donate to the project by following this link.
3. The team completed our fund raising presentation. Ms. Anna Hayes approached a local ACS Section in Arizona to present the project to them. It is our hope this presentation will be scheduled for fall 2019.

4. Chemists Without Borders was invited to speak at the 2019 Tripartite Symposium in Pittsburgh (May 18, 2019). The program was written up in the monthly Pittsburgh-section ACS Newsletter (pages 12-16, http://www.pittsburghacs.org/wp-content/uploads/2011/09/March-2019.pdf). Drs. Kanu, Gerber, and Grosse gave presentations on behalf of Chemist Without Borders. Dr. Kanu also presented about the project to the Local Central North Carolina-ACS section and the Winston-Salem State University faculty members.
5. Dr. Kanu has received funding from the Defense Intelligence Agency to implement the study abroad program in Sierra Leone. The project consortium comprises of four institutions namely University of North Carolina at Charlotte, Winston-Salem State University, Johnson C. Smith University, and South Carolina State University. The goal is to provide a STEM research center to support faculty-led research, and/or study abroad opportunities for students at each consortium member.

Biochar for Curious Minds

BY GLORIA FLORA
BIOCHAR@S-O-SOLUTIONS.ORG

Biochar is a highly porous, fine-grained charcoal, resulting from thermally converting woody biomass in a limited oxygen environment. It's made specifically for pro-biological use and carbon benefits versus energy. Biochar is a bio-mimetic addition to soil, following nature's pattern of soil building in grasslands and forests.

Thus biochar is simply charcoal made with the express purpose of boosting or protecting soil biology and sequestering carbon. Biochar can be made with any clean, relatively dry waste biomass, like woody yard debris, slash from forest thinning and agricultural waste that's too coarse for composting. Biochar can be made in high-tech ovens, double-barrel stoves, cone kilns, pits, in slash piles or even in a container in a woodstove.

Charcoal is about using densified carbon for energy or filtration; biochar is about saving the carbon to help protect and enhance biological functions, particularly in soil. Biochar can be used for filtration and remediation and still be called biochar if the actions focus on protecting life in terrestrial and aquatic ecosystems. Biochar has great porosity and surface area. A single cubic centimeter has 1000's of square meters of surface area, excellent for adsorbing water, nutrients, toxins and heavy metals. Adding biochar to soil tends to increase productivity and moisture retention along with many other benefits. Biochar can likewise play a significant role in soil and storm water run-off remediation.

Biochar's characteristics depend on the feedstock, the production technique and temperature (400- 1000°C) at which it's made, the time in residence, the cooling and aging, and what, if any, elements are added to 'charge' it. Extensive research and experimentation continues in the public, academic and private sectors.

HOW BIOCHAR FUNCTIONS

Biochar performs all of its seemingly overstated functions because of its gross and molecular structure and electro-chemical actions. Biochar's oxidized surfaces have a negative charge, attracting and loosely holding positively charged elements like water, nutrients and greenhouse gases (methane, nitrous oxide and carbon dioxide in particular). Additionally, research strongly suggests that since biochar can hold 5.6 times its weight in water, biochar adds 23-30% more water-holding capacity in soils thus reducing irrigation needs and moisture-stress on plants.

Biochar's high porosity reflects the cellular structure of the original feedstock after the water and gases are driven out by high heat. Different processing temperatures change the pore structure and cellular organization of biochar: the higher the heat, the more organized the structure. These pores make great habitat for microbes, bacteria and mycelia, giving these life-enhancing species protection from predators or physical displacement by rain and a moist, nutrient-rich environment. Plant root hairs wrap around biochar particles where biochar pore-dwellers exchange minerals and nutrients for the sugars and carbohydrates from plant photosynthesis.

The electro-chemical actions of biochar attract and hold soil greenhouse gases. Studies have demonstrated up to 80% reductions in nitrous oxide (N_2O) off-gassing from soil amended by biochar. Biochar then holds the nitrogen in place where it can be used by plants and soil biota.

BIOCHAR BENEFITS SUMMARIZED

Increased Nutrient and Water Retention — Biochar outshines all other organic soil material in its ability to attract and retain water and nutrients, as well as hold phosphorous and agrochemicals. So plants are healthier and fertilizers leach less into surface- or groundwater. Its porosity, surface area and negative cation exchange capacity allow biochar to perform these functions and make it valuable tool in water conservation.

Increased Soil Productivity — When added to soil, biochar improves plant growth and crop yields while reducing the total fertilizer applications.

Reduced fertilizer run-off – By attracting and holding nutrients and minerals, biochar thwarts fertilizer run-off, particularly of nitrogen and phosphorous, which poses major environmental problems. These nutrients travel through soil to surface water. The nutrient-enriched water exacerbates algae growth which depletes oxygen, suffocating aquatic species, creating extensive local to ocean dead-zones.

Persistence — Biochar is relatively inert and highly recalcitrant; therefore, far more persistent in soil than any other organic soil additive. Because biochar persists for hundreds to thousands of years, all its benefits of nutrient and water retention, carbon sequestration and soil tilth last, unlike common fertilizers and conditioners.

Micro-Habitat – Soil microbes and bacteria find the pores of biochar as excellent shelter from predators and allows for easy exchange with root hairs which are attracted to biochar.

Livestock Health –Biochar can be fed to livestock,

reducing their methane release by 50%. When added to bedding, biochar captures nitrogen and ammonia, improving animal health, reduces odors and flies.

Treating Acidification– Repeated additions of agricultural chemicals along with heavy tilling cause acidification of croplands. Biochar's relatively high pH sweetens soil and can replace liming.

Soil Tilth – The structure of biochar actually props open clay lenses, increasing soil tilth, or 'fluffiness'.

Horticulture – Biochar can replace non-renewable planting media additives like vermiculite (energy intensive, toxic production side effects) and peat (significant source of methane and carbon dioxide).

Energy – Combined Heat and Power (CHP) produced during pyrolysis can generate electricity and provide heat for homes or industries and communities. Thermally converting biomass through pyrolysis to produce energy replacing fossil fuels is a carbon-neutral process, with a positive Life Cycle Assessment if biomass is procured within 100 miles of production.

Carbon Sequestration - Biochar holds 50% of the biomass' carbon, sequestering it for centuries or more and reducing overall atmospheric CO_2 by removing it from the active cycle (biosphere and atmosphere) and sequestering it in the inactive cycle (lithosphere). Enhanced plant growth takes more CO_2 out of the atmosphere. Carbon credits can be a valuable asset for sale or trade in the offset and cap-and-trade markets. Biochar production/use can be carbon negative as long as biomass production is managed sustainably.

Scalable - Biochar production is fully scalable. Pyrolysis ovens are available in all sizes, mobile and stationary: from cooking stoves or furnaces, forest biomass burners, to industrial-sized units for power generation and heating in the rural-urban interface.

Biofuels — Bio-oil and combustible gases, including hydrogen, methane and carbon monoxide, are captured during pyrolysis. These can be cycled into the pyrolysis process, used on-site for energy production or sold.

Solid Waste Conversion — Tipping fees, the loading of landfills and open burning are avoided because biowaste becomes a marketable product, reducing CO_2 and methane emissions from landfills.

A once worthless and costly byproduct (in most cultures) is now a valuable resource. Through biochar, biomass becomes a sustainable and value-added product for urban and rural agriculture and forest communities while creating jobs, improving soil and reducing forest fire hazards.

For more information, visit the US Biochar Initiative at http://biochar-us.org and the international Biochar Initiative at http://biochar-international.org, for starters. A much longer version of this article can be found at the author's blog site at http://terraflora.us/blog.

Gloria Flora, among other things, is the director of Sustainable Obtainable Solutions and founder of the US Biochar Initiative. She can be reached at biochar@s-o-solutions.org.

Generation PReP: Examining the Newest Approach in HIV Prevention Among High-Risk People

BY CINDY TANNEY, ELLEN S. ENGELSON, EDD, AND ROLANDE HODEL, PHD, AIDSFREEAFRICA
ESEAIDSFREEAFRICA@GMAIL.COM AND RRHODEL@YAHOO.COM

The road to a cure for Human Immunodeficiency Virus (HIV) and Acquired Immune Deficiency Syndrome (AIDS) appears twisting and treacherous. Still, scientists are making breakthroughs to prolong the lives of those infected with the deadly virus. As well, they are finding more effective and accessible ways to prevent transmission.

We will explore an innovative way to prevent infection among people who are at high risk for contracting HIV. While its benefits are monumental, this method's short history comes with public backlash and, often, miscon-

ceptions in Cameroon, Africa. We take note of this country's tremendous need for a remedy where HIV infections have become endemic. Finally, we are hopeful that health organizations will be successful as they add this method to their arsenal in combating HIV/AIDS.

What is PrEP?

Pre-exposure prophylaxis for HIV infection, or PrEP, is relatively new but appears crucial in the fight against HIV. It is medication taken to prevent HIV infection in a person with a high risk of exposure to the virus. PrEP consists of tenofovir and emtricitabine, two antiretrovirals usually taken as therapy by people already infected with HIV. They work by blocking an enzyme (HIV reverse transcriptase) which is necessary for replication of the virus in a person's cells.

Risk factors for HIV infection are defined by the Centers for Disease Control and Prevention as sex without condoms with a partner of unknown HIV status, anal sex without condoms in gay or bisexual men, a sexually transmitted disease diagnosis within the past six months, sex with a partner who has been diagnosed with an STD within six months, use of drugs through shared needles, sex with a partner who uses drugs through shared needles, and sex with HIV-positive partners.

The risk of HIV infection through sex is reduced by 90 percent when an at-risk person takes PrEP as prescribed. For people who inject drugs, the risk is lowered by 70 percent when they take PrEP daily. However, PrEP should not be used in place of condoms because it does not protect against other sexually transmitted diseases, including chlamydia and gonorrhea, which are transmitted in body fluids. Also, PrEP does not prevent skin-to-skin transmitted STDs like human papillomavirus (HPV, or genital herpes) and syphilis. In people who become infected while on PrEP, continuing the treatment as prescribed will give them the same life expectancy as an HIV-negative person of the same age according to UNAIDS.

PrEP can be taken orally or as a topical vaginal gel (tenofovir only). Side effects may include headache, nausea, weight loss, and a small increase of serum creatinine. The CDC reports that no major health effects were shown in people who had taken PrEP for up to five years.

HIV/AIDS in Cameroon

Following malaria, HIV/AIDS is the second leading cause of premature death in Cameroon. According to a 2018 report from the United States President's Emergency Plan for AIDS Relief (PEPFAR), an estimated 3.8 percent of Cameroon's 23.4 million population has HIV. Approximately 27,000 new HIV infections are projected to occur each year and nearly 25,000 deaths from AIDS occur each year. Additionally, over 250,000 Cameroonian children are orphans due to AIDS-related deaths.

Nearly half of Cameroon's HIV-infected population is receiving antiretroviral therapy, but only less than 20 percent of people living with HIV have suppressed viral loads. This is likely an indication of treatment failure due to missed doses as a result of inadequate access to the medications.

Of the total population living with HIV, an estimated 24 percent are female sex workers, and 37 percent are males who have sex with males. Approximately 4 percent of prisoners live with HIV.

The number of HIV-positive pregnant women in need of antiretroviral therapies was measured at 31,040 total. Approximately 4,000 children were infected with HIV through mother-to-child transmission. An estimated 74 percent of pregnant women with HIV had access to methods like antiretroviral therapy and PReP to prevent transmission to their children.
There are signs of hope. For example, the total number of adult Cameroonians living with HIV decreased from 5.5 percent to 3.8 percent in 12 years. As well, the number of AIDS-related deaths has decreased by 13 percent since 2010.

PrEP Trials

Several clinical trials of PrEP began in countries like Cambodia, Thailand, Nigeria, and Cameroon 14 years ago. Trials were conducted to measure the efficacy of PrEP and to also counter the epidemic of HIV where

access to preventative methods is limited.

The Bill & Melinda Gates Foundation granted $6.5 million to Family Health International (FHI), a non-profit health organization, to perform trials of oral tenofovir in Cameroon, Nigeria, Ghana, and one location in Asia in 2002. The trials began in 2004 after a year of research was conducted in preparation.

By the beginning of 2005, health rights activist groups including Reseau Ethique Droit et Sida (REDS) and Act Up-Paris condemned the trials for not providing 400 participants with enough information about the risks involved and not providing antiretroviral therapy for those who tested positive for HIV.

"We are not opposed to clinical studies - on the contrary, this trial was legitimate, since this molecule could actually prevent HIV-infection. But we don't want trials that don't comply with ethical rules applied in the West," said an Act-Up-Paris spokesperson.

Many of these trials, including two in Cameroon, were stopped by government officials due to allegations of unethical conduct and protests from activist groups and local opposition in summer 2005. Claims that PrEP trial participants were intentionally infected with HIV and would not receive lifelong treatment of the virus would later be proven false by an audit commission.

In order for the trials' suspensions to be lifted, the audit commission had a few conditions. These included more defined responsibilities of all those involved in the research, and more formal collaborations with existing HIV/AIDS prevention organizations in Douala. The commission also recommended that reports from monthly meetings be shared with government bodies and FHI. Finally, they suggested that female condoms be included in HIV preventive services.

Following this, the Cameroon National Medical Council (CNMC) performed another investigation of the trials to determine if the allegations of unethical practices were valid. To do so, they spoke with 40 participants of the trial. While the final report of their investigation was submitted to Cameroon's Ministry of Public Health, it was not made public. Dr. Daniel Muna, President of CNMC, confirmed to the press that rumors that trial participants were intentionally infected with HIV were untrue. Muna reported that CNMC recommended the trials continue after a few changes were made. However, he did not specify them.

Nearly 75 percent of participants of the study returned to the trial site after it was suspended. Though they could no longer receive PrEP, the Prime Minister allowed the distribution of condoms to participants as well as counseling and health care.

Ultimately, researchers concluded that they could no longer continue the trials because too much time had passed. "Participants had been off the product for so long that the data were no longer useful scientifically," wrote authors, Elizabeth McGrory, Andrea Irvin and Lori Heise, in "Research Rashomon: Lessons from the Cameroon Pre-exposure Prophylaxis Trial Site" which details the history of the PrEP trials through case studies.

The Challenge of Social Stigma and Myths

Social stigma and myths are often a deterrent for PrEP use among those at risk. Women in South Africa claimed that they feared being associated with PrEP use because peers would assume they were already HIV positive. These women feared being socially isolated and discriminated against.

Kenyan women who began taking PrEP reported that they were initially afraid to be seen entering a health clinic for HIV prevention and also feared being caught with the medication. Additionally, some were reluctant to try PrEP because it was believed to promote promiscuity or unprotected sex. "Some community members used to say that PrEP will make their girls barren or they will never get children, or even that it is involved or associated with the Illuminati," said Maryanne Ajwang, a clinical nurse at LVCT Health, an NGO which distributes PrEP in Kenya. As a way to address these issues, LVCT Health began hosting group discussions with patients. They also created a series of videos to dispel myths surrounding HIV and PrEP use.

Adherence to PrEP also remains a challenge for users who experience side effects like headache and diarrhea. LVCT Health created a free hotline in which PrEP users could speak to a supportive person if they struggle with side effects. They reassure patients that the side effects are not long-lasting.

Fighting the Epidemic Today

As the threat of HIV infection continues, it is apparent to AIDSfreeAFRICA that Cameroonians can benefit from the use of PrEP. We hope to support efforts to make it available. PEPFAR has plans to partner with the Cameroon government to implement PrEP as a supplemental tool in HIV prevention to key populations in Douala and Yaoundé.

In its March 2018 operational plan, PEPFAR outlined a plan to test a total of 1,351,307 Cameroonians for HIV, including over a million pregnant women and other adults, as well as over 300,000 children. Antiretroviral therapy will begin for a total of 64,865 people. Continued treatment will be supported by PEPFAR for 254,103 people who are living with HIV. A total of 124,916 people will have access to test their viral load. As well, a total of 14,438 female sex workers and 7,541 men who have sex with men will have access to HIV prevention. A total of 13,194 people from this group will be screened for HIV. More HIV prevention services will be granted to nearly 13,000 adolescent girls and young women and 19,000 orphans and vulnerable children.

It is our hope that with more transparency, better communication, and inclusion of concerned citizens and activists, the implementation will be a success. Thus, Cameroonians can be empowered in maintaining good health. We will also be steps closer to an Africa free of AIDS.

Asset Stripping in Developing Countries: Agricultural Depletion and Export of Soil Nutrients

T.H. DELUCA, WA FRANKE COLLEGE OF FORESTRY AND CONSERVATION, UNIVERSITY OF MONTANA
TOM.DELUCA@MSO.UMT.EDU

Crop harvest and export to urban centers or to foreign countries results in a slow decline in nutrient capital from rural landscapes. This redistribution of nutrients from soils of naturally low nutrient capital is straining the capacity of these soils to provide regional nutrient demand for growing populations; however, to date there has been little effort to evaluate the impact of agricultural production on the nutrient stores of soils in developing countries. The following provides a brief sketch of the magnitude and potential impact of this problem and provides some suggestions for mitigation.

Concerns associated with the steady growth of human population (due to hit 9 billion by 2050) is punctuated by the uncertainties posed by global climate change and food security. Our past success with expanding food production during the 'green revolution' brought with it a level of complacency and broad sense of security that may be misplaced. The intersecting drivers of population growth, land development, narrowing genetic diversity of crops, climate change and long-term soil degradation place global food security at risk and evidence for the magnitude of this risk is just bringing to surface. Of the drivers of declining food security, soils and soil degradation are perhaps the most frequently overlooked. This is partly a result of the success with synthetic fertilization over the past century resulting in rapid increases in total agricultural productivity while total land in production remained relatively static. And although this is a notable achievement, the increasing intensity and industrialization of crop production is steadily degrading global soil resources in a manner that is greatly masked to the general population. Recent interest in soils and regenerative agriculture have unfortunately focused more on

soils as a form of carbon (C) sequestration than as the foundation for human sustenance.

The increasing industrialization of agriculture and increased dependence on external inputs of energy and nutrient has increased in global productivity including that on acidic, nutrient poor soils of the tropics and subtropics. However, yield increases in some locales are now stalling in spite of increased fertilization with N and P, likely due to trace element deficiencies that are not being replenished in fertilization practices (see Jones et al. 2013. Nutrient stripping: the global disparity between food security and soil nutrient stocks. J. Appl. Ecol. 50:851–862). Trace nutrient capital in soils is declining due to crop harvest and export of the most nutrient rich part of the crops. Agricultural products and the nutrients contained therein are most commonly exported to urban centers or shipped overseas, never to be returned to the soils from which they were removed.

The net effect of this annual removal of trace nutrients is a slow decline in soil productivity and a decline in crop quality in the form of trace mineral limitations which in turn translate to declines in human health. Pinpointing health declines due to trace element deficiencies can be challenging, because of vague symptoms or secondary impacts such as increased susceptibility to infectious disease (see Walker and Black. 2004. Zinc and the risk of infectious disease. Ann. Rev. Nutr. 24:255-275). However, major efforts must be made to redistribute nutrient resources that reside in municipal waste streams, an action especially important in developing countries where dependence on another expensive and nonrenewable agricultural input is an untenable solution. Interestingly, trace element excesses exist in soils surrounding industrial regions in India and China which simultaneously represents another health concern as well as an opportunity in terms of redistribution of resources (Steinnes 2009. Soils and geomedicine. Env. Geochem. Health 31:523-535).

Shifts in Productivity, Land and Fertilizer Use

Over the past fifty years, global increases in crop production have been daunting. Global annual production of commodity cereal crops: maize (corn) and rice have respectively increased from 205 and 212 million Mg in 1961 to 872 and 720 million Mg respectively in 2012 (http://www.fao.org/faostat/en/#data/EK). This tripling to quadrupling of crop production in just 50 years parallels population increases during this same period with only a slight increase in the acreage of land under cultivation. In the United States, maize production tripled during this period (91 million Mg ha-1 in 1961 to over 273 million Mg in 2012) and in India, maize production increased by a factor of five (4 million Mg in 1961 to 21 million in 2012). This simultaneously represents both boon to the agricultural economy and a net strain on soil nutrients and long-term productivity.

Trace Nutrient Deficiencies

In 2016, the world produced just over 1.1 billion Mg of maize, given the energy embodied in this volume of grain (4350 kcal kg-1 corn) is equivalent to 4.785 trillion kcal or just over 100% of what the world consumes in calories every year or (assuming 1,700 kcal person-1 d 1 and 7 billion people). However, the vast majority of this incredible wealth of food energy does not go directly to human consumption, but rather goes to feeding livestock and automobile fuel tanks (as ethanol) with little or no effect on offsetting our highly inefficient use of fossil fuels (Fig. 1). Recalibration of the value of animal protein versus caloric intake will need to be considered as we wrestle with issues surrounding food security.

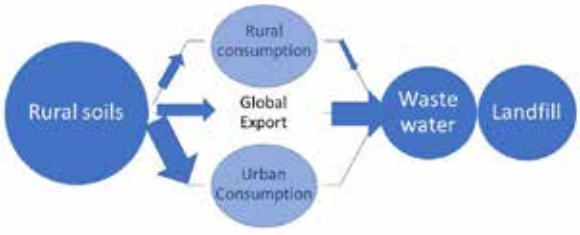


Figure 1a: Hypothetical nutrient flow path from rural landscapes to urban environments under current practice

Importantly and at the heart of this thesis, accompanying the increasing production of grain is the off take of nutrients from soils of rural landscapes that are not replenished. At a minimum this creates inefficiency in

agricultural production that makes industrial, segregated grain farms grossly dependent on synthetic fertilizer applications. And at a more insidious level, grain harvest represents the permanent removal of trace nutrients that are concentrated in urban centers, lost in wastewater streams, and ultimately lead to long-term mineral deficiencies in human populations (see Figure 1a).

The US produces approximately 356 million Mg of corn annually which represents an off take of about 8.35 million kg of Zn or roughly 245 g Zn ha-1 yr-1 removed from rural landscapes and transported to urban centers or exported overseas (http://www.fao.org/faostat/en/#data/EK) . Given that soils range from 8 – 240 mg kg-1 in US soils with a mean of about 43 mg Zn kg-1, corn removals of Zn represent 0.5% of the total Zn pool each year, thus over a 100 year period we could deplete 50% of the total Zn pool. Returning trace nutrients to rural landscapes via a robust municipal sludge application and manure spreading from confined animal feed operations is required to overcome the slow and persistent decline in soil trace metal concentrations (see Figure 1b).

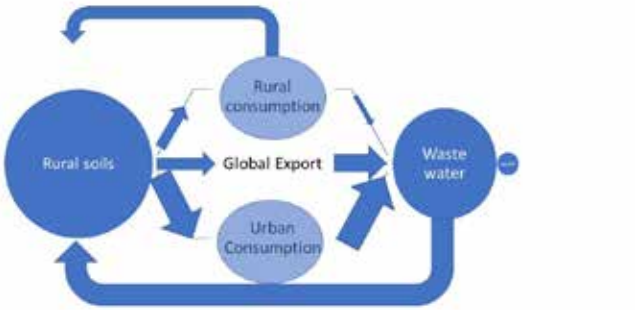


Figure 1b: Under a regime of increased recycling of nutrients to the landscape from rural and urban centers effective utilization of nutrients that reach wastewater treatment facilities

Soils of low latitudes are notably depleted in trace nutrients as a result of the advanced maturity of these soils. Examples of trace nutrient limitations and implications for long-term human health are common throughout low latitude countries and have a most notably impact to developing countries responses.

Zinc deficiencies are common throughout the Tropics and subtropics and can be found throughout temperate regions where soils are naturally Zn limited. For example, Zn deficient soils of India, Iran and Pakistan account for 50, 60, and 70 percent of the total arable land cover in those countries respectively (see Alloway, 2009. Soil factors associated with zinc deficiency in crops and humans. Environmental Geochemistry and Health 31:537–548). Increasing P fertilization of these soils with industrialization of agriculture exacerbates the Zn deficiency problems by inhibiting development of mycorrhizal relationships that otherwise increase Zn uptake.

In India, declining crop response to macronutrient (N, P, K) applications and occurrence of human trace mineral deficiencies which now exist in one half of our global population demonstrate that export of micronutrients in crop harvests represent a significant impediment to long-term productivity in mature soils of the tropics and subtropics (see Jones et al. 2013 above). The majority of crop production in India and other developing countries ultimately arrives in urban centers or as export to other countries resulting in a one-way removal of trace elements that are present in limited supply in soils of low latitudes. Over the last 10 years, export rates for India have increased markedly (Figure 2). In 2018 India exported over 9.8 million Mg of rice or an equivalent of 200 Mg Zn being removed from rural soils in India and permanently exported to other countries in rice alone. A total of 3,170 Mg Zn was removed from soils and exported to cities and villages across India. Over a 10 year period, 32,000 Mg Zn would be removed from the soils of India with the vast majority not returned to rural soils thereby drawing down the already limited Zn reserves of soils across India.

Health Implications of Declining Trace Nutrient Contents

There are real and significant health implications of increasing nutrient deficiencies in developing countries. Trace nutrient deficiencies have been identified as one of the leading causes of malnutrition globally. Approximately 1 billion people across the globe experience significant trace nutrient deficiencies as a result of poor diets and low nutrient content of grains produced in subtropical and tropical zones. In humans, Zn is particularly important during periods of

rapid growth putting the prenatal and young children at the greatest risk of deficiency. Zinc deficiencies result in stunted growth, delayed sexual maturation, weakened immune system function and increased susceptibility to infectious diseases including malaria, diarrhea, and pneumonia.

Soils can be amended with trace nutrients including Zn to overcome yield limitations imposed by trace nutrient deficiencies, but the costs of such amendments can be prohibitive for private land holders and subsistence farmers. Foods can be enriched with trace nutrients, but again, it is in developing countries where crops are consumed locally, that such nutrient deficiencies will likely go uncorrected.

There is no one single solution to the concerns surrounding the stripping of nutrient assets from soils of rural landscapes. Urbanization and globalization both enhance the export of nutrients away from rural landscapes and reduce the likelihood of effective local recycling of nutrients. Integration of livestock and grain operations is required to improve recycling of nutrients, but this will not address export of nutrients to urban centers or off shore for human consumption.

Urban centers can strive to recycle nutrients through sewage sludge composting programs (see Harder et al. 2019. Recycling nutrients contained in human excreta to agriculture: Pathways, processes, and products. Critic. Rev. Environ. Sci. Tech. 49:695-743), but most urban centers also have concentrations of transition state metals that are potentially phytotoxic or a human health hazard. New approaches to concentrating nutrients in urban waste streams in products such as struvite hold a great deal of potential, but must again avoid toxicity concerns associated with urban wastewater. Farmers and governments must work together to meet local and largescale food demands, yet protect soils and local communities from growing trace nutrient deficiencies.

Although few studies have directly addressed this issue of asset stripping and nutrient export from developing countries, numerous organizations are taking a holistic approach to soil management in an attempt to create a more sustainable future and ensure a nutrient rich food supply. Some links provided below.

https://regenerationinternational.org/
https://remineralize.org/
https://asi.ucdavis.edu/programs/ucsarep/about/what-is-sustainable-agriculture/practices/soil-nutrient-management

Water Treatment Without Borders

BY ANDREA S. S. DE CARMAGO AND EMMANUEL I. UNUABONAH
ANDREASC@IFSC.USP.BR AND UNUABONAHE@RUN.EDU.NG

Chlorine is the primary disinfectant in the world to kill the bacteria and other disease-causing organisms in the drinking water. It's inexpensive, highly effective and easy to use. However, there are concerns about the toxic byproducts, including some cancer-causing agents, formed by chlorine in the drinking water. A team of researchers from Nigeria, Germany, Brazil and South Africa have developed a low-cost efficient photocatalyst for disinfection of water.

The team, led by researchers from Nigeria under the Redeemer's University African Center of Excellence for Water and Environmental Research (RUN ACEWATER) have shown that combining kaolinite clay, *carica papaya* seeds and metal salts, under high temperature, for a short time, and in an inert atmosphere, produces a nanocomposite photocatalyst that is effective against pathogenic enteric bacteria (harmful bacteria found in the intestine of man and animals) in water. The test bacteria used was *E. coli* at a concentration of 10^7 colony forming units per millilitre (cfu/mL). Disinfection of the *E. coli* loaded water with two

grams of this material showed that the photocatalyst had an efficiency of 36 h after which there was release of the bacteria into the treated water. It was observed that three mechanisms were responsible for the disinfection efficiency of the photocatalyst: electrostatic interaction, release of reactive oxygen specie (singlet oxygen) and release of heavy metal ions into solution that poison the bacteria.

However, in the presence of a multi-drug and multi-metal resistant (MD-MMR) strain of the bacteria, the efficiency reduced significantly due to the resistance of the MD-MMR bacteria to very high levels of a variety of heavy metal ions including Zn^{2+} and Cu^{2+} used for preparing the photocatalyst. An interesting part of this photocatalyst is that it does not require the use of ultra-violet light to make it active. Rather, it utilizes ordinary sunlight for disinfection activity. This and the relative abundance of other components of the photocatalyst (kaolinite clay and *carica papaya* seeds) makes the material cheaper than conventional photocatalysts. Re-growth study indicates the absence of any living *E. coli* cells in treated water even after 4 days.

These and the long flow times (without the aid of a pump) of water through the photocatalyst during photodisinfection of water, point to its potentials in being useful for the development of efficient, affordable and sustainable point-of-use systems, that can be deployed in developing countries for the disinfection of potable water. Studies are on-going to make this material more efficient against MD-MMR bacteria.

The work was supported by a visiting professorship grant from the Sao Paulo Research Foundation in Brazil (FAPESP 2017/ 26803-3) and an equipment donated by Alexander von Humboldt Foundation, Germany. The work is now published as *Ugwuja, C.G. et al. Visible-Light Mediated Photodynamic Water Disinfection @ Bimetallic Doped Hybrid Clay Nanocomposites. ACS Applied Materials & Interfaces 11, 25483-25494 (2019).*

Chemists Without Borders Symposium at the Fall National ACS Meeting

BY RONDA GROSSE
RONDAGROSSE@CHEMISTSWITHOUTBORDERS.ORG

At the invitation of the American Chemical Society, Chemists Without Borders organized a symposium for the 2019 Fall National ACS meeting in San Diego, California. The overall meeting topic was "Chemistry & Water", so a number of clean water projects were discussed. Additionally, the symposium covered other applications of chemistry to humanitarian work including sustainability and climate change topics. Hands-on science training and field work in Latin America, combating heavy metal contamination in Bangladesh, and establishing an AIDSfreeAFRICA laboratory in Cameroon were also discussed. Presenters included representatives from universities, industry, and nonprofit organizations.

Progress on projects documented in the book "Mobilizing Chemistry Expertise to Solve Humanitarian Problems" were covered, with focus on new authors' contributions. This ACS symposium, aptly titled "Chemists Without Borders: Celebrating 15 Years of Scientific/Humanitarian Collaboration", was held on Sunday morning, August 25, 2019. Both the Multidisciplinary Program Planning Group and Environmental division of the ACS sponsored the symposium. Directly following, the Chemistry & Water opening plenary session on Sunday afternoon featured one of our founders, Bego Gerber, on the panel. We appreciated the great questions and participation from interested audiences. A special thanks to our invited speakers, who did a wonderful job! Together, we will continue to help people around the globe using the power of chemistry, and chemists and their networks.