SPECIFIC AIMS: for Proposed Research Study

Overview. The broad aims of this research are to increase multi-disciplinary understanding of the risks at the Agbogbloshie electronic waste site in central Accra, Ghana, and to use study findings to inform evidence-based implementation activities and policy options at the national, regional, and international levels. The specific scientific goals include: 1) characterize work-related, time-varying, job-specific exposures of electronic waste recycling workers at the Agbogbloshie site, and assess biological markers of dose, to metals, organic compounds, and markers of combustion products; 2) provide estimates of potentially increased lifetime, work-exposure-associated cancer risks; and, 3) evaluate associations of exposures with measures of acute and chronic respiratory morbidity in workers. These scientific goals are fully integrated with an overarching goal to rapidly strengthen the capacity of the West African region to address critical environmental and occupational health (EOH) challenges. The proposed Agbogbloshie study is intended to provide a setting for high-quality research training in EOH for doctoral and masters students, postdoctoral fellows, and junior faculty from academic institutions of the several participating countries to accelerate thusly the development of a robust West African EOH hub.

Specific Aim 1. To enroll 132 study participants over a 12-month period: 92 Agbogbloshie waste recycling workers, including at least 40 new hires (an inception cohort), and including at least 52 workers (‘burners’) [note: the first job assignment of many new hires is as a burner] whose primary job responsibility is to manage the burning of electronic equipment, as well as a group of 40 ‘controls’ residing in Madina Zongo, an area of greater Accra more than 10 km from Agbogbloshie many of whose residents are known to be quite similar to the waste workers with respect to age, length of time residing in the greater Accra area (and region of the country from where they moved), socioeconomic position, and religion and culture. Each of the 132 participants will have exposures and health status assessed at three points in time: baseline, at 12 months post-enrollment (estimated minimum n of 100 remaining in the study), and at 24 months post-enrollment (estimated minimum n of 70).

Specific Aim 2. To collect and analyze, at 0-, 12-, and 24-months for each participant, 1) biological samples (blood and urine) for a) metals, b) organic compounds including flame retardants, polycyclic aromatic hydrocarbons (PAHs), dioxin-related compounds, and, 2) personal air monitoring, through a combination of real-time measurements and analysis of size-specific samples collected on filters, including markers of combustion products: PM 2.5 and formaldehyde, as well as quantitative analysis of filter samples for the same suite of organic compounds being evaluated in blood samples, as well as for elemental carbon. The results of biological and filter samples will be used to estimate potentially increased lifetime, work-exposure-associated cancer risks using standard methodologies.

Hypotheses: 2.1 Biomarkers of exposure to both metals and to organic compounds will vary across worker classifications. Specifically, those actively processing electronic waste (especially those primarily doing burning, and, to a lesser extent, those primarily doing dismantling) will have greatest exposures; 2.2 Metal and organic compound exposure biomarker levels will vary over time, even within the same participant. 2.3 Variation in metals exposures can be explained by differences in concentration and bioavailability of metals in soil, dust, food, and water collected from an individuals’ work site and home; 2.4 Variation in organic compound exposures can also be explained by differences in concentration and bioavailability across multiple media, though for those actively processing electronic waste, especially if involved with burning, exposures will be predominantly explained by work activities; 2.5 As compared to the control population, working at the Agbogbloshie site, and, especially, working as a burner on the site, will be associated with significantly increased estimated lifetime cancer risk.

Specific Aim 3. To collect respiratory health status data at 0-, 12-, and 24-months for each participant. Health measures to be assessed: respiratory symptoms, reported frequency of upper and lower respiratory infections, pulmonary function assessed by hand-held spirometer, interference with ability to work or with other activities of daily living, medication use, and, health services utilization.

Specific Aim 3a. To evaluate -- while controlling for covariates such as previous history of respiratory illnesses, gender, age, tobacco use, current or historical use of biomass fuels for cooking in domiciles, potential respiratory hazards at previous or current (among controls) work environments, body mass index, religion, socioeconomic position -- whether working on the Agbogbloshie site, and especially working as a burner on the site, and whether quantified exposures to potential respiratory hazards (PM 2.5, elemental carbon, PAHs) are associated with differences in respiratory health status.

Hypotheses: The covariate-adjusted probability and severity of adverse respiratory conditions or outcomes will be higher: 3a.1 among workers at the Agbogbloshie as compared to the control participants, and, 3a.2 among current burners as compared to those on other jobs at Agbogbloshie, and, 3a.3 among those with higher quantified exposure to potential respiratory hazards. 3a.4 Among those who went from being a burner to a different job at Agbogbloshie over the course of their participation in the study, measures of exposure will be lower and measures of respiratory status will show improvement at the newer job as compared to the job as a burner.

Specific Aim 3b. To investigate interactions between occupational exposures to respiratory hazards at Agbogbloshie and 1) current or historical use of biomass fuels for cooking in domiciles, 2) tobacco use, 3) pre-employment history of diagnosis of, or symptoms consistent with, asthma or tuberculosis, in producing adverse respiratory health effects.
Hypotheses: 3b.1) Those working in Agbogbloshie, and, especially, those working as burners, with 1) a substantial current or historical exposure to biomass fuels used for cooking in domiciles, or, 2) substantial tobacco use, or, 3) pre-employment history of diagnosis of, or symptoms consistent with, asthma or active tuberculosis, will demonstrate higher probability and/or more severe adverse respiratory outcomes associated with their work-related exposures as compared to those in the same jobs without histories of such additional risk factors.

SPECIFIC AIMS for Proposed Research Training

Below are the unified set of research training-related Specific Aims for the linked U01 and U2R grants, slightly modified to reflect the further consolidation of the plans for the proposed central study of Agbogbloshie e-waste workers. The numbering for these specific aims begins with the letter "A" for training to avoid any confusion with the research study specific aims above.

Specific Aim T1. Pursue innovative multidisciplinary scientific research studies with high public health relevance and likely significant policy implications addressing key EOH threats in the informal sectors of participating countries in West Africa. Specific Aim T1A. Finalize key hypotheses and suitable approaches to data collection for studies in three identified regional priority areas, electronic waste, informal gold mining, and transportation-related ambient air pollution. Comment: This specific aim has been fully accomplished for the Agbogbloshie e-waste study as reflected in the research specific aims above and the details presented in the 'Proposed Research' section further below in this application. Substantial progress has been made in the planning of pilot studies addressing informal gold mining, addressing transportation-related ambient air pollution, as well as further e-waste comparative studies of Agbogbloshie to other e-waste sites in West Africa, as described for all further below. Specific Aim T1B: Organize the approach to these studies so as to assure the carefully mentored, interactive participation of trainees at various levels (post-docs, doctoral students, etc.) from multiple complementary disciplines in all study stages (conceptualization, design; detailed protocol; data collection, management, and analysis; manuscript preparation, etc.). Comment: A detailed plan of training approach has been settled upon for the Agbogbloshie e-waste study, and is described further below. Planning for training associated with the gold mining, ambient air pollution, and comparative e-waste studies are in formation with the expectation that approaches will be quite similar to the approach for the Agbogbloshie e-waste study.

Specific Aim T2. Increase sustainable capacity to conduct EOH research in West Africa through: Specific Aim T2A. Strengthening of existing, and launching of new, Masters and doctoral EOH research training programs through a combination of: i) sharing of existing curricula; ii) cross-country curriculum development workshops; iii) consultation by faculty from well-established degree programs to new or recently launched programs. Specific Aim T2B. Enhancing training of West African postdoctoral fellows organized into interdisciplinary, inter-country project teams spending 4 months on the UM or McGill campus, followed by 6 months in WA home countries executing research projects in the informal sector. The months at UM/McGill will include: i) mentoring by teams of NA and WA senior scientists; ii) customized courses in the responsible conduct of research, interdisciplinary research, advanced statistical methods, scientific writing, and use of technology and information resources; iii) auditing other relevant courses; iv) presentations on planned research projects. Specific Aim T2C. Implement innovations in mentoring and team-building. A key innovation will be WA senior scientists will reside on the UM/McGill campus for the 1st two months the postdoctoral teams are there. Specific Aim T2D. Offer similar training at UM/McGill for WA doctoral students teams.

Specific Aim T3: Conduct ongoing monitoring and evaluation (M & E) of progress of the grant: using qualitative and quantitative methods and jointly developed metrics, assess: a) successes, and any barriers to progress; b) quantity and quality of research training; c) administrative & management abilities; d) cross-country collaborations; e) academic/governmental collaborations. Make changes in approach and allocation of resources as indicated. Use long-range cumulative evaluation to monitor participants’ peer reviewed publications, submitted research grant applications, successful grant applications, and career trajectories. Monitor broader impacts on the participating institutions’ research environments, including faculty retention and promotion rates, and overall institutional productivity measures such as mean annual number of peer-review publications and number and size of grants per faculty member.

RESEARCH STRATEGY. Please note: the inclusion in this application of a detailed proposed research plan for the Agbogbloshie study creates space limitations. Therefore, for a number of the sections under Research Strategy only an abbreviated summary is included. Fuller descriptions for most of such sections can be found in the parallel U2R grant application.

SIGNIFICANCE

We believe this proposal has outstanding potential to help establish Ghanaian institutions as world-class interdisciplinary and translational environmental and occupational health (EOH) research and education centers that will thus serve as a regional GEOHealth Hub for low to middle income countries (LMICs) in West Africa. Reasons for this high potential include: a) excellent and mutually reinforcing EOH resources among the lead institutions; b) highly productive history of trust and collaboration; c) previous and on-going successes in the training of Ghanaian researchers in EOH; d) a history of highly interdisciplinary and innovative approaches to research training; e) building upon our 16-year EOH capacity strengthening
experience several Southern African Development Community (SADC) countries; and f) strengthening collaboration among Francophone and Anglophone countries across the West Africa region.

BACKGROUND

**EOH Situational analysis.** In Ghana, morbidity is characterized by high levels of communicable diseases as well as a rising number of non-communicable diseases. Despite these challenges, Ghana is unusual in having academic and political infrastructure that makes it well positioned to benefit from and capitalize on investments in human resources and research infrastructure. Signers of the pan-African Libreville Declaration have committed to the declaration by developing national strategic plans from country-based Situation Analyses and Needs Assessment (SANA). For Ghana, key findings of such a SANA were: a) inadequate funding, lack of coordination among stakeholder institutions and lack of utilization of research findings; and b) a highly trained human resource base but short of quantity and facilities for maximum utilization of their potential in relation to health and environment issues.

**Scientific Topic and Rationale.** We have selected environmental and occupational health threats associated with work activities in the informal sector of the economies of countries in the West Africa region as the unifying theme for the proposed research and research training activities. Reasons for this choice include: a) in West Africa, the distinct majority of workers are employed in the informal sector; b) associated environmental and occupational health hazards are believed to be especially pervasive; c) because of being largely unaddressed previously, such hazards are likely to lend themselves more quickly to amelioration through relatively simple technical interventions and education; d) effective and lasting solutions to health challenges in the informal sector are especially likely to require innovative, highly interdisciplinary approaches.

Within the informal sector, the E-waste sector has emerged over the past decade to be of great global public health concern (Schmidt 2006; Robinson 2009; Grant et al. 2013). In 2009, 35% of second-hand EEE imports into Ghana were non-functioning waste electronic and electrical equipment (WEEE), also known as “e-waste” (Amoyaw-Osei et al. 2011). In LMICs, WEEE is principally processed in an informal sector that consists of manual dismantling of EEE with rudimentary tools and open-air burning. Most workers are young, and few use protective equipment. Furthermore, the sector is at its infancy and expected to grow tremendously. These challenges also present an opportunity as evidence-based interventions acted upon now may be expected to greatly shape the sector’s future. West Africa represents one of the world’s most significant hubs of WEEE activity as showcased in a recent UNEP report (UNEP 2014). Internationally, Agbogbloshie is amongst the most studied sites and thus represents an excellent training field laboratory/site for us to base the proposed research activities. Further, PI-Fobil has been leading research studies at this site for >5 years, with key outputs being seven (7) MSc thesis projects completed, 6 publications in leading journals, and the establishment of international partnerships with five (5) universities.

**Prior Planning Grant.** Our GEOHealth pilot grant (2012-2015) sought to increase capacity in Ghana to serve as a Hub in West Africa. A number of crucial steps and successful activities have occurred during the planning grant: a) a series of meetings which brought together proposed grouping of collaborators (25+ high-level partners from 15+ organizations from 7 West African nations; plus partners from South Africa and Canada) and established strong consensus in topics and approaches to research questions and training approaches; b) in Ghana, a 1-day stakeholder meeting in 2013 of EOH representatives from government, academia, NGOs; c) strategic linkage (including 3 face to face meetings, and a signed Memorandum of Understanding, MOU) made with the existing West African (Benin, Burkina Faso, Côte d’Ivoire, Mali, Sénégal) Francophone-based Community of Practice in Eco-Health for West and Central Africa (COPEH-WC); d) the International Libreville Declaration of Development Research Centre (IDRC); e) the West Africa region-wide needs and opportunity assessments in EOH have been largely completed; e) a new MSc (research thesis-based) program in environmental and occupational hygiene/medicine launched at the University of Ghana in 2013; f) allied research and training grants from NIH Fogarty International Center, Gates Foundation, University of Michigan, McGill, and various Foundations (as well as link with COPEH-WCA) mutually reinforce GEOHealth.

**Partnerships.** As described in detail in the parallel U2R grant application, our research and research training strategies built upon a long history of highly productive partnerships, focused on environmental and occupational health and/or broader LMIC health issues, characterized by trust, open communication, and transparency. Many of the activities of these partnerships have been, and continue to be, supported by long term funding from NIH (Fogarty International Center, and NIEHS), Bill and Melinda Gates Foundation, IDRC, and the Graham Sustainability Institute. Key ongoing partnerships include University of Michigan with University of Ghana and other academic and governmental Ghanaian organizations, University of Michigan with multiple countries in the Southern African Development Community including South African institutions that have also built strong ties to Ghana, McGill University with multiple Francophone countries of West Africa as well as Ghana, and close partnering between Michigan, McGill, and institutions in Ghana with institutions in West African Francophone countries (Benin, Mali, Senegal, Côte d’Ivoire, and others).

**APPROACH**

**Overview.** The overall objective of “The West Africa-Michigan Collaborative Health Alliance for Reshaping Training, Education, and Research for Global Environmental and Occupational Health-
Investing in Innovation (short title: ½ The West Africa-Michigan CHARTER II for GEOHealth) is to build upon long-standing, extensive occupational and environmental health (OEH) research and training collaborations between academic and government partner institutions in Ghana, as well as other countries of West Africa, and the University of Michigan (UM) so as to sustainably enhance capacity for world-class scientific research and research training which address and inform key national and regional occupational and environmental health priorities and policies. Our strategy, based on extensive needs and opportunities assessments we have carried out in the region, is to leverage numerous existing strengths among consortium partners.

Other Research Activities. As elaborated upon elsewhere, this proposal builds upon the extensive experience of the lead investigators in the conduct of scientific research studies in collaboration with lead academic institutions and governmental ministries across Ghana and many other sub-Saharan African countries in EOH areas deemed likely to be of highest concern (EOH laws and regulations; air pollution; toxic chemical mixtures; exposure assessments; epidemiology and biostatistics; occupational health).

History of Interdisciplinarity and Innovation. One hallmark of the longstanding Ghana-UM partnership is on-going intensive collaboration of faculty from multiple units – both in Ghana and at UM. In Ghana, collaborating faculty come from the Colleges of Health Sciences at both KNUST and UG, as well as colleges of engineering, midwifery training schools, Ghana Health Service research units, and Ministry of Health. At UM, faculty working in Ghana represent the School of Public Health, School of Medicine, School of Nursing, School of Dentistry, College of Engineering, Institute for Social Research, Institute for Research on Women and Gender, and Center for Global Health. Such diversity of collaboration may be unusual for efforts between North/South institutions, but in the case of Ghana and UM, it is built upon a firm foundation of transparency and trust.

Program Faculty & Team Members. A great strength of this proposal is the outstanding expertise and experience of, and the large number of relevant EOH disciplines represented by, the faculty at UG who have agreed to serve as collaborators, as well as the members hailing from other Ghanaian institutes (KNUST, GHS/MOH), UM, McGill, South Africa, and from across Anglophone and Francophone West Africa (COPEH-WCA; Nigeria). Input from UM faculty will be critical to the success of the research activities. The majority of the involved UM faculty have conducted research in LMICs, many in sub-Saharan African countries. The UM faculty also have deep experiences in research areas that we have identified to be of priority focus here, namely air pollution, toxic chemical mixtures, exposure assessments, epidemiology and biostatistics, and occupational health. In addition, several of the UM Faculty have shaped EOH academic curriculum and training programs (e.g., NIOSH ERC, NIEHS Toxicology Training Grant, Fogarty PARTNER grant), and utilize innovative and leading-edge teaching approaches (e.g., online distance learning, hybrid teaching, field-based courses). Many of the faculty from both countries have strong histories of participating on innovative interdisciplinary research projects and of training of students from the undergraduate to graduate to post-graduate levels.

Program administration: Coordination. For a complete description of program administration and coordination, please refer to this section in the parallel U2R grant. Briefly, project management, ongoing evaluation, and key decision-making for the two closely linked U01 research grant and U2R research training grant, will reside with a single Administrative Oversight Committee (AOC), which will include among its members representatives from the US (UM), Canada (McGill), Ghana (UG, KNUST, and MOH/GHS), Benin (UAC, also representing COPEH-WCA), and South Africa (UKZN). The likely individuals to serve represent a broad range of highly complementary scientific disciplines. In fact, this grouping has already begun acting as a de facto AOC: a consensus decision, informed by a regional needs and opportunities analysis, was reached to focus research under the U01 grant on critical environmental and occupational health issues in the informal sector of the economies of countries in West Africa, by first developing full-scale EOH projects around electronic waste recycling activities, while initiating studies addressing the informal sector mining and ambient air pollution associated with the informal sector transport. The AOC will meet (usually electronically using Skype, operator assisted: thru central number, or other reliable approaches) at minimum on a quarterly basis. Standing agenda items of every meeting will include: 1) any new or changed proposed research and research training activities, 2) coordination of the respective administration of research and research training activities, 3) monitoring and evaluation of progress of the overall GEOHealth Hub, and 4) planning for new activities which build on the strengths of the Hub.

Selection of Topic & Skills. As part of our GEOHealth planning grant, a series of meetings, evidence gathering endeavours (e.g., review of well-researched and comprehensive SANA documents from each country), and report writing activities were conducted to develop a consensus on essential regional EOH research priorities. From our various exercises we identified more than a dozen potential EOH research topics that would represent excellent training laboratories for interdisciplinary research activities. Unfiltered, the identified topics clearly indicated the need to focus on the informal sector, and within this we selected E-waste as our primary research focus. Foremost in the selection of this topic is that it emerged as a priority from the aforementioned and diverse needs and opportunities assessment activities, and that it lends itself for use as a training laboratory to further the EOH skillsets, namely occupational health, exposure assessment, air pollution, identified to be of greatest need. We also carefully considered existing research strengths and expertise amongst the involved parties (e.g., Fobil: E-waste and regional environmental and occupational health expert; Robins: air pollution and occupational health; Basu:
exposure assessments and metals toxicology), the existing research infrastructure in the lead institutions, as well as the policy landscape in Ghana, and across West Africa and the world. A great opportunity is present to sustain and accelerate activities in the electronic waste recycling arena, and to increase the likelihood that findings would be translated into actionable interventions to improve health.

A great advantage of these areas is that the skills, involved disciplines and methodologies needed to tackle these topics are grounded in foundational aspects of environmental and occupational health sciences of relevance to almost all EOH-based research projects. Such key aspects include, for example, strong and deliberate study design, epidemiology and biostatistics, exposure assessment and biomarkers, data management, and interdisciplinary approaches (including socioeconomic and policy contexts). Carefully executed research in these topics will help trainees and faculty develop the needed skill sets to successfully tackle other EOH issues.

Agbogbloshie as a Training Laboratory. Our primary research studies will focus on the Agbogbloshie Electronic Waste site in Ghana. It is located in Central Accra, and is within a 20 min drive from the University of Ghana, Ghana Health Service, and a number of health clinics. Amongst e-waste sites worldwide, Agbogbloshie is arguably one of the best two that have been researched (other is Guiyu, China), most documented via traditional and social media, and most easily accessible sites of its type (note, access to notorious sites in Nigeria, China, and elsewhere are being restricted, whereas the Agbogbloshie site benefits from great relations amongst the workers, their employers, and local government and academics).

A great opportunity is available to build from recent (and largely descriptive yet requisite) activities by our group (Asante et al. 2012; Atiemo et al. 2012; Akormedi et al. 2013; Feldt et al. 2014) and conduct more sophisticated and deeper analytical and multi-disciplinary studies at Agbogbloshie to help inform policy and guide interventions, both in Ghana, regionally and globally. For example, partly funded by our GEOHealth planning grant, we have conducted several recent studies at the Agbogbloshie site. Our studies have focused on the workers and have found elevated levels of heavy metals and polycyclic aromatic hydrocarbons (PAHs) in their urine (Asante et al. 2012; Feldt et al. 2014, Wittsiepe et al., 2015), reported elevated concentrations in dust at the site and its surroundings (Atiemo et al. 2012), and characterized the types of accidents and injuries and social support systems via in-depth surveys (Akormedi et al. 2013). Recent, unpublished studies have expanded upon the exposure assessments (via more survey tools, collection of blood and urine, sampling of water, soil, air and food) and health measures (physiological stress, cardiovascular function, respiratory function), which we intend to build upon via this proposal. Of relevance to this proposal, many of these recent studies at Agbogbloshie were co-performed by trainee/Faculty teams hailing from the University of Ghana, Ghana Health Service, and Michigan/McGill, and pursued using a diverse portfolio of grants (including our GEOHealth pilot grant) thus showcasing our ability to finance and run projects that can be sustainable. As per our long-history of embarking upon studies with trust, saliency and fairness, all team members were intimately involved in all aspects of the study. In addition, a number of exchanges have been held with Ghanaian students coming to North America to utilize sophisticated equipment to analyse their samples, and with U.S. students spending quality time in Ghana to engage with counterparts and co-conduct the field study.

PROPOSED RESEARCH

Overview. The broad aims of this research are to increase multi-disciplinary understanding of the occupational risks at the Agbogbloshie electronic waste site in central Accra, Ghana, and to use study findings to inform evidence-based implementation activities and policy options at the national, regional, and international levels. As detailed in the specific aims, scientific goals include characterizing work-related, time-varying, job-specific exposures of electronic waste recycling workers at the Agbogbloshie site, and assessing biological markers of dose, to metals, organic compounds, and markers of combustion products; provide estimates of potentially increased lifetime, work-exposure-associated cancer risks; and, evaluating associations of exposures with measures of acute and chronic respiratory morbidity in workers. These scientific goals are fully integrated with an overarching goal to rapidly strengthen the capacity of the West African region to address critical environmental and occupational health (EOH) challenges. The proposed Agbogbloshie study is intended to provide a setting for high-quality research training in EOH for doctoral and masters students, postdoctoral fellows, and junior faculty from academic institutions of the several participating countries to accelerate thusly the development of a robust West African EOH hub.

Building upon successes to date to extend our previous work through research design improvements. The proposed study design builds upon our research teams’ extensive experience and success on the Agbogbloshie site with creating strong rapport and collaboration with the site leaders and site workers, using data collection methodologies successfully tailored to conditions on the site, and our deepening understanding of relevant socio-cultural aspects of the work force. At the same time, the proposed study will go beyond previous work by ourselves and others in a number of ways including: 1) a repeated measures design to capture changes over time in employment status, exposures, and health status measures; 2) addressing a more complete array of measures of exposure and dose including personal monitoring of workers’ airborne exposures to PM 2.5, elemental carbon, formaldehyde, metals, flame retardants, PAHs, and dioxin-like compounds, and characterizing important determinants of exposure such as by the inclusion of upwind and down when measures of air contaminants during burning operations; 3) assessing associations between exposures and detailed measures of respiratory health status. It is intended that this study help establish a set of protocols for data collection analysis and interpretation which
Population & recruitment. E-waste workers. Targets are to initially enroll 52 burners, and 40 other E-waste workers (dismantlers, collectors, and sorters) at the site over a 12 month period. For each study participant, measures of exposure and health status will be sought at enrollment, 12 months post-enrollment (estimated minima n’s of 40 burners and 30 other e-waste workers remaining in the study), and 24 months post-enrollment (estimated minima n’s of 28 burners and 20 others). Targets were chosen so as to average, across the three rounds of data collection, at least 40 burners and 30 other workers participating. We expect to include at least 50 new entrants among these 92 e-waste workers, representing an inception cohort as the majority of recruited worker participants, with recruitment of additional workers already employed at the time of enrollment to reach desired numbers for adequate statistical power. The advantages of having a substantial inception cohort include: i) neither baseline levels of measured metals and organic compounds in blood and urine, nor any measures of adverse health status, can be due to prior e-waste exposures, ii) repeated measures of biomarkers, e-waste associate exposures, and health status in these workers will allow unbiased estimation of the relationship of new exposures on any changes in biomarkers and health status; iii) the ability to estimate the level of any healthy worker survivor effect [which may create a bias toward the null in a purely cross-sectional study], e.g., the ability to test whether those with higher exposures and/or increased health symptoms/problems are more likely to leave employment as an e-waste worker (or switch jobs) early; iv) the ability to track in real-time any typical patterns of job changes on the site. We expect that these recruitment numbers will be highly feasible based on the following: a) workers at the site function under the management and control of one “chairman”; b) our study team enjoys a history of excellent rapport with this leader reflected in our ability to recruit substantial numbers of workers in previous studies with more than 90% of approached workers giving informed consent to participate; c) the total number of workers at the site is estimated at well over 500 with at least 100 new hires per year; d) the first job assignment of many new hires is as a burner (Akormedi M et al, 2013) (enabling us to oversample burners while having the slight majority of recruited workers being part of the inception cohort); e) all, or almost all, new entrants will be without previous exposures to e-waste sites with the vast majority having recently migrated from the north of Ghana (Akormedi M et al, 2013) [where there are no known e-waste sites]. Study staff will check with the chairman (or his vice-chairman) on a semi-weekly basis to learn of any new entrants, and will attempt to recruit into the study up to a maximum of 10 new entrants in any one month (this monthly cap is intended to avoid unrepresentative seasonal distributions, and to ensure adequate staff to obtain biological, exposure, and health status measures at intended time intervals). Study staff will obtain lists of current workers, categorized by job, from the chairman or vice-chairman at the initiation of recruitment, and check for monthly changes thereafter. A maximum of 10 per quarter (at least 2 burners, at least 3 dismantlers [expected to be a job with the next highest exposures after burners], with the rest from other jobs, will be randomly selected (within job categories) for recruitment. The number of current workers recruited per quarter-year is capped at 10 in order to maximize opportunity for inception cohort recruitment, and to retain the ability to adjust the ratios of job titles in later quarters dependent on distributions of those recruited into the study to date. Workers under age 18 will only be eligible if a parent or legal guardian is available to give informed consent. Controls. Target is to enroll 40 residents of Madina Zongo, with the expectation of a minimum of 30 remaining in the study at 12 months and of 20 remaining in the study at 24 months. This is an area of greater Accra more than 10 km from Agbogbloshie many of whose residents are known to be quite similar to the e-waste workers with respect to age, length of time residing in the greater Accra area (and region of the country from where they moved), socioeconomic position, and religion and culture. Our study team has had great success in recruiting such control populations from other areas of Accra (Wittsiepe J et al, 2015; Feldt T et al, 2013), with very high participation rates similar to those among workers at Agbogbloshie. The percent of controls (out of the total of 40 to be recruited) enrolled in each quarter will be roughly matched to the percent of e-waste workers enrolled per quarter to reduce the probability of seasonal or temporal patterns affecting worker-control comparisons. Controls will be recruited so as to roughly group match the distribution of recruited workers in each quarter with respect to age, gender, length of time residing in greater Accra, area of country from which person migrated to Accra, and religion/ethnicity. Persons with mental or physical disabilities interfering with your ability to understand the informed consent or complete health status measures will be ineligible as controls. Potential controls under age 18 will only be eligible if a parent or legal guardian is available to give informed consent.

Exposure and Dose Assessment.

Biological Sample Collection: For each study participant (all e-waste workers and all controls), at enrollment, 12-, and 24-months, for an estimated total of 300 samples, will provide samples of urine (30-50 ml) and venous whole blood (20-30 ml), using methods described in Basu et al. 2010; collected in vacutainer tubes: including two retained as whole blood for metals analysis, and two spun and fractionated into serum for analysis of organic compounds, with all samples frozen within an hour of collection. Samples will be stored and consolidated for shipment back to the US on dry ice. All samples will be securely stored frozen at -80°C at the University of Ghana. Samples will be bi-annually transported to the University of Michigan and/or McGill on dry ice for analyses.
Analytical Determination of Metals: Metals (focus: aluminum, arsenic, cadmium, chromium, copper, lead, manganese, mercury, nickel, zinc) analysis will be performed at Basu’s laboratory at McGill using previously published methods (Basu et al., 2010). All samples will be handled in a Class 1000 clean hood. All samples will be digested with 2% nitric acid for 24 hours (blood will include 3% hydrogen peroxide). Concentrations of metals will be determined using inductively coupled plasma mass spectrometry (ICPMS; Agilent 7500C, Agilent Technologies, Palo Alto, CA). Mercury will be measured using a direct mercury analyzer (DMA-80, Milestone Inc, Shelton, CT). Rigorous analytical quality control measures include use of ICPMS calibration verification standard (NIST SRM 1640), procedural blanks, duplicate runs, spiked samples, method detection limits (3xSD of blanks), and various certified reference materials from the Public Health Institute of Quebec.

Personal air samples will be collected from all participant e-waste workers on three occasions (n=210) to collect full-shift samples of size-specific particulate matter (PM2.5) on Teflon filters collected with a high flow (SKC, 15 L/min) battery operated personal sampling pump. These filters will be analyzed for semivolatile compounds and elemental carbon (EC; see below). Continuous formaldehyde samples using a small, stable and sensitive monitor (Graywolf FM-801, Shelton CT) will be collected simultaneously with every other particulate matter sample (n=105). These samples will be contemporaneous with environmental samples (see below). This design will quantify individual and task-specific air exposures in the breathing zone (after removing the background/upwind concentration from each sample).

Area (environmental) samples will be collected simultaneously at an upwind site (control area) and a downwind highly exposed (to combustion products of burning) site each week during working hours (n=200 samples = 2 sites x 50 weeks x 2 years). Each site will collect air samples using a high flow pump, Teflon filters, and a polyurethane foam (PUF) adsorbent backup for gravimetric, reflectometry EC, and particulate and vapor phase semivolatile analyses (see below). The combined filter/PUF captures both particulate and vapor phases. We have developed and validated a semi-portable system precisely for this approach (Batterman S, Chen TC et al, 2009). In addition, each site will have a continuous, real-time formaldehyde monitor. We will also collect and archive soil and dust samples for possible future analyses.

The personal and area exposure monitoring approach for semivolatile organic compounds is designed to balance costs, practicality concerns, and the need for comprehensive exposure information. Because vapor phase sampling requires a separate analysis (see below) and additional sampling hardware, combined vapor/particulate phase shift personal sampling is difficult and potentially infeasible in the study environment. However, the study design allows us to establish the vapor/particulate phase partitioning using the area monitoring. Based on our work and the literature, partitioning is a function of environmental conditions (e.g., temperature and source (e.g., burning-related emissions and particulate size distribution), and we anticipate that simple empirical (e.g., regression) partitioning models should adequately explain variation (e.g., $R^2 > 90\%$) as a function of temperature and possibly the source or concentration. Using these models and the personal measurements of particulate phase semivolatiles, we will estimate the total semivolatile exposure of workers from the air pathway. Exposure can also occur via dermal absorption and ingestion, but these pathways are incorporated in the biomonitoring samples. The combined use of area, personal and biomonitoring measurements will capture the total exposure (biomonitoring), the dominant occupational exposure anticipated to be airborne (personal shift air sampling), and background environmental (area background sampling). Additional sources, e.g., through the diet, will be captured by the biomonitoring measurements; the choice of the control population is designed to estimate non-occupational sources.

Biological, personal and area sampling will follow strict protocols using well developed written standard operating procedures (SOPs). In the field, the protocols will include extensive training, system checks, daily flow calibrations, field blanks, replicate samples, and other measures designed to assure the highest QA/QC practicable in the field.

Laboratory analysis of organic compounds. Analyses will be conducted in the Organic Chemistry lab of the UM NIEHS P30 Exposure Assessment Core (directed by Dr. Batterman). We have used all of the proposed methods for exposure assessment purposes for many years (Batterman S, Chen TC et al, 2009; Batterman S, Chernyak S, Gouden Y et al, 2009; Batterman SA, Chernyak S, Jia C et al, 2009; Batterman S et al, 2008; Miller MF et al, 2009; Miller MF et al, 2012; Wang W et al, 2008) and all of the equipment and facilities are available in this laboratory. On receipt, samples will be frozen rapidly and stored at -80°C. Serum samples will be analyzed for brominated flame retardants (BFRs, PBDEs and PBBs), polycyclic aromatic hydrocarbons (PAHs), and dioxins, furans, and dioxin-like compounds (dioxins) by liquid-liquid extraction, acidification, florisil column cleanup, gas chromatography-mass spectrometry (GC-MS) separation and quantification. In parallel with sample analyses, the QC procedures to be conducted will include: (a) standard reference materials (SRMs) and spike and surrogate recoveries are tested periodically; (b) linearity and drift checks are performed with each sample batch; (c) internal standards consisting of deuterated standards are used on each sample; (d) duplicates are analyzed in each batch; (e) method detection limits (MDLs) for each target compound are determined for each matrix; (f) blanks (instrumental, field and laboratory) are run with each sample batch; and (g) use of authentic standards. All solvents and other materials contacting samples are proved to be clean, as confirmed using blanks.

For gravimetric analyses of particulate matter for the personal and area samples, the Teflon filters will be conditioned in a temperature and humidity controlled environment, weighted to the microgram using a
Databases and appropriate data checking and quality control systems will be created. The databases will be created in Microsoft Access. To ensure data entry accuracy, 10% of records will be double entered.

Pulmonary function and symptom data from the EasyOne Spirometry will be collected, handled, and extracted will follow manufacturer's recommendations. With these samples, we will use the Puregene Buccal DNA Isolation Kits (Gentra Systems; Minneapolis, MN). Sample collection, handling, and extraction will follow manufacturer's recommendations. As part of the consent process we will inform parents or legal guardians that: a) if we receive additional funding in the future, we will check the sample for genes that may put a parent or legal guardian at risk for more severe effects on respiratory health owing to e-waste associated exposures; b) the sample will be used only to look at genes affecting susceptibility to potentially harmful exposures and in the risk for respiratory conditions; c) they are free to decline participation in this aspect but still participate in all other aspects of the study, and also free to change their minds from "yes" to "no" at any time during or after the sample has been collected (in that case, we would destroy the sample promptly); and d) that all stored DNA samples will be destroyed no later than 5 years after the end date of the study. To obtain buccal DNA samples, we will use the Puregene Buccal DNA Isolation Kits (Gentra Systems; Minneapolis, MN). Sample collection, handling, and extraction will follow manufacturer's recommendations. The lung function indices (forced expiratory flow (FEF25-75), mid-expiratory flow (FEF25-75), and the EC measure, job task, and estimated of semivolatile organic constituents. All filters will be archived for possible future analyses.

Health Measurements

Interviews and questionnaires. All interview instruments will be administered by trained study staff. Interviews will be conducted in English, Dagbani, or Hausa (these are the two African languages spoken most frequently in Greater Accra in which most of the e-waste workers and controls will have grown up), depending on with which language the interviewee is most comfortable, by staff fluent in the chosen language. Instruments will be written originally in English, and then translated back translated for other languages. All new enrollees will provide an extensive baseline interview. For enrollees under the age of 18 a parent or legal guardian will be interviewed together with the enrollee. Briefly, the interview will include demographics (age, gender, religion/ethnicity, education, measures of socioeconomic position, location of birth and childhood, and location of all residences), information to assess past and current potentially adverse exposures with particular reference to the respiratory tract (use of tobacco/exposure to environmental tobacco smoke, exposure to indoor cooking using biomass fuels, type of housing, detailed job history), personal and family medical history (diagnosed illnesses, reported symptoms) with particular emphasis on the respiratory tract (including questions on frequency of upper and lower respiratory infections, interference with ability to work or with other activities of daily living, medication use, and health services utilization). Our study team has extensive experience with the design and administration of such interview instruments at the Agbogbloshie e-waste site as well as other sites in Ghana, using well-validated questions and protocols. During the repeated visits with each participant at 12 months and 24 months after enrollment, a more limited interview will be administered focusing on any changes from the previous year. Also, we will first administer a much briefer screening questionnaire to potential controls to determine if they will be invited to join the study. The screening questionnaire will assess items on which we wish to roughly group match the controls to the recruited e-waste workers (age, gender, length of time residing in the greater Accra, area of country from which person migrated to Accra, and religion/ethnicity).

Spirometry. Trained study personnel under the direction of a physician or respiratory therapist will conduct spirometry using the EasyOne Diagnostic spirometer (ndd Medical Technologies, Andover, MA) and following all American Thoracic Society (ATS) guidelines (Miller MR et al, 2005). The lung function indices of primary interest will include FVC, FEV1, and mid-expiratory flow (FEF25-75). Ethically appropriate reference values will be used for interpretation (Hankinson JL et al, 1999). Each participant will perform spirometry at enrollment, 12 months, and 24 months.

Buccal swab sample for possible future genetic analyses. Owing to the already substantial costs and complexity of the proposed study, and the somewhat limited level of available funding, we will not be conducting concurrent genetic testing of participants. We will request consent to obtain a sample of the DNA through buccal swabbing for storage for possible future genetic testing, should additional funding become available. As part of the consent process we will inform parents and guardians that a) if we receive additional funding in the future, we will check the sample for genes that may put an individual at risk for more severe effects on respiratory health owing to e-waste associated exposures; b) the sample will be used only to look at genes affecting susceptibility to potentially harmful exposures and in the risk for respiratory conditions; c) they are free to decline participation in this aspect but still participate in all other aspects of the study, and also free to change their minds from "yes" to "no" at any time during or after the sample has been collected (in that case, we would destroy the sample promptly); and d) that all stored DNA samples will be destroyed no later than 5 years after the end date of the study. To obtain buccal DNA samples, we will use the Puregene Buccal DNA Isolation Kits (Gentra Systems; Minneapolis, MN). Sample collection, handling, and extraction will follow manufacturer's recommendations (http://www.flowgen.co.uk/html/prodinfo/tech/dna%20extraction.html#c_dna_kits). All DNA samples will be aliquoted, bar-coded and stored at −80 °C.

Data Management. Interviews and test results will be established as both paper and computer versions. Pulmonary function and symptom data from the EasyOne spirometers will be directly downloaded onto computers into Microsoft Access. To ensure data entry accuracy, 10% of records will be double-keyed. Databases and appropriate data checking and quality control systems will be created. The databases will...
contain several sources of data, including baseline in repeated interviews, biologic samples and personal air sampling test results, caregiver interview, ambient air pollutant exposures. The person-specific data will be indexed by participant ID numbers so that they can be easily merged when analyzing the data. A computerized tracking system database will be created, maintained, and periodically updated to track each participant’s status during the study. It will contain a personal identifier field which will include each participant’s name, ID number, and home address, and phone number, and each needed contact. To ensure confidentiality, data used for analysis will only contain participants’ ID numbers. Data will be read in the Statistical Analysis System (SAS, Cary, NC) version 9.4. Independent checks of range, validity, consistency and missing data will be performed. Logic check programs will be run to ensure that each value found in the data falls within the expected range or corresponds to possible values in the codebook created specifically for each type of data collected. Any discrepancies found will be resolved by the research team. SAS will be utilized for data management. A secured “data library” website will be established to allow for tracking data entry and data management activities and to allow for data sharing among investigators.

**Data Analysis.**

Specific Aim 2. After standard checks, adjustments, quality assurance, and other processing of the biological measures of metals and organic compounds, personal exposure measures of PM$_{2.5}$, formaldehyde and other organic compounds (flame retardants, PAHs, dioxins), we will provide a descriptive and exploratory analysis in order to understand trends, correlations and outliers. This will include univariate descriptive analyses (mean, median, measures of central tendency, standard deviations, time plots, scatter plots). ANOVAs, t-tests, and, dependent on the normality of original log transformed exposure and does data, potentially non-parametric tests such as Kruskal-Wallis will be used to determine whether biomarkers of metals and organic compounds vary significantly when comparing e-waste workers to controls, and, among e-waste workers, across jobs (hypotheses 2.1 and 2.2). To look for associations between biomarkers and other variables, including meteorological and time-of-day factors, and concentrations and bioavailability of metals and organic compounds across various media, including personal and area measures of airborne exposures to specific compounds, multivariate analyses will be conducted, including ANOVAs, correlations and factor analyses (hypotheses 2.3 and 2.4). Lastly, using well-established, accepted methodologies (Van den Berg M et al, 2005; Budroo JD et al, 2009), we will investigate whether predicted cancer risks associated with measured levels of certain metals, flame retardants, PAHs, and dioxins, will significantly vary between e-waste workers to controls, and among e-waste workers, between burners and other workers (hypothesis 2.5).

Specific Aim 3. Preliminary analyses will include descriptive statistics such as frequencies, means and variances of the variables of interest will be calculated. Normality assumptions of continuous variables will be examined. Outliers will be identified. Univariate and bivariate analyses will be used to describe the characteristics of the study population and to look at the crude associations between variables of interest. For categorical dependent variables, odds ratios will be calculated. For continuous dependent variables, correlation coefficients will be calculated. Correlations, scatter plots, and other analyses will provide an overall picture of the data and will be useful in the subsequent multivariate analyses. Multivariate analyses using multiple regression models of longitudinal data will be performed. We will use Generalized Estimating Equations (GEE) which account for the correlation among the observations over time obtained from the same participant by constructing a robust covariance matrix in estimation of the standard errors of the regression coefficients. For continuous outcome variables, e.g., FEV$_1$ percent of predicted, GEE linear models implemented in the SAS procedure PROC GENMOD will be used. Distributions of these continuous outcome variables will be examined and appropriate transformations will be taken to achieve normality. For discrete outcome variables, such as frequency of cough we will use the GEE logistic and Poisson approaches, which are multivariate analogs of conventional logistic and Poisson regression.

The key exposure variables in our analyses of respiratory outcomes include the 3-level categorical exposure groupings (controls, e-waste workers other than burners, burners) and quantitative personal and area measurements of workplace ambient air pollutant levels. Other than the 3-level categorical exposure grouping, the key explanatory variables will be time-varying ambient exposures. Parametric exposure effects (e.g., linear or quadratic effects) using parametric GEEs and nonparametric exposure effects (e.g., complicated nonlinear or threshold effects) using spline mixed effects models and kernel GEEs, adjusted for relevant covariates, will be explored.

Power calculations. Our exposures of greatest interest are the 3-level exposure category groups used to define the recruiting strategy, and individual-specific measures of exposures. Our primary health outcomes include measures of FEV$_1$ percent of predicted and common lower respiratory symptoms (e.g., wheezing,
<table>
<thead>
<tr>
<th>Job category mean FEV1 (% of predicted(^d))</th>
<th>(A) Controls</th>
<th>(B) Non-Burners</th>
<th>(C) Burners</th>
<th>Std. Dev.</th>
<th>rho(^d)</th>
<th>(A) vs (B)</th>
<th>(A) vs (C)</th>
<th>(B) vs (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Direct effect of job category on respiratory health outcome(^a)</td>
<td>91.3</td>
<td>99.0</td>
<td>99.0</td>
<td>12.5</td>
<td>0.5</td>
<td>90.5</td>
<td>90.5</td>
<td></td>
</tr>
<tr>
<td>2) Effect of job category on respiratory health outcome based on interactions with substantial past or current exposure to indoor cooking using biomass fuels(^5)</td>
<td>Exposed substantially to biomass fuels</td>
<td>12.0</td>
<td>84.0</td>
<td>90.5</td>
<td>82.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not exposed substantially to biomass fuels</td>
<td>12.0</td>
<td>84.0</td>
<td>90.5</td>
<td>82.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent of job category reporting cough</td>
<td>1) Direct effect of job category on respiratory health outcome(^4)</td>
<td>89.7</td>
<td>90.1</td>
<td>88.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2) Effect of job category on respiratory health outcome based on interactions with substantial past or current exposure to indoor cooking using biomass fuels.</td>
<td>Exposed substantially to biomass fuels</td>
<td>47.0</td>
<td>81.2</td>
<td>82.5</td>
<td>80.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not exposed substantially to biomass fuels</td>
<td>47.0</td>
<td>81.2</td>
<td>82.5</td>
<td>80.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1: “Job categories” include those burning e-waste to recover metals (C), all other e-waste jobs (B), those not working with e-waste and residing in a distant community (A)
2: Each outcome is measured three times in each participant at enrollment and at follow-up at 12 and 24 months
3: Estimated FEV1% predicted for controls is 90, and estimated SD of 12.5, are based on representative data collected by our team in a study in northern areas of Ghana from which the majority of current study participants (controls and e-waste workers) have migrated to Accra.
4: Estimate of 30% with cough is based on data collected in northern Ghana as per footnote 3
5: Estimate is that 50% have substantial past or current exposure to indoor cooking using biomass fuels based on data collected in northern Ghana as per footnote 3

As can be seen in the table, for the direct effect of job category on the two respiratory outcomes, power was excellent (a minimum of 90.5% for any of the three 2-group comparisons for FEV1 percent of predicted, and a minimum of 88.1% for a report of cough). Inclusion of an interaction term between job category and substantial exposure to biomass fuels somewhat diminished the power for estimating the effect of job category on respiratory outcomes, but values are still in acceptable ranges of 82.9% and 80.7% respectively for FEV1 percent of predicted and for cough.

**Future e-waste studies.** There are a number of appealing potential directions for additional e-waste studies in West Africa beyond this fully planned e-waste workers study at Agbogbloshie. The first three of these we expect our research groups to be engaged with over the next few years, the fourth is more dependent on future circumstances. As is true for the workers study at Agbogbloshie, we expect the development and launch of these future opportunities to provide excellent training opportunities that can be integrated into the overall strategy of the developing West Africa EOH hub.

Comparative studies of e-waste workers at the other West African sites. We will work with our regional collaborators to conduct descriptive studies and initial/comparative analytical studies (e.g., cross-sectional studies on exposure biomarkers and demographic health surveys) most likely on e-waste facilities in Tema, which is the entry port city near Accra, as well as in two other countries (most likely Benin and Senegal, though this would be decided after a phase of information gathering about potential sides: criteria for selection would likely include size of site and workforce, work methods being used, ease of access and level of enthusiasm of leaders and workers on site for the study, level of interest of in-country academic/governmental institutions for a study at this site, fit with the overall research training structure and plans of the GEOHealth initiative.). Since Agbogbloshie is expected to be “mature” compared to most other sites, lessons learned from our work in Ghana may inform us of better and safer practices elsewhere in the
region where e-waste is in its infancy and thus may be better managed. In addition, while we will invite researchers from other West African countries to work at Agbogbloshie as part of a large team effort, to further ensure a vibrant and integrated GEOHealth hub for West Africa we recognize that parallel research efforts are needed in other countries. Study design at a new site most likely will incorporate many of the elements being used at Agbogbloshie in order to improve and better interpret comparisons across sites.

Studies of acute trauma among workers at Agbogbloshie. Anecdotally, this appears to be a major health and safety issue at the site with frequent reports of lacerations and some reports of fractures. Because of recent studies of acute trauma our group has conducted at an informal gold mines, we have well-developed draft instruments and data analysis strategies that can readily be adapted to e-waste. As compared to exposures to metals and organic compounds, job categories at highest risk are likely to differ (e.g., dismantlers for acute trauma), and any recommended interventions may be more "common-sensical" than those for unseen pollutants and rapidly taken up by well-informed workers.

Studies of persons residing in communities adjacent to the Agbogbloshie. Especially smoke created during burning may result in substantial exposures to residents of adjacent communities. Certain populations (pregnant women, fetuses, infants and young children) may be at particularly high risk for adverse health outcomes. The inclusion of various sampling and modeling of exposures in the workers study, lays a foundation for developing refined methods of exposure estimation for community members. A birth cohort study with enrollment of women early in their pregnancy is likely to be an appealing design.

Studies with major focus on interactions between e-waste associate exposures and indoor cooking with biomass fuel exposures. If populations at high risk of exposure to both sources could be identified, high health risks might be demonstrated which could be substantially ameliorated with identifiable interventions.

Identified areas for pilot studies.

Metals exposures in the informal mining sector and other extractive industry exposures. Metals persist indefinitely in the environment and understanding their impact is crucial to achieving sustainable land-use. Several metals, such as manganese and zinc, have essential roles in human health but these same metals can also be toxic at high concentrations. Other metals such as lead, arsenic, cadmium, and mercury have no known biological function and are ranked as top priority pollutants by regulatory bodies including the U.S. Environmental Protection Agency (EPA) and the U.S. Centers for Disease Control CDC). The mining sector is a major source of metals pollution worldwide. Currently there are approximately 15,000 active and 550,000 abandoned mines across the United States, and many more internationally (CDC NIOSH, 2005; Hu et al., 2007). Understanding the health risks associated with these sites is essential for land reclamation, remediation efforts, and designing sustainable mining operations for the future. Electronic waste recycling can be viewed as a modern form of mining with many of the same challenges as traditional sites. The wastes generated from recycling electronic items are comprised of chemically complex metal mixtures, as our pilot studies at Agbogbloshie have shown. Elucidating routes (i.e., soil, food, air, water) by which humans are exposed to these real-world mixtures is challenging but necessary to gauge risk and intervene. In addition, the bulk majority of electronic waste sites are situated in low- and middle-income countries in informal sector activities which often pose barriers to conduct the studies and implementation of public health interventions.

Ambient air pollution from informal sector transport. Air pollution is the focus of the COPEH-WCA group, who have received a 5-year International Development Research Centre (Canada) EcoHealth Chair to launch a series of urban air pollution studies across Francophone West African cities. A great opportunity exists here to work with COPEH-WCA to co-design studies that would also include Ghana to utilize the same methods, techniques, and study designs to ensure comparability of findings (note, at their invitation and financial support, we attended the COPEH-WCA planning meeting in Spring 2014). The planned COPEH-WCA ambient air pollution studies in Cotonou, Benin and Dakar, Senegal can be complemented with a parallel study in Accra (Ghana). In addition to the focus on informal sector transport (most of these exposures are expected to arise from trucks and vans), exposures from the Agbogbloshie electronic waste site (which is located near the central business district) could be included in such a study. In keeping with the focus on electronic waste and but also being cognizant of this pan-West African effort on urban air pollution. Proposed parallel studies could address two objectives of (1) characterizing ambient air quality impacts from the informal transport sector, and from electronic waste, in two or more African cities using low-cost portable air pollution instruments; and (2) evaluating the impacts and the benefits of strategies intended to reduce truck and van emissions and exposures.

Experimental approach. For objective 1, activities could include: field campaigns measuring particulate matter (PM2.5), black carbon (BC), and other pollutants along high and low traffic roads simultaneously in two seasons using several types of low-cost and portable instrumentation in conjunction with fixed site monitors; conducting simultaneous traffic surveys for these roads; quantifying local-scale spatial variation by contrasting results at high and low traffic sites while accounting for traffic and meteorology; and apportioning PM2.5 sources using spatial and temporal variation, traffic surveys, receptor modeling, and near-road dispersion modeling. For objective 2, activities include the use of measurement and modeling approaches to assess benefits associated with several approaches that can decrease emissions from the transport sector.

Expected results. The proposed project will provide new information regarding the use of low-cost portable instrumentation in urban settings, local scale variation in air pollutants, the impact of traffic and especially
truck traffic, and the effectiveness of several controls. The research is significant in its focus on traffic, one of the most significant urban emission sources; its innovative and easily replicated design that accounts for potential confounders; its application of up-to-date analytical and modeling techniques to interpret the collected data; its attention to quality assurance and sensor intercomparisons; its application to multiple sites and seasons, providing statistically robust results, and its evaluation of several control strategies. Overall, the project will identify and demonstrate effective ways to use low cost portable sensors and the knowledge gained to inform policy and environmental management actions that can reduce emissions and exposures.

Data Management, Sharing, and Dissemination Plan. A number of investigators on our team (especially key individuals from UM, including Drs. Mukherjee, Robins, and Batterman) have extensive experience in running data-intensive research studies. Notably, Dr. Mukherjee runs a number of NIH-funded Data Management Core facilities, and thus we would draw upon her leadership in this area. Many on our team have prolific dissemination records, and we further commit ourselves to disseminating findings through traditional approaches (conferences, publications, policy briefs, fact sheets) as well as social media (e.g., through our website, list-serv, twitter, etc.). Through the U2R application, activities are proposed to better train our students to manage and analyse data. All data generated from the proposed research will be shared across the West Africa institutional partners, but also shared with the full network of funded GEOHealth Hubs according to the Network Steering Committee and guided by our AOC. The AOC designated responsibilities will include the establishment and periodic review of plans for ensuring access to data by all sites, analytic resources, publication and authorship rights, the possibility of public use of research materials and data, or other means of distributing research and training materials to the wider community, and a means of arbitrating disagreements on publication and other issues. The guidelines for the establishment and future direction of the AOC will include a willingness to engage in research and capacity building activities, including data sharing, across the network of funded GEOHealth Hubs.
Planned Enrollment Report

This report format should NOT be used for collecting data from study participants.

Study Title: The West Africa-Michigan CHARTER II for GEOHealth

Domestic/Foreign: Foreign

Comments: All participants will be native Ghanaian male workers [no females employed on the study site]

<table>
<thead>
<tr>
<th>Racial Categories</th>
<th>Ethnic Categories</th>
<th>Not Hispanic or Latino</th>
<th>Hispanic or Latino</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>American Indian/Alaska Native</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Asian</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Native Hawaiian or Other Pacific Islander</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Black or African American</td>
<td></td>
<td>0</td>
<td>132</td>
<td>0</td>
</tr>
<tr>
<td>White</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>More Than One Race</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>0</td>
<td>132</td>
<td>0</td>
</tr>
</tbody>
</table>
LITERATURE CITED


NIOSH. 2005. NIOSH Mining Safety and Health Research – Mining Operations. CDC NIOSH. Available at: http://www.epa.gov/region6/6sf/pdffiles/tar-creek-rod-ou2-res.pdf [accessed 01/20/08]


