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English IV

1 Oct. 2019

### The Multidisciplinary Field of Environmental Toxicology

Despite how it is portrayed in the media, toxic waste usually is not a glowing, neon green goo that gives you superpowers. While instantly recognizable in its stereotypical steel drums associated with nuclear disasters and bad sci-fi films, people often fail to notice the numerous forms of hazardous waste present in their own houses, such as the corrosive agents found in cleaning products or the poisons used in pesticides (“Frequently Asked Questions: Household Hazardous Waste”). What happens to these chemicals after they get poured down the drain or sprayed on the front yard? Although these products may only contain small quantities of hazardous chemicals, when used indiscriminately and disposed of improperly, they can quickly increase in concentration in an area, posing several threats to local ecosystems and public health. This issue represents one of the fundamental pillars of toxicology, the idea that “the dose makes the poison,” as first described by Paracelsus, a sixteenth-century chemist who is widely viewed as the “father of toxicology” (Gilbert). In order to be successful in the field of environmental toxicology, prospective environmental toxicologists must build a strong educational foundation at the undergraduate level across the field’s multidisciplinary focuses. While numerous colleges across the United States offer reputable environmental science curriculums, the University of California, Davis; the University of California, Berkeley; and the University of Washington offer

particularly strong programs capable of providing prospective students with the diverse skill set needed to enter the field of environmental toxicology.

As the name suggests, environmental toxicology is the study of toxic chemicals and their effects on the human body and the environment (Tjeerdema 4). According to ToxTutor, a website operated by the United States Department of Health and Human Services, environmental toxicologists study a variety of current environmental issues, from measuring the proliferation of microplastics in the world's oceans to monitoring the effects of herbicides on bee populations. Environmental toxicology is an extremely diverse field, focusing on several aspects of chemistry and the biological sciences, while also encompassing a variety of other subjects, such as computer science or statistics ("Environmental Toxicology"). Despite the fact that this major primarily focuses on the applications of environmental toxicology within the scope of environmental science, it can easily be applied to other fields, such as forensic science or law due to this multidisciplinary approach (Tjeerdema 4). Degree programs in environmental toxicology currently are largely only offered at the graduate level at most universities ("Best Colleges with Environmental Toxicology Degrees in the U.S.").

Out of the ten schools offering undergraduate toxicology degrees, the University of California, Davis is the only university in the country to offer a specific major in environmental toxicology. Although reputable programs in their own right, the toxicology degrees offered at these other schools are not as well suited for prospective environmental toxicologists, as their programs focus more on the pharmaceutical applications of toxicology ("Why Major in Toxicology?").

Within UC Davis' environmental toxicology major, students are quickly immersed in a huge variety of scientific disciplines associated with the major, from analytical chemistry to anatomy (ariasnu). In the program, offered by UC Davis' Department of Environmental Toxicology in the College of Agricultural and Environmental Sciences, there are currently thirty-three courses—including twenty-seven upper-division courses—that specifically pertain to the field of environmental toxicology ("Majors by College;" "Courses"). The environmental toxicology major offers students to further explore their interests by specializing in one of three areas of emphasis: ecotoxicology and environmental chemistry; forensic science and regulatory toxicology; and molecular and biomedical toxicology ("Emphases"). The ecotoxicology and environmental chemistry emphasis offers classes in aquatic toxicology, ecology, and chemical fate (Tjeerdema 10-11). Branching out to the more regulatory and policy-oriented aspects of the major, the forensic science and regulatory toxicology emphasis includes classes in environmental policy and management; forensic science; and public health (11-12). For those interested in potentially entering the medical field, the molecular and biomedical toxicology emphasis covers topics on biotechnology, food toxicology, medicine, pharmacology, and veterinary medicine (12-13). Finally, in addition to the three pre-established emphases, students may—with instructor approval—also select their own area of emphasis ("Emphases"). Students in the program are also presented with numerous internship and research opportunities, notably a six-week summer research program at the UC Davis Bodega Marine Lab as a part of its Environmental Stress and Development in Marine Organism course ("UC Davis Environmental Toxicology Major" 2).

Another major advantage of UC Davis' environmental toxicology major is its small classes, which further enhance the quality of the program's numerous available academic

opportunities. According to several former students, class sizes rarely exceeded twenty people, making it easy for them to reach out and make personal connections with their peers and professors, who “tended to know [their students] by name” (ariasnu; peaceoutdude).

Furthermore, the UC Davis Environmental Toxicology Club hosts numerous events throughout the year—from career workshops to annual paintball outings—that provide students with great chances to connect with their peers and professionals in the field (ariasnu; “Paintball 2018;” “ETOX Club at UC Davis”). Building on the many career-building opportunities offered by the Environmental Toxicology Club, the Department of Toxicology also publishes a weekly newsletter detailing new available internships and jobs on and off campus related to the field of environmental toxicology (“Job / Internship Newsletter”). According to Bryn Phillips, a research specialist at the UC Davis Marine Pollution Studies Laboratory at Granite Canyon, success within the field of environmental toxicology is highly dependent on one’s connections to other professionals in the field (Phillips; “Who are We?”). As a result, these initial relationships fostered at events offered by the Department of Toxicology—combined with the rigorous curriculum—give students in the major a great head start in their efforts to develop careers in the field of environmental toxicology.

While a specific environmental toxicology major does not exist at the University of California, Berkely and the University of Washington, their highly distinguished environmental science programs are excellent alternatives for those interested in the field of environmental toxicology.

Being ranked as the best school in the world in the fields of ecology and the environment by *U.S. News and World Report*, the University of California, Berkeley boasts an impressive

major in environmental science (Morse et al.). The major, offered by the Department of Environmental Science, Policy, and Management at UC Berkeley's College of Natural Resources, is an interdisciplinary program, and students have the chance to take classes that allow them to specialize in a variety of fields, from toxicology to environmental justice. Graduates of the program are equipped with a wide range of skills needed in careers across many scientific fields and graduate programs if they choose to pursue a higher degree (“About the Program”). There are over one hundred upper-division elective courses available to environmental science students; however, the major has only three available toxicology courses, compared to UC Davis’ twenty-seven upper-division environmental toxicology courses (“Environmental Sciences,” *Berkeley Academic Guide*; “Courses”). This major requires a minimum of thirty units of upper-division courses, including statistics, environmental modeling, and electives specific to one’s area of concentration (“Environmental Sciences Major Snapshot”). Like Davis, the environmental science major at UC Berkeley is divided into different emphases, offering concentrations in the physical, biological, or social sciences (“Environmental Sciences,” *College of Natural Resources*). Both schools also offer honors programs in their respective majors. At UC Berkeley, the honors program is available to students with a 3.6 or higher grade point average (“Courses;” “About the Program”).

Another highlight of this program is the research-oriented senior year. The major culminates in a year-long senior capstone research project, offered under the ESPM 175 or ESPM 175 Honors series of classes (“Environmental Sciences,” *College of Natural Resources*). This research project, according to the ESPM 175A website, enables students enrolled in the environmental science major to investigate and conduct research on an environmental issue of

their choosing, and then pose a potential solution or policy to address this problem in an extensive senior thesis (“Environmental Sciences Senior Thesis”). The published senior research theses from last year covered an extremely diverse list of topics, from the effects of the invasive American bullfrog and its associated parasites in a California regional park, to land acquisitions in Sub-Saharan Africa (O'Neil; Mohan; “ESPM175 May 2019: Table of Contents”). By having the chance to research and present their original findings on environmental issues they are interested in, environmental science students at UC Berkeley receive a unique introductory experience in the exact types of research that is an essential element of most graduate programs, as well as the careers within the field of environmental science and environmental toxicology.

Great environmental science programs also exist outside of the UC system, with the University of Washington’s environmental science and terrestrial resource management major being a prime example. Offered at the University of Washington’s School of Environmental and Forest Sciences in the College of the Environment, the ESRM major offers four unique specialization options, equivalent to UC Davis’ emphases within its environmental toxicology major (“ESRM Major Requirements”). The natural resource and environmental management option focuses primarily on landscape ecology. For this option’s honors program capstone, students investigate “the ecology and conservation of a particular site or region” (“Natural Resource and Environmental Management Option”). The restoration ecology and environmental horticulture option focus on ecology, sustainable land management, habitat restoration, and plant sciences (“Restoration Ecology and Environmental Horticulture Option”). The sustainable forest management option provides students with the skills needed to assess and manage an ecosystem’s ecology and services (“Sustainable Forest Management Option”). This option also

meets the requirements to become a Society of American Foresters Candidate Certified Forester. Additionally, graduates from this option can directly enter the University of Washington's Master of Forest Resources program, which is also certified by the Society of American Foresters ("ESRM Major Requirements").

At the University of Washington, there are over seventy-five courses directly related to the ESRM major. All but seven are upper-division courses, with the majority being level 400 courses. Despite this large diversity of electives, the ESRM 457 Fish and Wildlife Toxicology class is currently the only available elective that directly pertains to environmental toxicology in the program ("COLLEGE OF THE ENVIRONMENT"). In addition, while it is now only required to earn the degree for honors students as of fall 2019, all ESRM seniors have the option to complete a research thesis or "restoration ecology capstone," much like the ESPM series of courses offered at UC Berkeley. To fund their capstones, students can apply to receive a grant of up to one thousand dollars from the University of Washington's Campus Sustainability Fund ("ESRM Capstone").

While the specific environmental toxicology major offered at UC Davis would best prepare students to immediately start a career in environmental toxicology after graduation, in reality, the vast majority of currently active environmental toxicologists—particularly those with larger salaries—have obtained higher degrees in the field due to its incredibly advanced nature (McGowan et al.). In this case, the programs from all three schools would likely sufficiently prepare their students for entry into graduate programs.

Once obtaining a degree in environmental toxicology, it opens up numerous possible career paths within the field. According to a job market survey published by the Society of

Toxicology, the number one employer of toxicologists are “chemical, consumer products, and pharmaceutical industries,” which employ over forty-seven percent of currently active toxicologists. The second-highest job outlook for toxicologists is in education, with twenty-one percent finding work in this field. Government agencies are the third highest employment area for environmental toxicologists, whose skills are needed in many federal and state regulatory agencies, such as the Environmental Protection Agency. Furthermore, the majority of toxicology jobs in industry and in the government are on the West Coast (McGowan et al.).

The pay of toxicologists varies considerably based on education and experience level. The salaries of toxicologists holding a bachelor's degree can vary from under thirty-thousand dollars up to ninety-thousand dollars based on experience. In comparison, the pay of doctoral positions can vary from 35,000 dollars to 150,000 dollars, leaving plenty of room for advancement as experience is accumulated (McGowan et al.). This clearly shows the incentive for toxicologists to pursue a higher education, and is why the environmental science programs at UC Berkeley and the University of Washington are acceptable alternatives to UC Davis' Environmental Toxicology major, as they both adequately prepare students to enter a graduate program, which is often a prerequisite to enter the field.

With the world bearing the scars of two centuries of industrialization, there has been a large push in recent efforts to mitigate the impacts of our past actions to protect the future. As we discover the externalities associated with everyday products, there has never been a better time to enter the field of environmental toxicology, as environmental toxicologists are playing critical roles in mitigating the environmental harm caused by everyday “safe” household goods. To fulfill these duties, environmental toxicologists must obtain a strong educational foundation, as



they must be experts in many skills found across a variety of different scientific disciplines.

While a specific environmental toxicology major is only available at the University of California, Davis, the diverse and rigorous environmental science programs offered at the University of California, Berkeley and the University of Washington would also be great choices for any prospective environmental toxicologist.

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