A Prototype Research-PUI University Environmental Course to Expand Research Opportunities for Undergraduates

Aaron A. Jennings, Ph.D., P.E.
(aaj2@po.cwru.edu)
Department of Civil Engineering
Case Western Reserve University
Cleveland, OH 44104-7201

Zuhdi Aljobeh, Ph.D., P.E.
(zuhdi.aljobeh@valpo.edu)
Department of Civil Engineering
Valparaiso University
Valparaiso, IN 46383

Abstract

Case Western Reserve University (CWRU) is a research university in Cleveland, Ohio. Valparaiso University is a predominantly undergraduate institution (PUI) in Valparaiso, Indiana. These two universities are experimenting with a unique teaching/research partnership that represents a new model for how National Science Foundation (NSF) Research Experience for Undergraduates (REU) programs can be designed. The program builds on the strengths of partner universities to expand the research opportunities for undergraduate students who might otherwise not be aware of these possibilities and extends research activities to predominantly undergraduate institutions. This manuscript describes the design of this program's prototype Environmental Engineering course titled "Heavy Metal Contamination in the Urban Environment" (CE 490 B) that is being offered at Valparaiso University in the spring semester of 2004.

Introduction

The CWRU-Valparaiso teaching/research partnership is designed to experiment with a new model for involving undergraduate students in Civil Engineering research. The fundamental concept is to have faculty from CWRU and PUIs team-teach special topic research courses taken for academic credit at PUIs during the academic year. The goal of improving research exposure for PUI students was recently identified at an NSF workshop. Team-taught courses offered at PUIs that focus on the topics of ongoing NSF research projects at "research universities" appear to be excellent opportunities for accomplishing this. Furthermore, students of these courses will be given the opportunity to continue on into more advanced summer research residencies at CWRU. The program is similar to existing NSF REU programs, but adds several important innovations.

(1) This new model will focus on interactions with engineering schools that do not have graduate programs, or do not offer a Ph.D. in engineering. The students of these institutions, and especially the students at schools that do not have graduate programs,

have less opportunity to experience research, so they are less likely to respond to "typical" REU opportunities if and when they hear about them.

(2) This new model will generate more direct participation than would otherwise be possible with conventional REU funding. It will reach a whole class of students rather than one or two individuals. It will also create sustained semester or yearlong events that impact whole departments of undergraduate students at PUIs since essential project tasks will be conducted using the facilities of these "home" institutions.

(3) This new model will engage both undergraduate students and the teaching faculty of PUIs and will do so for sustained periods of time. The intention is to design research courses so that they may become a permanent feature of PUI curricula.

(4) This new model will bring together PUI undergraduate students from multiple institutions for more advanced research experiences hosted at CWRU. These advanced experiences will build upon the research activities conducted at the home institutions, so these students will have a competitive advantage over their more traditional REU counterparts.

(5) This new model will require institutional commitment on the part of both CWRU and the PUI. It will require allocation of faculty and facility resources at both institutions. It will also require flexibility in the use of special topic courses to allow students to accumulate academic credit for participation in research. Although all of these might be thought of as disadvantages, overcoming these challenges helps to build commitment. The required administrative details will be finalized at the Department Chairman level, which, in addition to implementing specific program details, helps to reinforce the academic relationship necessary to sustain the program in subsequent years.

PUIs are a largely untapped source of high quality undergraduate students who are less likely to appreciate the impact that advanced scholarship can have on their careers. Offering research courses at PUIs helps to introduce students to research and provides the expertise they need to participate in advance REU activities at research universities. This also extends the impact of research to a larger student population than would be possible with typical REU funding. In addition, the relationship developed between the research university and PUI participants helps promote faculty professional development, helps to introduce innovative special topics courses as a sustainable feature of PUI curricula, helps laboratory development efforts and opens doors to more undergraduate research opportunities for PUI faculty and students. It also helps to disseminate results of Civil Engineering research and can be a source for laboratory and field data that would not otherwise be available to research projects. However, accomplishing all of this requires research courses that can be transported to PUIs and implemented with a realistic effort by the participating faculty.

Program courses are currently being designed for Environmental, Geotechnical and Structural Engineering using the following general template.

(1) **Initial Course Planning** - The type of courses to be offered will be planned and scheduled by CWRU and PUI Department Chairmen who will determine which of the potential research courses will work best at the PUI given student interests and the availability of faculty and laboratory resources. Chairmen will finalize issues of faculty compensation, student academic credit, faculty and course evaluation and the mechanisms for establishing course grades.

(2) **Course Recruitment -** Students will be recruited into the selected special topics course offered as a one or two semester Junior/Senior research elective at the participating PUI. Student participants will be recruited by the PUI faculty member who will work with the CWRU professor to design and conduct the course. Course implementation details will be established in a curriculum planning meeting conducted at the PUI to finalize curriculum details, develop course promotional materials, identify potential technical or administrative challenges, identify research material needs, visit possible field research sites and determining course end products.

(3) **Inaugural Course Meeting -** At the beginning of the course, the CWRU professor will travel to the PUI to help the home institution professor meet with enrolled students and present a framework plan for the research course to its students. This will help reinforce the idea that the both professors have formed a team to offer the course, and help establish lines of communication between the students and the CWRU professor. This will improve the effectiveness of the upcoming research residency.

(4) **Research Residency -** Midway through the course (as weather or research facility utilization dictate), the CWRU professor will travel to the PUI to participate in a one-week research residency. This will be a concentrated period of course activity where both professors supervise the students in laboratory and/or field research tasks.

(5) **Course Closure -** The CWRU professor will also travel to the PUI at the end of the semester to help conclude the course. Both professors will participate in the evaluation of student presentations and research reports, and will help in establishing final student grades. Course evaluation tasks will also be conducted to determine where improvements can be made to enhance the quality of the research experience. This meeting will also provide an opportunity to select students for an advanced CWRU summer REU experience that builds on the content of the course.

The prototype Environmental Engineering course titled "Heavy Metal Contamination in the Urban Environment" (CE 490 B) is being offered at Valparaiso University in the spring semester of 2004 by the authors. This course will explore the recent research conducted at CWRU on the "expected" heavy metal contamination found at brownfields, the "unexpected" legacy heavy metal contamination found in the public lands (commons) in brownfield communities, and the "unheard of" growth of stormwater runoff heavy metal contamination from feral batteries. The following sections provide a brief summary of each of these topics, and describe the roles that undergraduate researchers have played in their development.

Brownfield Heavy Metal Contamination

Brownfields are abandoned or underutilized industrial properties that are difficult to redevelop for several reasons including concerns about environmental contamination in the buildings and surrounding lands. Often these sites suffer from the unique problems of "old contamination". Because they have been contaminated for many years (many decades in some cases), they are selective for "residual" contamination that can be difficult to remediate. If the contaminants were water soluble, volatile or biodegradable, they would not have been able to linger at these sites for prolonged periods of time. Therefore, when contamination is found, it tends to be very immobile and is often firmly attached to the soil. This is generally the case with heavy metals. Often heavy metals are found in the near surface soils of these sites and are very immobile under normal environmental conditions. However, these heavy metals can pose significant health risks when people come in contact with these surface soils. Children in particular are prone to ingesting and inhaling soil "dust" as they play. Because the digestive system is an HCl acid environment, the metals can be solublilzed and become much more available to exert toxic impacts. Therefore, the "immobile" heavy metal contamination of surface soils can lead to an unacceptable accumulation of human health risk.

Interest in Cleveland area brownfield soil contamination grew out of a 1996 study in the area of a notorious lead smelting site in the Cuyahoga River "flats" (Pfaff, 1996). Dr. Jennings joined the faculty of CWRU in 1993 to launch a new program in Environmental Engineering that concentrated on emerging topics such as urban soil remediation. Ms. Lisa Pfaff was an undergraduate student recruited to work with Dr. Jennings during the summer of 1994 on a summer internship project that included equipping new Environmental Engineering laboratories for advance heavy metal analysis. Ms. Pfaff continued on into graduate studies at CWRU and did her thesis research on lead soil contamination around Cleveland's Master Metals site. This work led to an assessment of soil extraction techniques and the development of a screening extraction method (the CWRU 1N HCl, 2h Hr. Ex.) that is still in use today (Pfaff and Jennings, 1996). The work also identified near surface soil lead contamination as high as 23,750 mg/kg. The current standard of "child contact" residential soil is 400 mg/kg (USEPA, 2001), so values like 23,750 mg/kg represent profound contamination and serious health risk.

The work of Ms. Pfaff and other graduate students who examined remediation of lead-contaminated soil led to major NSF funding of CWRU's heavy metal soil contamination research. One of the tasks of this program was to identify soils that were contaminated with heavy metals other than lead (Ms. Pfaff focused exclusively on lead). The necessary field survey of Cleveland area soils was to focus on brownfields as likely sources of old contamination soils and involve use of REU students to help staff field crews.

An extensive survey of Cleveland area brownfield heavy metal soil contamination was conducted in 2001 by field crews made up of Dr. Jennings and three REU students: Ms Allison Cox, Ms. Sara Hise and Mr. Elijah Petersen. Together, Dr. Jennings and the students sampled over 50 Cleveland area brownfield sites and eventually identified 8 soils that were ideal for future research on the mechanisms of old soil contamination of Cd, Cr, Cu, Ni, Pb and Zn. However, in doing so, the field team also generated an unprecedented amount of data on the extent of heavy metal contamination in Cleveland area brownfields. Sites were identified with concentration as high as 55 mg/kg for Cd, 575 mg/kg for Cr, 22,500 mg/kg for Cu, 836 mg/kg for Ni, 15,170 mg/kg for Pb and 13,400 mg/kg for Zn (see Jennings et al. 2002) using extraction techniques based on the work of Pfaff (1996).

Once the magnitude and extent of brownfield heavy metal concentrations was identified, the team began to seek a context within which to interpret the numbers. This began with an analysis of state soil contamination/remediation standards, which were found to have an amazing degree of variability for all heavy metals except lead. The lead standards appear to have been stabilized by the presence of a national guideline, which many states have adopted (USEPA, 2001). Because the standards in use around the U.S. left a great deal of uncertainty in the interpretation of contamination levels, the team began to investigate "background levels" (i.e. levels of naturally-occurring heavy metals in soils) as a basis for interpretation. This was done by literature survey of background studies and by seeking sampling locations that had not been used as industrial real estate. Ultimately it was the last investigation that led to the ongoing research on legacy heavy metal contamination in commons.

In seeking non-industrial real estate in which to measure more natural heavy metal concentration levels the team began to sample public commons such as parks, playgrounds, school yards, city gardens and nature preserves in and around the greater Cleveland area. Surprisingly, many of this location also yielded significant (potentially unacceptable) heavy metal concentrations. Values as high as 1.8 mg/kg for Cd, 70 mg/kg for Cr, 360mg/kg for Cu, 27 mg/kg for Ni, 811 mg/kg for Pb and 527 mg/kg for Zn were originally measured (see Jennings et al., 2002). These levels of contamination led to ongoing research on the magnitude, risk and remediation of heavy metal contamination in commons discussed in the following section.

During the field survey work of 2001, the field crew also made an interesting observation about another source of heavy metal contamination in the urban environment. Field activities often required shopping for supplies (and food !). While shopping at a Wal-Mart for "shoe box" sample containers, the team observed several batteries lying on the parking lot pavement. This prompted a discussion of the types of materials that batteries would release to the environment, and a more careful assessment of the number of batteries present. A systematic survey of the parking lot recovered 54 batteries in various stages of deterioration, and to the identification of "feral batteries" as a new class of urban pollution. Ultimately, this led to CWRU's ongoing research on the stormwater pollution potential of feral batteries (also described in a following section).

Of the three undergraduate students who participated in the summer 2001 surveys, all went on into graduate studies in Environmental Engineering. Ms. Allison Cox did research on the use of an electronic nose to characterize solid waste odors (Cox, 2002). She completed her MSCE degree in 2002 and is currently serving in the Peace Corps. Ms. Hise formed a team (discussed below) to examine issues associated with feral batteries. She participated in a REU/RET project in the summer of 2002 and completed her MSCE degree in 2003, (Hise, 2003). Mr. Petersen participated in a research project to quantify the risks of Cleveland area commons heavy metal contamination. He completed 2 BS degrees and a MSCE degree in 2003 (Petersen, 2003) and is currently in Ph.D. studies at the University of Michigan.

The prototype Environmental Engineering course titled "Heavy Metal Contamination in the Urban Environment" will examine heavy metal burdens at Valparaiso area brownfields identified by the participating Valparaiso University students.

Legacy Common Heavy Metal Contamination

Based on the results of 2001 field surveys, a research project was launched to quantify the risks of heavy metal contamination in Cleveland area commons. Near surface soils were sampled at over 50 sites and analyzed for their "whole grain" and "dust fraction" heavy metal concentrations (Petersen, 2003). Screening analyses base on the work of Pfaff (1996) were used, but samples were also analyzed using other more aggressive extraction methods (Jennings and Deng, 2003; Deng and Jennings, 2003) including EPA Method 3050B (USEPA, 1996).

Chemical analysis of these samples yielded values as high as 6 mg/kg for Cd, 76 mg/kg for Cr, 360 mg/kg for Cu, 40 mg/kg for Ni, 811 mg/kg for Pb and 527 mg/kg for Zn based on a 1N HCl, 24 hr. extraction (Petersen, 2003; Jennings, 2003). However, dust fraction analysis indicated that the dust fraction burden of these soils (i.e. particles with dia. <125 mm) was, on average, 50 % higher than that for whole grain analysis. In some soils the burden was over three times more concentrated (Jennings, 2003; Petersen et al., 2003. Therefore, basing risk analysis on whole grain analysis could underestimate risk since children are more likely to ingest or inhale the small grain size fractions of soil.

The risk associated with heavy metal contamination was evaluated using the hazard index (HI) approach defined as follows (IDEM, 2001; OEPA 2002; ADEC, 2002; CDPH&E, 1997; WDNR, 2001).

$$\mathbf{HI} = \sum_{i=1}^{6} \frac{C_i}{Cs_i} \; \text{£ (?)} \; 1.0$$

Here C_i is the measured heavy metal burden for the i^{th} heavy metal, Cs_i is a guidance reference value for the i^{th} heavy metal and i = (1, 2, 3, 4, 5, 6) correspond to Cd, Cr, Cu, Ni, Pb and Zn. This method assumes that impacts of heavy metal exposures are cumulative so that high but acceptable exposures of individual metals sum to an unacceptable total exposure (HI > 1.0).

To determine appropriate Cs_i guidance values, an assessment was made of the current risk assessment procedures of 31 states (see Fig. 1) and several EPA regions. For the states highlighted in black, additional detail was analyzed using the risk exposure models the states used to develop their guidance levels.

Table 1 summarizes the guidance values used, but readers are cautioned that there is a great deal of "context" associated with each of these numbers. Often the values are default maxima that may be altered by additional site-specific analysis. None of these values should be used without a careful assessment of the state-specific risk analysis instructions. References for each of these guidance values may be found in Jennings (2003b). No states currently identify "commons" as a unique class of site, so guidance values for residential soils were used. Guidance values are presented here for the purpose of illustrating the wide range of variability that currently exists. The state of Ohio is among the least conservative (i.e. highest values) of the states examined.

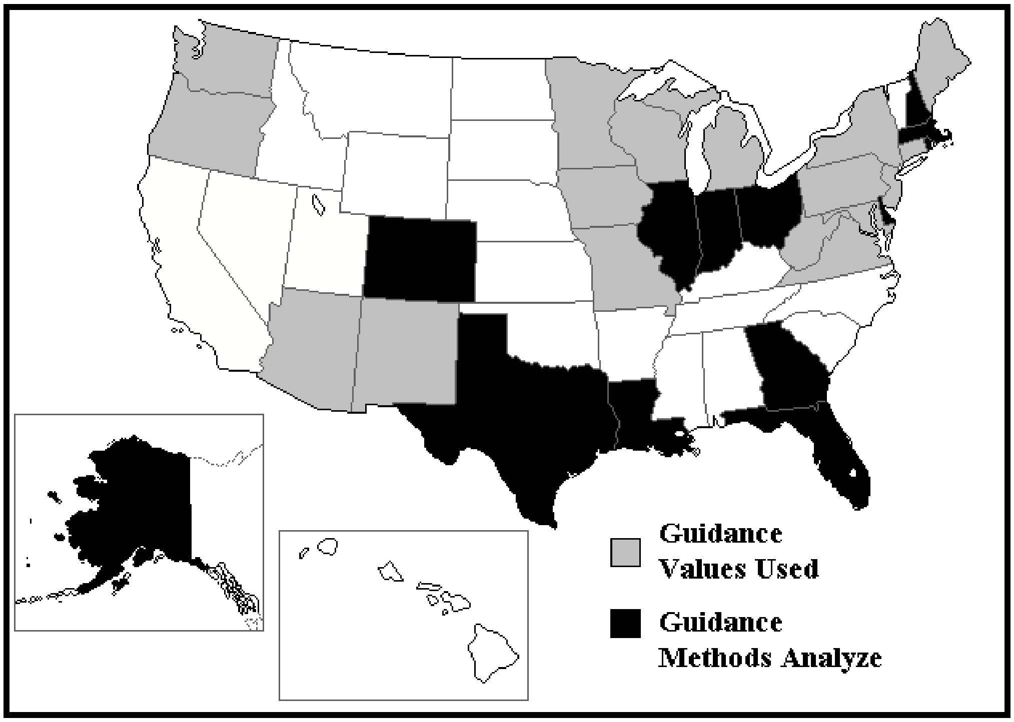

Fig. 1 – States for Which HI Guidance Values Were Used (Jennings, 2003b)

Table 1 – Guidance Values for Heavy Metals in Residential Soils (mg/kg),(Jennings, 2003b)

Location	Cd	Cr(III)	Cr(VI)	Cu	Ni	Pb	Zn
Alaska	83	124400	250	3320	1660	400	24900
Arizona	38	77000	30	2800	1500	400	23000
Colorado	99.5	-	53.94	2570	-	400	-
Connecticut	34	3900	100	2500	1400	500	20000
Delaware	40	120000	35	3100	1600	400	23000
Florida	75	-	210	110	110	400	23000
Georgia	39	1200	1200	1500	420	400	2800
Illinois	78	120000	230	2900	1600	400	23000
Indiana	12	520000	430	13000	6900	400	100000
Iowa	39	120000	230	2900	1600	400	23000
Louisiana	39	120000	230	3100	1600	400	23000
Maine	27	-	950	650	3800	375	1500
Maryland	39	120000	230	3100	1600	400	23000
Massachusetts	3	1000	40	-	30	300	2500

Michigan	550	790000	2500	20000	40000	400	170000
Minnesota	175	172000	355	100	2600	400	43500
Missouri	110	2100(3)	2100	1100	4800	260	38000
New Hampshire	32	1000	130	-	580	400	1000
New Jersey	39	120000	240	600	250	400	1500
New Mexico	70	100000	230	2800	1500	400	23000
New York	1 or SB	10 or SB	10 or SB	25 or SB	13 or SB	61 or SB	20 or SB
Ohio	35	120000	230	-	1500	400	23000
Oregon	100	1000	1000	10000	5000	200	-
Pennsylvania	47	190000	94	8200	4400	500	66000
Rhode Island	39	1400	390	3100	1000	150	6000
Texas	52	30000	120	550	840	500	9900
Virginia	78	120000	230	3100	1600	400	23000
Washington	2	2000	19	-	-	250	-
West Virginia	39	78000	390	3100	1600	400	23000
Wisconsin	40	80000	70	-	-	250	-
Average	**71**	**140000**	**430**	**3900**	**3400**	**370**	**30000**
Maximum	**550**	**790000**	**2500**	**20000**	**40000**	**500**	**170000**
Minimum	**2**	**1000**	**19**	**100**	**30**	**150**	**1000**
EPA Region III	78	120000	230	3100	1600	400	23000
EPA Region VI	39	100000	30	2900	1600	400	23000
EPA Region IX	37	100000	30	3100	1600	400	23000
USEPA	70	120000	230	-	1600	400	23000
Quebec	20	-	-	500	500	1000	1000

(see Jennings, 2003b) for table notes.

Table 2 lists the number of commons sites found to have heavy metal burdens that led toHI values of greater than 1.0. Numbers are indicated based on Cr(III) and Cr(IV) guidance values because the analytical techniques used did not distinguish between Cr(III) and Cr(IV). Generally, old contamination is expected to be Cr(III), but the results of Table 2 indicate that this should be confirmed before making any conclusion about the safety of a site. It should be noted that the results of Table 2 are for 23 states rather than for the 30 states included in Table 1. Connecticut, Iowa, Maryland, Michigan, New Mexico, New York and West Virginia were omitted either because of uncertainty about values, because (as in the case of NY) values were changing, or because the state guidance was not available when the analysis was done

From Table 2 it can be seen that Ohio is among the least conservative in determining "safe" levels of residential soil contamination. Indiana (where the Valparaiso University project will be conducted) is also relatively generous in allowing higher levels of residential contamination.

Figures 2 and 3 present detail on the site-specific HI values computed using Ohio guidance values. Although fewer sites are identified as having HI values >1 than most states, there are at least 8 sites with HI values worthy of concern and at lest two sites where immediate attention is probably warranted.

Mr. Elijah Peterson participated in this research as a graduate research assistant and components of the work became his MSCE thesis (Petersen, 2003). Mr. Peterson was also successful in competing for a NSF graduate fellowship and is currently pursuing a Ph.D. degree at the University of Michigan.

The prototype Environmental Engineering course titled "Heavy Metal Contamination in the Urban Environment" will examine heavy metal burdens in Valparaiso area commons identified by the participating Valparaiso University students. Students will participate in sampling and measuring contamination levels and computing HI values. The students will also develop a plan to address the legal and ethical issues associated with generating this type of knowledge.

Table 2–Number of Commons with Hazard Index >1 Commons Based on Cr(III) and Cr(VI) Guidance

State	Cr(III)	Cr(IV)	State	Cr(III)	Cr(VI)
Alaska	8	10	Missouri	14	14
Arizona	8	32	New Hampshire	12	17
Colorado	7	20	New Jersey	12	16
Delaware	8	10	Ohio	8	11
Florida	18	18	Oregon	19	19
Georgia	11	11	Pennsylvania	2	12
Indiana	9	11	Rhode Island	27	28
Illinois	8	10	Texas	8	10
Louisiana	8	11	Virginia	8	46
Maine	13	14	Washington	28	24
Massachusetts	33	44	Wisconsin	13	12
Minnesota	16	16			
Average	9	10			
Minimum	2	10			
Maximum	33	46			

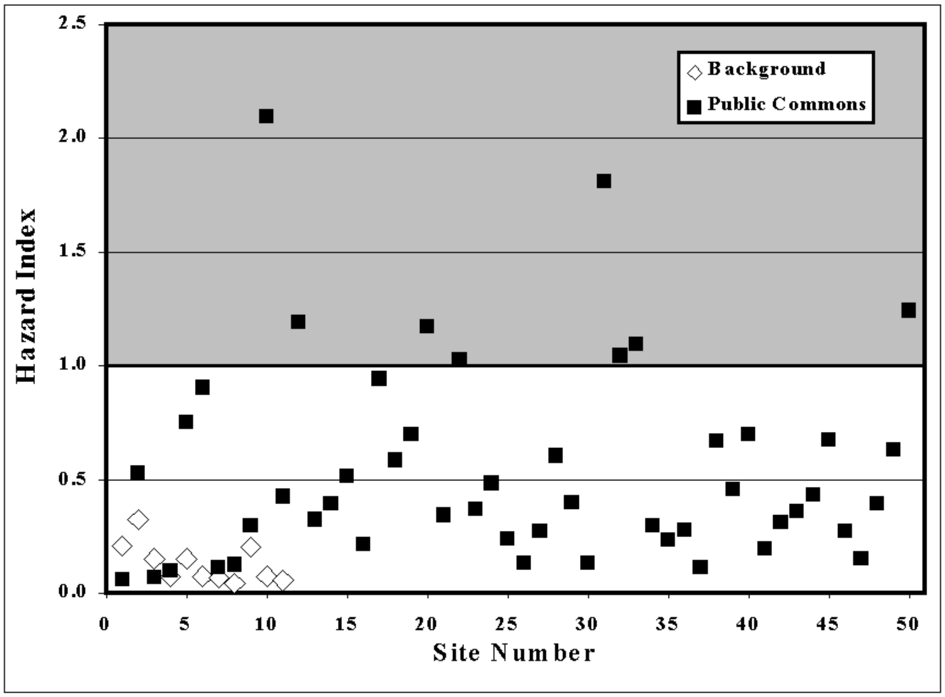

Fig. 2 - Results of HI Analysis for Cleveland Commons and Background Value Based on Ohio Guidance Values and Assuming All Chromium is Cr (III), (Jennings, 2003b)

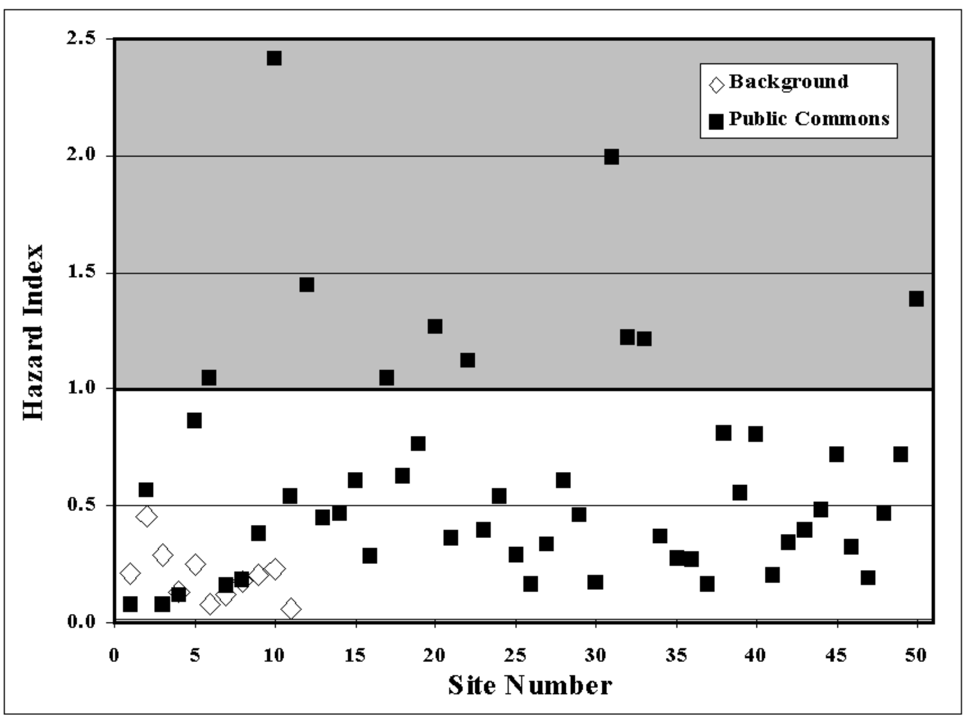

Fig. 3 - Results of HI Analysis for Cleveland Area Commons and Background Values Based on Ohio Guidance Values and Assuming All Chromium is Cr (VI), (Jennings, 2003b)

Stormwater Pollution Potential of Feral Batteries

During the brownfields survey of 2001, the problem of feral batteries was first identified. This has grown into a significant ongoing research topic at CWRU and led to a very successful REU/RET project in the summer of 2002.

Feral batteries are consumer batteries (D, C, AA, AAA, 9v cells etc.) that have "run wild" and can now be found lying in parking lots and on urban street pavements releasing heavy metal contamination to stormwater runoff. Example feral batteries are illustrated in Fig. 2.

Fig. 2 – Example Feral Batteries Decaying on Urban Pavements

During the summer of 2002, Dr. Jennings formed a field survey team made up of two REU students (Ms. Sara Hise and Mr. Bryant Kiedrowski) and one RET (Research Experience for Teachers) participant (Mr. James Clark, a Cleveland area science teacher). This team conducted random feral battery survey in Cleveland area parking lots and on Cleveland area streets, and conducted a series of repeated surveys at two case study locations. The team also developed and documented feral battery survey techniques that would be appropriate to use in K-12 grade educational projects that address environmental issues associated with batteries. Mr. Clark also implemented feral battery surveys at the Brecksville-Broadview Heights High School using the SAFE (Students Active For the Environment) student organization. Details of these efforts were presented at last years ASEE Conference (see Jennings et al., 2003) and will only be summarized here.

Awareness of feral batteries as an environmental issue is new. Little is known about the magnitude or distribution of this form of pollution, and little has been done to mitigate the source or its impacts. The research conducted at CWRU appears to be the first organized work done on this subject. As such, it is "preliminary", but it does provide a great deal of information that will be useful in determining how this issue should be handled.

In over 100 surveys of urban pavements (parking lots, streets), an average of 20 feral batteries were recovered. Furthermore, by following two urban case study sites more closely, annual rates of approximately 2 feral batteries for every urban retail parking space and 1 feral battery for every 6 feet of urban street curb were identified. These sites should probably be characterized as "hot spots" with respect to battery litter, but the data demonstrate that at some locations the battery litter rates are very high (Jennings, 2003a).

Chemical testing of batteries confirmed that they are capable of releasing high concentrations of heavy metals. The work done to date concentrates on zinc releases because this is one of the most common reactants used in disposable alkali or zinc chloride/zinc carbon batteries, and because of zinc's low aquatic toxicity limit. Extraction tests demonstrated that alkali batteries can release soluble zinc in the range of 20-50 mg/l and that zinc chloride/zinc carbon batteries can release zinc in excess of 1000 mg/l (Hise, 2003). Physical deterioration testing also demonstrated that, under passive environmental conditions (i.e. batteries lying undisturbed in a well drained location), feral batteries deteriorate slowly (on a time scale of months) but under "hostile" environmental conditions (batteries in poorly drained conditions and in the presence of an external electrolyte), deterioration and chemical release occurs much more rapidly (Kiedrowski, 2003). Batteries subjected to auto tire loading or to inundation in an aggressive electrolyte such as road salt can deteriorate to the point at which they release their internal contents in as little as a 2 or 3 days (Jennings, 2003a).

Field observations also uncovered what appear to be trends in the consumer battery industry that may compound the environmental impacts of feral batteries. Sales of alkaline batteries manufactured in the United States are losing market share to zinc chloride/zinc carbon batteries manufactured in Malaysia, Indonesia, China, Korea, India, ... This is a problem because these "bargain" imports are manufactured with less environmental control, are manufactured in a way that is much more conducive to leakage, and these power cells have less capacity than U.S. made alkaline batteries. They are gaining market share because they are cheap. They are often sold in "bargain" stores in packs of 12 or 16 for $1.00 and can be purchased in bulk even cheaper over the Internet. This is a problem because these batteries do not last as long as alkaline batteries so they are changed more often which increases their litter rate. Also, when these batteries are littered, they pose a greater contamination potential because of the type of power chemistry used, and more of this contamination potential is realized because their "soft" construction is more easily ruptured.

Of the students who participated in the summer 2002 REU/RET project, both went on to complete MSCE degrees in Environmental Engineering in 2003 (Hise, 2003; Kiedrowski, 2003).

The prototype Environmental Engineering course titled "Heavy Metal Contamination in the Urban Environment" will examine feral battery release properties at a minimum of two Valparaiso area retail parking lots and along at least one Valparaiso "urban" street.

Prototype Course - "Heavy Metal Contamination in the Urban Environment"

The prototype course "Heavy Metals Contamination in the Urban Environment" is being implemented by Dr. Jennings and Dr. Aljobeh in the spring of 2004 with a student enrollment of approximately 10. The first portion of the course will concentrate on introducing the students to subjects such as the details of heavy metal soil analysis, the ethics and responsibilities of environmental sampling, brownfield and commons contamination, risk analysis based on soil contamination data and issues involving disposable consumer batteries and feral battery litter. This will be accomplished by Dr. Aljobeh using reference material that has resulted from CWRU research. During this process, students will plan a field sampling campaign to examine heavy metal contamination a Valparaiso area brownfields and commons, and feral battery litter on Valparaiso area retail parking lots and streets.

Midway through the course, Dr. Jennings will travel to Valparaiso University to work with the course participants for a week of concentrated field activity. Dr. Jennings will present seminars on the subjects of heavy metal soil contamination and feral battery pollution, and will work with the students to conduct field sampling for soil contamination and feral batteries. Feral battery sampling kits were developed as part of the summer 2002 NSF REU/RET project and these will be supplied to the Valparaiso students. Materials for sampling and analyzing soils will also be supplied. Selected soil samples will be analyzed at Valparaiso University with the (anticipated) help of the Chemistry Department. Others will be prepared at Valparaiso University and then sent to CWRU for advanced analysis such as grain-size partitioning, dust fraction analysis and sequestering analysis. However, this analysis will not be completed during the course duration. Rather, this will become the subject of more advanced REU projects during the summer of 2004.

The authors would very much like to include here information about how well this course worked, but this is not possible. This paper is being drafted on literally the first day of classed at Valparaiso University. We are both very enthusiast about who well this will work, but readers will have to wait for our Utah presentation to hear about our successes, challenges, student achievements and student evaluations.

Acknowledgment

Elements of the research described here were supported by National Science Foundation Grant CMS 99-01108 and the NSF Research Experience for Undergraduates (REU) and Research Experience for Teachers (RET) programs. Elements were also supported by the Great Lakes Protection Fund Grant "Feral Battery Heavy Metal Loading on the Great Lakes Ecosystem", by the Cleveland State University Program of Excellence in Risk Analysis Grant "Risk Assessment of Legacy Heavy Metal Contamination in Cleveland Area Commons" and by Case Western Reserve University. The authors also wish to acknowledge the contributions of the previous undergraduate participants Ms. Lisa Pfaff, Ms. Allison Cox, Ms. Sara Hise, Mr. Elijah Petersen and Mr. Bryant Kiedrowski for advancing our understanding of all of the topics addressed in the manuscript and acknowledge the ongoing support of Case Western Reserve University and Valparaiso University and NSF.

Bibliographic Information

ADEC (Alaska Department of Environmental Conservation Division of Spill Prevention and Response Contaminated Sites Remediation Program), (2002), "Cumulative Risk Guidance", Nov., www.state.ak.us/dec/dspar/csites/guidance/cumrisk02_10_07.pdf.

CDPH&E (Colorado Department of Public Health and Environment Hazardous Materials and Waste Management Division), (1997), "Proposed Soil Remediation Objectives Policy Statement", Dec., www.cdphe.state.co.us/hm/soilplcydraft.asp.

Cox, A. (2002), ***Electronic Nose Technology Applied to Environmental Odors***, Thesis, Department of Civil Engineering, Case Western Reserve University, Cleveland, OH.

Deng X. and Jennings, A.A. (2003), "Evaluating an Electrokinetically-Driven Extraction method for Measuring Heavy Metal Soil Contamination, ***Journal of Environmental Engineering*** (in review).

Hise S. (2003), ***Feral Battery Generation Rates and Chemical Release Properties***, Thesis, Department of Civil Engineering, Case Western Reserve University, Cleveland, OH.

IDEM (Indiana Department of Environmental Management), (2001), "RISC Technical Resource Guidance Document", Feb., www.in.gov/idem/land/risc/techguide/index.html.

Kiedrowski, B. (2003), ***Experimental Analysis of Feral Battery Deterioration Rates***, Thesis, Department of Civil Engineering, Case Western Reserve University, Cleveland, OH.

Jennings, A.A. , (2003a), ***Feral Battery Heavy Metal Loading on the Great Lakes Ecosystem***, Great Lakes Protection Fund, Final Report, Case Western Reserve University, Aug. (140 pg).

Jennings, A.A. ,(2003b), ***Risk Assessment of Legacy Heavy Metal Contamination in Cleveland Area Commons***, Cleveland State University Program of Excellence in Risk Assessment Final Report, Case Western Reserve University, Sept., (238 pg).

Jennings, A.A., Clark, J., Hise, S. and Kiedrowski, B., (2003), "Environmental Education Projects Built Around Feral Battery Research", ***Staying in Touch with Engineering Education***, Proceedings of the 2003 American Society for Engineering Education Annual Conference and Exposition, Nashville, TN, June 22-25, (on CD).

Jennings, A.A., Cox, A.N., Hise, S.J. and Petersen, E.J., (2002) "Heavy Metal Contamination in the Brownfield Soils of Cleveland", ***Soil and Sediment Contamination***, 11(5): 719-750.

Jennings, A.A. and Deng, X., (2003), "Evaluating Extraction Methods for Measuring Heavy Metal Burdens in Old Contamination Soils", ***Journal of Environmental Engineering and Science,*** (in review).

OEPA (Ohio Environmental Protection Agency Division of Emergency and Remedial Response), (2002b), "Support Document for the Development of Generic Numerical Standards and Risk Assessment Procedures, Feb. 2002", www.epa.state.oh.us/derr/vap/rules/vaprules.html.

Petersen, E. (2003), ***Legacy Heavy-Metal Contamination in Cleveland Area Public Commons***, Thesis, Department of Civil Engineering, Case Western Reserve University, Cleveland, OH.

Petersen, E.J. and Jennings, A.A. and Ma, J., (2003), "Risk Assessment of Heavy Metal Contamination in Cleveland Area Commons", ***Journal of Environmental Engineering***, (in review).

Pfaff, L. (1996), ***Remediation Alternatives of 'Old' Metal-Contaminated Brownfields Soils***, Thesis, Department of Civil Engineering, Case Western Reserve University, Cleveland, OH.

Pfaff, L.M. and Jennings, A.A., (1996), "Analysis of Lead Contamination in Brownfield Soils", in ***In-Situ Remediation of Contaminated Sites***, Proceedings of the 4th Great Lakes Geotechnical and Geoenvironmental Conference, (ed) K.R. Reddy, University of Illinois at Chicago, May 17, (107-122).

U.S. EPA (2001), "40 CFR Part 745 – Lead: Identification of Dangerous Levels and Lead; Final Rule", ***Federal Register*** , 66(4), Fri., Jan 5, 2001, 1206-1240.

U.S. EPA (1996), "Method 3050B – Acid Digestion of Sediments, Sludges and Soils", SW-846 (3000 series Methods) http://www.epa.gov/SW-846/3_series.htm#3_series

WDNR (Wisconsin Department of Natural Resources), (2001), "Chapter NR 720 Soil Cleanup Standards. Jan.", www.legis.state.wi.us/rsb/code/nr/nr700.html.

Biographical Information

AARON A. JENNINGS, Ph.D., P.E. –

Dr. Jennings is a Professor of Civil Engineering at CWRU. He has taught undergraduate courses in Fluid Mechanics, Hydraulics, Water Supply, Environmental Engineering, Solid and Hazardous Waste and Water Resources and graduate courses in Hazardous Waste, Remediation, Groundwater and Environmental Modeling. Current research projects include improving remediation technology, analyzing soil contamination in public commons and quantifying the stormwater quality implications of consumer battery litter.

ZUDHI ALJOBEH, Ph.D., P.E. -

Dr. Aljobeh is an Associate Professor of Civil Engineering at Valparaiso University. He has taught courses in Environmental Engineering, Environmental Modeling, Water and Wastewater Treatment, Solid and Hazardous Waste Management, and Biological Waste Treatment. Current research projects include cost analyses of stormwater conveyance systems, swine odor control technologies, improving water quality of Indiana Dunes marshes, and modeling of landfill liners hydraulic behavior.