# Increasing Capacity for Environmental Engineering in Salta, Argentina

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**Background** *The Fogarty International Center (FIC) of the United States National Institutes of Health includes the International Training and Research in Environmental and Occupational Health (ITREOH) Program. The "International Training Program in Environmental Toxicology and Public Health" Center, funded in 2002 is based at the University of California, Davis, and is part of the ITREOH group of Centers. It has major efforts focused at the public universities in Montevideo, Uruguay, and Salta, Argentina.*

**Results** *Training and research efforts in Salta begun in 2005 in the College of Engineering. A donated used real-time PCR machine was the starting point and the initial FIC support was instrumental to face other problems including physical space, research projects and grants, trainees, training, networking, and distractions/opportunities in order to develop local capacities in Environmental Engineering using modern methodology. After 6 years of successful work, the Salta center has become a reference Center in the field, and is still growing and consolidating.*

**Conclusions** *This program has had a significant impact locally and regionally. The model used in Argentina could be easily adapted to other fields or types of projects in Argentina and in other developing countries.* Am. J. Ind. Med. 56:11–19, 2013.


***KEY WORDS: Fogarty Center; ITREOH program; infectious disease; water quality; distance learning; training grant; graduate education***

## INTRODUCTION

Society has many needs such as food, energy, and services like water, sanitation, security, and shelter [Krieger, 1999] that must be met in order to increase people's welfare and development. Engineering can play a decisive role in this process by trying to develop products and services as efficiently as possible not only in terms of cost but also in terms of resource consumption and waste generation [Bañares-Alcántara, 2010]. However, development has often been accompanied by adverse consequences to the environment, affecting the health of the population and causing a high social cost [Aucamp, 2003].

In contemporary society environmental problems, such as acid precipitation, groundwater contamination, stratospheric ozone depletion, and global climate change, are regular issues local, regional, or global, and are recognized to be clear consequences of development [Redclift, 1989; Chisari et al., 1996; Dincer and Rosen, 1999]. They can impact on the environment in many different ways, for example, affecting plant's ability to grow [Heisler et al., 2003; Streck, 2005] or aquatic ecosystems

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[Schindler, 1988; Xenopoulos et al., 2000], and increasing the toxicity to terrestrial inhabitants [Solomon et al., 2003], among other impacts. Evidently, there were many factors, external but generated by the productive process, which were not taken into account to arrive at the current environmental situation. These externalities (indiscriminate use of natural resources, inadequate disposal or final destination of the residues, discharge of effluents into waterways, air emissions, etc.) were not originally considered to be part of the cost of production, but have a high impact on environmental health, and consequently on public health [Githeko et al., 2000; Valent et al., 2004]. These impacts involve economic and social costs, which are distinct in different geographical areas (industrialized vs. non-industrialized countries, cities vs. countryside, developed vs. developing world), generally difficult to quantify, and ultimately absorbed by the State and Society [Chisari et al., 1996; Burtraw et al., 1997; Burtraw, 1998; Berger, 2008; Lopes Soares and de Souza Porto, 2009]. In that sense, Kapp defined social costs as "all direct and indirect losses sustained by third persons or the general public as a result of unrestrained economic activities. These social losses may take the form of damages to human health; they may find their expression in the destruction or deterioration of property values and the premature depletion of natural wealth; they may also be evidenced in an impairment of less tangible values." [Kapp [1963a] 1977]

According to the World Health Organization "Environmental health addresses all the physical, chemical, and biological factors external to a person, and all the related factors impacting behaviors. It encompasses the assessment and control of those environmental factors that can potentially affect health. It is targeted towards preventing disease and creating health-supportive environments. This definition excludes behavior not related to environment, as well as behavior related to the social and cultural environment, and genetics" (*sic*) [WHO, 2011].

The World Health Organization has estimated that 24% of global disease (measured in years of healthy life lost), including infectious and non-infectious causes, and 23% of all deaths can be attributed to environmental factors, with differences between various regions due to differences in environmental exposure and access to health care (in developing regions 25% of deaths were attributed to environmental causes, while in developed regions this estimate was only 17%) [Prüss-Üstün and Corvalán, 2006].

Environmental health and public health constitute an interacting system with complex problems (and solutions), which is why there are so many factors that must be controlled and modified. The problem has reached such a magnitude that it requires the active participation of all socially involved participants to develop technologies that will improve productive processes in a comprehensive way, while minimizing adverse environmental effects that tend to prevent disease. Thus, the primary responsibility for public health is no longer only a burden for the professionals who traditionally were involved (doctors, nurses, health, and security officials, sanitary engineers) in curing diseases, caring for the sick, eliminating pathogens, and reducing damage. Environmental health is also now clearly the responsibility of designers, architects, engineers, teachers, employers, industrial managers, economists, biologists, and all others who influence the social or physical environment [Yassi et al., 2002]. The formation of multidisciplinary working teams arises as the only possibility to confront and solve the challenges arising from industrial development. It is expected that each professional involved in this sort of multidisciplinary team effort will have specific training in their own field, but that their education will also be supplemented with a general basic training to enable them to achieve a basic understanding of problems from other areas of knowledge.

Another effective way of solving complex problems is creating networks, which can be formal and informal, personal, or institutional. Networks favor communication and the possibility of sharing resources (information, ideas, technologies, strategies) and contribute to information and education about the constant advances in this field of specialty in the region, thus providing a clear advantage to professionals involved.

While the trend in recent years in the field of engineering has been to design "green" or "clean" manufacturing processes [Tabone et al., 2010; Diwekar and Shastri, 2011; Jimenez-Gonzalez et al., 2011], there is still no full awareness on behalf of the producers, or of the many parts involved in the productive process (engineers, economists, businessmen, and professionals in general), to assume the costs arising from these activities.

For all these reasons, it is essential to professionally train engineers so they are capable of early recognition of the impacts produced by their activities and can engage in emerging technological trends to try to avoid or minimize their consequences and/or remedy them. Only in this way can their future performance help improve and develop effective means of protection against environmental dangers and reduce them, contributing to the development of a healthier, and therefore a more sustainable, environment.

However, today's curricula and training in different careers in engineering generally aim to educate students (future professionals) in the optimization of productive processes from a technical and economic viewpoint, without considering (or considering minimally) the social and environmental aspects involved. Hence the importance of completing or complementing the professional training in engineering, particularly as it relates to the health of the environment and its impact on the health of populations.

This article describes a contribution that is being made from the College of Engineering at the National University of Salta (Universidad Nacional de Salta, UNSa, in Salta, Argentina) that may be of broad interest in other developing countries. The main objectives were to increase the capability and training to assist the public policy maker in decision making related to environmental issues, to impact on the education of professionals to evaluate environmental aspects while accomplishing their roles and to develop collaborative work with other research and educational centers.

Through a grant from the Fogarty International Center (FIC), together with other national and international grants, it was possible to form and consolidate a group of researchers that present different options of training in the study of environmental pollution and its risks for human health through research opportunities for graduate students who want to acquire advanced degrees, and through regular and continuing education courses for advanced and graduated students, who want to acquire additional knowledge before and during the course of their professional careers.

## RESULTS AND DISCUSSION

### The Fogarty Center From University of California in Davis (UC Davis). Brief History and Purpose

The International Training and Research in Environmental and Occupational Health (ITREOH) Fogarty Centers were established to increase research and training capacity in Occupational and/or Environmental Health in the collaborating institutions in low- and middle-income countries. All of the centers share the goal of advanced training of graduate students, postdoctoral fellows, and established practitioners in their field of expertise to increase exposure of new students and established practitioners to modern methodology in occupational and public health. Center trainees are expected to return to or remain in their native country to transmit advanced knowledge and training to future generations of practitioners in their own countries. Each of the centers develops its own unique characteristics depending upon the cultural, economic, and intellectual milieu in the target country and upon the style and creativity of the program director in the US institution.

The UC Davis International Training Program in Environmental Toxicology and Public Health began by training two Major Foreign Collaborators (MFCs), Drs. Gualberto Gonzalez and Beatriz Brena from the University of the Republic in Montevideo, in Bruce Hammock's laboratory in the development and use of ELISAs for environmental monitoring. This program and its contributions to public health in Uruguay have been described previously [Brena et al., 2005]. The UC Davis Center's next step was training the third MFC Veronica Rajal, from the National University of Salta, as a postdoctoral fellow in Stefan Wuertz's laboratory in Environmental Engineering at UC Davis. Her postdoctoral studies allowed her to gain research experience in environmental pollution and pathogen detection in water, using modern molecular techniques such as quantitative PCR analysis.

All three MFCs are dedicated academic scientists who perform research on developing better analytical methods to train graduate students and postdoctoral fellows in the use of modern molecular methods that can be applied to important public health issues in Latin America. With encouragement from the parent program at the University of California, both programs have made a major effort to do translational studies that apply molecular methods to urgent public health problems in their region, so have had impacts in several countries besides their own.

### The Program in Salta, Argentina

Professor Rajal returned to Argentina after completing her postdoctoral training in Davis to form a research group at UNSa that would allow her to train students in this area of knowledge. A timely donation of a used real-time PCR machine from her postdoctoral mentor and an ongoing collaboration with UC Davis allowed her to envision developing local capacity in Salta to perform molecular studies to identify pathogens in water. However, UNSa was not an institution with a strong tradition in modern research and various problems (physical space, projects and grants, trainees, training, and distractions/opportunities) had to be solved to realize this vision. Most of these problems are probably universal when modern research methods are being imported into a developing university in a developing country, and some of them occur everywhere, so the problems and their solutions seem to be worthy of discussion here.

#### *Physical space*

The first problem that had to be solved was to find some space to set up a laboratory where the students could carry out the experiments proposed in their respective work plans. UNSa has grown a lot in the recent years, not only with regard to the number of registered students, but also with regard to the number of researchers and research projects developed in this institution. All of these factors led to a lack of physical space. However, the administration at UNSa, in collaboration with the Research Institute for Chemical Industry (Instituto de Investigaciones para la Industria Química, INIQUI, jointly funded by UNSa and

**TABLE I.** Projects funded by International (AECI, UCD), National (ANPCyT), and Local Agencies (CIUNSa)

| Project title | Funding agency | Period | Total amount ($) | Amount to Salta ($) |
|---|---|---|---|---|
| Water matrix effect on the water disinfection process by ultrafiltration | CIUNSa | 2006–2008 | 2,000 | 2,000 |
| To organize a systematic approach to distance learning to assist UNSa to develop and improve post-graduate degree programs in environmental engineering, toxicology, environmental studies, and public health | UCD | 2006–2008 | 24,000 | 24,000 |
| Ibero American network for research and development of sustainable technologies for water treatment and disinfection | AECI | 2007–2008 | 17,000 | 5,600 |
| Synthesis, modification, and characterization of membranes for separative processes | ANPCyT | 2008–2010 | 45,000 | 45,000 |
| Detection and characterization of enteric viruses from superficial waters with impact on public health in Argentina | ANPCyT | 2008–2011 | 112,500 | 37,500 |
| International Congress on sustainable management of water: Reuse, treatment and quality assessment | AECI | 2008–2009 | 17,000 | 4,200 |
| Microorganisms isolation and identification from areas contaminated with boron | CIUNSa | 2008 | 200 | 200 |
| Dynamic of microbial population in soils contaminated with boron compounds in the Province of Salta | CIUNSa | 2009–2011 | 5,000 | 5,000 |
| Water disinfection by ultrafiltration. Scale up | CIUNSa | 2009–2011 | 5,000 | 5,000 |

the National Council of Scientific and Technical Research [Consejo Nacional de Investigaciones Científicas y Técnicas, CONICET]), provided a small laboratory, initially called the "Water Laboratory," allowing us to initiate the research program.

## Projects and grants

As soon as physical space was identified in which research could be performed, several training projects for graduate students in Salta were initially seed funded by the Fogarty Center, starting in 2005. The relatively low stipends paid to graduate students in developing countries made this initial approach feasible financially, and allowed for substantial leveraging of the available Fogarty funding. Selected projects were aimed at increasing Environmental Engineering capacities through the education and training of students and professionals in the field, and by the development of collaborative work with other centers. Three main lines were followed: water monitoring for pathogens using novel techniques (real-time PCR), study of contaminated soils and strategies to mitigate the corresponding pollution, and provision of additional education for students and professionals in the field. However, sustained growth required a strategy for obtaining extramural funding for the various research projects. Potential competitive, peer-reviewed funding sources at this stage included local sources, especially the Research Council of UNSa (Consejo de Investigaciones UNSa, CIUNSa), national sources including the CONICET and the National Agency for Promoting Science and Technology (Agencia Nacional de Promoción Científica y Tecnológica, ANPCyT), and international sources including the Spanish Agency of International Cooperation (Agencia Española de Cooperación Internacional, AECI, Spain) as well as the University of California at Davis (UCD) (Table I, Fig. 1). The initial FIC support was instrumental in obtaining the funds shown in Table I and also allowed major growth of the research group. In addition, various regional, national, and international research collaborations related to environmental topics were initiated to begin to develop the necessary networks to support multidisciplinary training of graduate students in the UNSa program. All of these

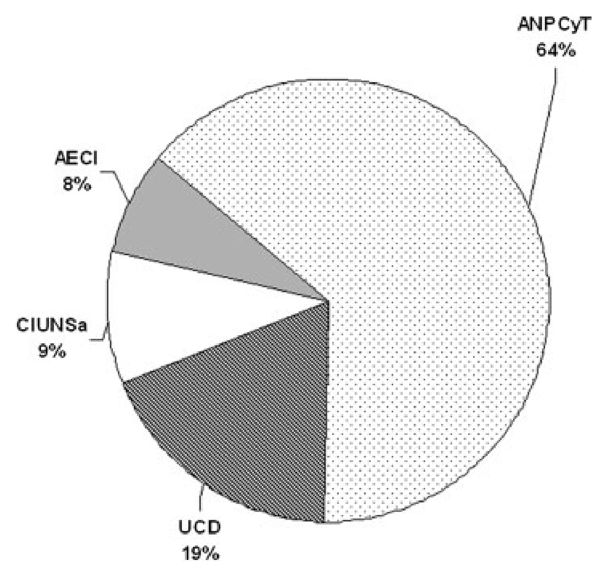


**FIGURE 1.** Sources of funds obtained by the Salta group from a total of $128,500 received since 2006. UCD, University of California, Davis; AECI, Spanish Agency of International Cooperation; ANPCyT, National Agency for Promoting Science and Technology (Argentina); CIUNSa, Research Council of UNSa (the National University of Argentina at Salta).

activities were and are being carried out at the old "Water Laboratory," at other laboratories at UNSa, or in specialized centers elsewhere.

## Trainees

As additional research funds were obtained, it became possible to incorporate professionals interested in developing a postgraduate career (PhD) into the group. Since the grants from local and national agencies specifically cannot be spent on salaries, it was necessary to find other ways to support these students. All of these students have been encouraged to apply for doctoral scholarships to CONICET and CIUNSa. Fifteen out of 16 applications submitted thus far have been successful. To put this number into perspective, these are the first students awarded national CONICET fellowships in the history of the engineering program at UNSa. The total number of students trained has increased over the years (Fig. 2). The contribution of the FIC was crucial to support the first graduate students at the beginning, which allowed them to develop the research projects and supporting curricula to apply for other scholarships later (Fig. 2).

Postdoctoral students, professionals, and technicians were also incorporated into the group of researchers in order to develop additional methodology to attack the problems we wanted to study, through postdoctoral scholarships and/or participating as researchers or technical staff on the grants funding the projects. All of this led to the formation of multidisciplinary working teams, which allows us to reach a better solution to a particular problem or situation, since different knowledge and points of view are provided by professionals from various areas as discussed in the Introduction section (Fig. 3).

We feel strongly that it is important to create networks as an effective way of sharing information, experience, and resources. Thus, some of the projects were developed with other national and international research centers to strengthen the research lines, and to make it possible that students could carry out part of their work in other laboratories. At the same time, it allowed students from other research centers to develop some of their work in the "Water Laboratory" at UNSa, which has available, for example, real-time PCR capability. This capability is not available in Argentine laboratories outside of Buenos Aires, Córdoba, and Santa Fe, the main cities of the country. Since 2007 to date, six professionals or graduate students from other universities have worked during short-term visits to UNSa in this laboratory on topics related to diagnosis, evaluation of drug treatment for some endemic regional illnesses, and gene expression. In the other direction, five of the nine advanced students from our laboratory have visited other national and international research centers for up to 6 months of specialized training. This knowledge returns to UNSa to increase our capabilities.

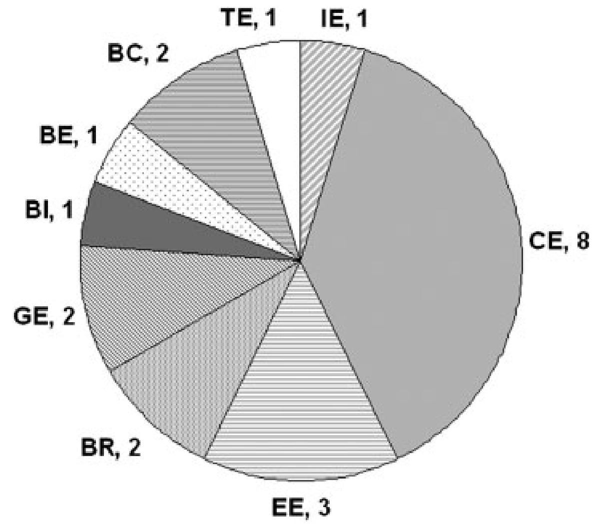


**FIGURE 3.** Composition of the research group since 2005 to date, according to the degree: Chemical Engineer (CE); Industrial Engineer (IE); Chemist Technician (TE), Biochemist (BC); Bioengineer (BE); Biologist (BI); Geneticist (GE); Bromatologist (BR); Natural Resources; and Environmental Engineer (EE).

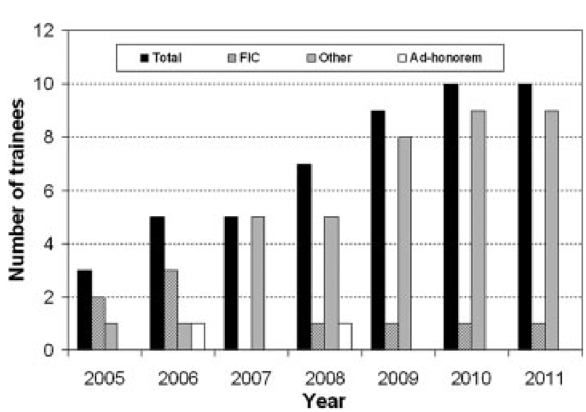


**FIGURE 2.** Number of long-term trainees funded by the Fogarty International Center (FIC) and by other sources. Some students did not have funds (Ad-honorem).

## Training

In the Faculty of Engineering of UNSa, there are currently three majors in engineering, each of 5-year duration: Civil Engineering, Industrial Engineering, and Chemical Engineering. The Curricula (Amendments to the Plan 1999) include subjects in the area of basic sciences (mathematics, physics, chemistry, and modeling), common to all careers, plus basic specific classes, basic vocational, and advanced specific classes for each specific major. It is also necessary in order to complete any of the majors to have a Supervised Professional Practice and to pass a Final Capstone Project, which allows students to integrate the knowledge acquired by applying it to a particular process. All three of the engineering majors have in their fifth year curricula subjects related to the environment, both in the process plant or workplace and outside. Thus, in Civil Engineering we find subjects such as Sanitary Engineering and Environmental and Occupational Health and Safety in the second quarter. Industrial Engineering, on the other hand, has Industrial Management and Industrial Safety and Health in the first and second quarter, respectively. Chemical Engineering includes the subject Clean Production in the second quarter.

Additionally, other curricular requirements that must be fulfilled by students to graduate are required in the curricula. One of them is to demonstrate a certain number of hours obtained through the approval of complementary elective courses, or by participation in seminars or conferences about various chosen subjects. This requirement allows us to enrich and complement the engineering training in all three of the majors.

Before our program was initiated there were few opportunities in the Faculty of Engineering at UNSa to train students or professionals in environmental topics. Now we focus on long- and short-term training to address this goal. For long-term training we are developing postgraduate research studies for professionals, and for short-term training we are assisting in the development of complementary courses to acquire specific knowledge.

***Long-term training*** The main research lines proposed and developed for our students who wanted to get a PhD are related to environmental pollution in the province of Salta.

One of the most important projects involves water monitoring in Salta province for detection of pathogens in the Arenales River that impact on public health. This project is based on previous epidemiological studies showing a correlation between adverse public health outcomes and issues related to water quality of this river [Aramayo et al., 2009]. Our activities were initially focused in this area and later extended to other regions of the province, including the design of a sampling plan taking into account the critical points in terms of potential or actual water contamination, the construction of a laboratory ultrafiltration facility to increase the pathogen concentration of water samples and enhance detection limits [Rajal et al., 2007a], the development of methodology for the detection of pathogens by microbiological and molecular techniques [Rajal et al., 2007b], the evaluation of the efficiency of various pathogen concentration methods, the water sampling, concentration and analysis to determine the presence of bacterial and viral pathogens like *Salmonella*, *Escherichia coli*, adenovirus, enterovirus, and norovirus, and the proposal of strategies for the mitigation of contamination as a result of these studies.

Another project includes the study of contaminated soil areas in the province of Salta, which impact upon environmental and public health in different ways: by direct contact of people with soil in that area or indirectly by polluting water and air that will transport contamination to people from other regions. An area of Salta city is highly contaminated by soil piles rich in boron compounds that were deposited for many years until 1993; this contamination is now affecting a highly populated area (25,000 inhabitants) [PNUMA, 2004]. The work was extended to other regions of Salta to study different contaminants, such as glyphosate, an herbicide used extensively in this province; its use is still controversial. In these research lines, the proposed activities were the evaluation of the contaminant concentration in the region by the collection and analysis of soil samples, the screening of the microbial populations present in that soil and isolation of microbes able to resist and/or tolerate high concentrations of the contaminant and the study of the minimum inhibitory concentration and the pollutant uptake capacity for each microbe in pure culture.

Since then, other research lines have emerged, but all of them are related to the same objective, to get knowledge of environmental pollution, to be able to get an idea of the associated health risks and to propose mitigation programs.

***Short-term training*** This type of activity includes short-term internships and organization of courses in molecular methods, environmental pollution, and/or the associated risks.

Many doctoral and postdoctoral students have come to the ''Water Laboratory'' to get training in different laboratory techniques, especially with regard to real-time PCR. This opened the door of our laboratory to many people to give them the opportunity of working with some equipment and/or techniques. Some of this training has led to subsequent new research collaborations and the development of new research networks for the laboratory.

***Publications*** As a result of all of the research work done as an essential component of long-term training of students to become PhDs, several articles related to environmental and public health have been published in scientific journals [Cruz et al., 2008; Aramayo et al., 2009; Rajal et al., 2010]. Additional manuscripts are in peer review or are being written. Publication in high impact international journals is encouraged. To accomplish this, most of the articles are being written and published in English, and results are being presented at national and international scientific meetings. A total of 81 participations (not listed here), as oral presentation and posters, are also part of the production of the research group, and allow the students to have more exposition on the topics of interest and to interact with other research groups.

## Serendipity—Distractions/Opportunities

Two major distractions to this Master Plan are worthy of mention here. Both are examples of additional unplanned projects that simultaneously slowed down the pace of research training productivity, but also resulted in significantly enhanced impacts of the program on regional public health needs and regional capacity building. The first was the Swine Flu epidemic in Argentina in 2009 and the second was the opportunity to link graduate student support with curricular development and distance learning initially funded by a seed grant from UC Davis.

Argentina, being in the Southern hemisphere, was hit with Swine Flu at the beginning of the worldwide pandemic when little was understood about the course of the disease. There was an urgent need for rapid characterization of the causative agent when patients were hospitalized with flu-like symptoms. Our research group was the only laboratory with the capability to perform rapid, quantitative real-time PCR in northwest Argentina following the methodology published by the Center of Disease Control [WHO, 2009]. The Health Ministry of the Province of Salta trusted the detection and diagnosis of influenza A to this laboratory during the pandemic period of risk to the population of Salta. After a brief week in Buenos Aires to become certified as a clinical laboratory that could perform PCR of viruses, nasopharyngeal aspirate samples from patients in the region were analyzed. While the flu season continued through the winter months (June–October) hundreds of clinical samples were evaluated, which had a major impact on public health throughout the region. The results of inter-laboratory tests showed the excellent quality of the analyses that were performed in Salta. While the motivation for volunteering was humanitarian and patriotic, the result was that the laboratory gained a reputation for careful and accurate science that increased its visibility and desirability as a collaborating partner throughout the country. The hard work done by the laboratory during the pandemic was recognized by the University, which made new laboratory space available and helped to equip it.

The ability of this specific research group in environmental engineering to make a meaningful and practical contribution to regional public health in the area of infectious diseases is testimony to the powerful impact of the ITREOH program in ways that could not be anticipated by its founders, but exemplify the benefits of the capacity building approach.

The second opportunity was seed funded by a small grant to Professors Last and Rajal from the International Outreach Program at UC Davis to begin development of distance learning capacity in Salta. Initially, several of the new graduate students in the research group were funded by this seed grant to translate course materials donated by UC Davis faculty members into Spanish to provide the core material for a new Master's degree program we envisioned for UNSa, and ultimately for other universities in the region via distance learning. The activities of these students involved translation of courses that were donated by UCD professors, course organization with local, and/or regional teachers to use syllabus translations and foreign specialists to teach and add available course materials and proficiency, workshops, or discussion meetings with other organizations to advertise and propagate the developed activities and to promote interactions with different groups working on or affected by the same issues. Most of the courses were offered as lecture classes, while others were organized in lectures and practical classes, including laboratories. Development of true distance education has taken a lot longer to accomplish. All of the new courses, except for three that were taught in Uruguay, Buenos Aires, and Brazil, have been piloted at UNSa to ensure their acceptability to students and that their content is rigorous. A total of 318 students (89% graduate and 11% undergraduate) participated in the 15 courses (Fig. 4) and this activity also helped the group to become a recognized resource for training. In average three courses per year were taught with the exception of 2006 (only one) and 2010 (two courses with relatively low participation, maybe due to not enough diffusion). Thus far, only one of the courses has been taught using distance learning. The distance learning modality offers a lot of important benefits like collaborative learning that can include participation by students in Medicine and Public Health, neither of which is taught formally in Salta, and the opportunity to attend despite the distance, so we plan to expand this activity as time and

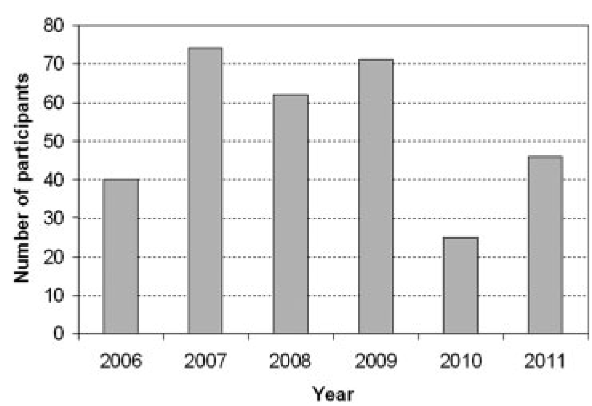


**FIGURE 4.** Participants of the 15 courses organized and taught, mainly in Salta, between 2006 and 2011. Undergraduate and graduate participants were included (only three courses accepted undergraduate students).

resources allow. In addition, UNSa faculty members are building upon this effort to develop a new graduate degree program with a significant research component (this could be a Master's degree) in an environmentally related specialty area.

## CONCLUSIONS

This program has had a significant impact locally and regionally. It has been guided from its inception by Professor Rajal's concept that broader training of engineers in public health and environmental issues, and encouraging the formation of collaborative research networks will allow the region to increase its capacity to solve its environmental and public health problems. The ITREOH Center has assisted UNSa in programmatic development and research training, is currently encouraging the development of a potential new Master's degree program, and has participated in developing an expanded network of teaching and research between UNSa and the University of California. Now, facing the future, even though the project may be discontinued in terms of funds from the ITREOH Center, the Argentinean Center had built a strong foundation that will continue to grow and consolidate its acquired capacities, while continuing to disseminate the experience regionally.

Finally, the model used in Argentina could be easily adapted to other fields or types of projects in Argentina and in other developing countries. Oftentimes, the possibility of a researcher that is willing to lead a process like this receiving training abroad is the first step to influence great change. But equally essential is the commitment of the individual to return to develop training programs in the developing country. To continue the process back in the country of origin after the training abroad is completed, the initial financial support in country is crucial since it allows the new program to build a foundation for building new capacities that eventually can grow independently of the seed funding.

## REFERENCES


Aramayo CF, Gil JF, Cruz MC, Poma HR, Last MS, Rajal VB. 2009. Diarrhea and parasitosis in Salta, Argentina. J Infect Dev Ctries 3(2):105–111 (PMID: 19755739).

Aucamp EJ. 2003. Eighteen questions and answers about the effects of the depletion of the ozone layer on humans and the environment. Photochem Photobiol Sci 2(1):ix–xxiv.

Bañares-Alcántara R. 2010. Perspectives on the potential roles of engineers in the formulation, implementation and enforcement of policies. Comput Chem Eng 34:267–276.

Berger S. 2008. K. William Kapp's theory of social costs and environmental policy: Towards political ecological economics. Ecol Econ 67:244–252.

Brena BM, Arellano L, Rufo C, Last MS, Montaño J, Cerni EE, Gonzalez-Sapienza G, Last JA. 2005. ELISA as an affordable methodology for monitoring groundwater contamination by pesticides in low-income countries. Environ Sci Technol 39:3896–3903.

Burtraw D. 1998. Cost savings, market performance, and economic benefits of the U.S. Acid Rain Program. Washington: Resources for the future. Available at: http://www.rff.org/documents/rff-dp-98-28-rev.pdf

Burtraw D, Krupnick A, Mansur E, Austin D, Farrell D. 1997. The costs and benefits of reducing acid rain. Washington: Resources for the future. Available at: http://www.rff.org/rff/documents/rff-dp-97-31-rev.pdf

Chisari OO, Fanelli JM, Frenkel R. 1996. Argentina: Growth resumption, sustainability, and environment. World Dev 24(2):227–240.

Cruz MC, Gil J, Gómez S, Rajal VB. 2008. Diagnóstico de la calidad microbiológica del agua superficial en una zona semirural de la provincia de Salta. Cienc 3(3):145–163.

Dincer I, Rosen MA. 1999. Energy, environment and sustainable development. Appl Eng 64:427–440.

Diwekar U, Shastri Y. 2011. Design for environment: A state-of-the-art review. Clean Technol Environ 13(2):227–240.

Githeko AK, Lindsay SW, Confalonieri UE, Patz JA. 2000. Climate change and vector-borne diseases: A regional analysis. B World Health Organ 78(9):1136–1147.

Heisler GM, Grant RH, Gao W. 2003. Ultraviolet radiation and its impacts on agriculture and forests. Agr Forest Meteorol 120:3–7.

Jimenez-Gonzalez C, Poechlauer P, Broxterman QB, Yang BS, Ende D, Baird J, Bertsch C, Hannah RE, Dell'Orco P, Noorman H, Yee S, Reintjens R, Wells A, Massonneau V, Manley J. 2011. Key green engineering research areas for sustainable manufacturing: A perspective from pharmaceutical and fine chemicals manufacturers. Org Process Res Dev 15:900–911.

Kapp KW. [1963a] 1977. The social costs of business enterprise (second enlarged edition of The social costs of private enterprise (1950)) Nottingham: Spokesman, p. 13.

Krieger EM. 1999. Scientific capabilities in the research on basic needs for development. In: Cetto AM, editors. World Conference on Science. Science for the twenty-first century. A new commitment. London: UNESCO, pp. 103–106. Available at: http://unesdoc.unesco.org/images/0012/001207/120706e.pdf

Lopes Soares W, de Souza Porto MF. 2009. Estimating the social cost of pesticide use An assessment from acute poisoning in Brazil Ecol Econ 68:2721–2728.

PNUMA. 2004. Programa de las Naciones Unidas para el Medio Ambiente Oficina Regional para América Latina y el Caribe, Resumen de Prensa-Daily News. México, América Latina y el Caribe/México, Latin America and the Caribbean. September 29th, 2004.

Prüss-Üstün A, Corvalán C. 2006. Preventing disease through healthy environments. Towards an estimate of the environmental burden of disease. France: World Health Organization.

Rajal VB, McSwain BS, Thompson DE, Leutenegger CM, Kildare BJ, Wuertz S. 2007a. Validation of hollow fiber ultrafiltration and real-time PCR using bacteriophage PP7 as surrogate for the quantification of viruses from water samples. Water Res 41:1411–1422.

Rajal VB, McSwain BS, Thompson DE, Leutenegger CM, Wuertz S. 2007b. Molecular quantitative analysis of human viruses in California storm water. Water Res 41:4287–4298.

Rajal VB, Cruz C, Last JA. 2010. Water quality issues and infant diarrhoea in a South American province. Glob Public Health 5(4):348–363 (PMID: 20473801).

Redclift M. 1989. The environmental consequences of Latin America's agricultural development: Some thoughts on the Brundtland Commission Report. World Dev 17(3):365–377.

Schindler DW. 1988. Effects of acid rain on freshwater ecosystems. Science 239:149–157.

Solomon KR, Tang X, Wilson SR, Zanis P, Bais AF. 2003. Changes in tropospheric composition and air quality due to stratospheric ozone depletion. Photochem Photobiol Sci 2:62–67.

Streck NA. 2005. Mudança climática e agroecossistemas: Efeito do aumento de $CO_2$ atmosférico e temperatura sobre o crescimento, desenvolvimento e rendimento das culturas. Cienc Rural 35(3):730–740.

Tabone MD, Gregg JJ, Beckman EJ, Landis AE. 2010. Sustainability metrics: Life cycle assessment and green design in polymers. Environ Sci Technol 44:8264–8269.

Valent F, Little DA, Bertollini R, Nemer LE, Barbone F, Tamburlini G. 2004. Burden of disease attributable to selected environmental factors and injury among children and adolescents in Europe. Lancet 363:2032–2039.

WHO, World Health Organization. 2009. CDC protocol of real-time RTPCR for swine Influenza A (H1N1). Revision 1. Atlanta, US: April 30, 2009. Available at: www.who.int/csr/resources/publications/swineflu/CDCrealtimeRTPCRprotocol_20090428.pdf

WHO, World Health Organization. 2011. Environmental Health. Available at: http://www.who.int/topics/environmental_health/en/

Xenopoulos MA, Prairie YT, Bird DF. 2000. Influence of ultraviolet-B radiation, stratospheric ozone variability, and thermal stratification on the phytoplankton biomass dynamics in a mesohumic lake. Can J Fish Aquat Sci 57:600–609.

Yassi A, Kjellström T, De Kok T, Guidotti TL. 2002. Salud Ambiental Básica. Programa de las Naciones Unidas para Medioambiente. Oficina Regional para América Latina y el Caribe, Organización Mundial de la Salud, Instituto Nacional de Higiene, Epidemiología y Microbiología, Ministerio de Salud Pública de Cuba. First Edition. Available at: http://www.rolac.unep.mx