ENVIRONMENTAL FLUID MECHANICS

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PREFACE

When one thinks of environmental pollution, the first thought coming to mind is that of chemical or biological materials negatively affecting some person or some ecosystem. Yet, those chemicals would not be where they are if they had not been transported somehow through the environment from their source. This simple fact and the fact that a large degree of dilution and transformation takes place along the transporting path makes one quickly realize that the environmental impact of any type of pollution depends as much on the nature of the contaminant as on the physics of its transport, hence the expression *Environmental Transport and Fate*. Put another way, environmental pollution has both physical and biochemical aspects.

Transport of contamination in the environment (a contaminant is not a pollutant until it has had an adverse effect) can take many forms, from downstream flow of water and air, to migration through soils, deposition in lungs and transfer through the food chain. Of all possible pathways, transport by water and air is by far the most common and therefore deserves special attention. The investigation of the processes by which contaminants are transported and diluted in water and air, such as convection and turbulent dispersion, and the study of water and air systems from the perspective of environmental health, such as a watershed or the atmospheric boundary layer, collectively form a body of knowledge, the synthesis of which is becoming recognized today as forming a new discipline, called *Environmental Fluid Mechanics*. This synthesis is the object of the present book.

Environmental Fluid Mechanics (EFM) borrows most of its materials from classical fluid mechanics, meteorology, hydrology, hydraulics, limnology and oceanography, but integrates them in a unique way, namely with a view toward environmental understanding, predictions and even decision making. EFM should therefore not be confused with basic fluid mechanics, hydraulics or geophysical fluid dynamics. Unlike general fluid mechanics, EFM is strictly concerned with the flows of air and water as they naturally occur, that is, at ambient temperatures and pressures, in a state of turbulence, and at relatively large scales (a few meters to the size of the earth). Ironically also, while fluid mechanics tends to view turbulence as a negative aspect (increasing drag forces), EFM views turbulence as beneficial (conducive to dilution). Further, EFM is distinguished from hydraulics not only because it treats air as well as water, but chiefly because it is aimed at environmental applications. Thus, whereas hydraulics tends to be preoccupied by water levels (floods) and pressures against physical structures (dams and bridges), EFM is concerned with thermal stratification, turbulent dispersion and sedimentation. Finally, geophysical fluid dynamics restricts its attention to the very largest natural fluid flows of the atmosphere and oceans (weather patterns and oceanic currents), thereby emphasizing the role of Earth's rotation (Coriolis effects) to the point of neglecting turbulence; in contrast, EFM assigns a central role to turbulence and deals with length scales down to the human size.

Complexity is a hallmark of natural fluid flows: Turbulent fluctuations, complicated geometries, multiple external forces, and thermal stratification all combine to make the subject rather challenging. No single approach can suffice, and a mix of in-situ observations, theoretical investigations, numerical simulations, and laboratory experiments is most necessary. Such mix is naturally reflected in the contents of the book. Furthermore, a system outlook is essential to the pursuit of environmental fluid mechanics. Yet, the study of a system (ex. an urban airshed) must proceed from the prior study of underlying processes (ex. waves and boundary layers), which itself relies on the elucidation of fundamental concepts (ex. vorticity and stratification). The organization of the book follows a deductive progression, from generalities and concepts, to processes, and finally to entire systems.

The book is aimed at upper-level undergraduate students in environmental science and engineering. The text therefore assumes some familiarity with calculus and basic physics as well as some prior exposure to fluid mechanics. Those students who have taken a prior course in fluid mechanics can omit Chapters 2 and 3. To assist professors, a series of problems is offered at the end of every chapter. It is expected that the book will also be useful to environmental scientists and engineers, who may want to consult it as a reference. Finally, it is the expressed hope of the author that this book will facilitate the development and offering of a course in environmental engineering as part of a curriculum in environmental transport and fate.

This book would not have been possible without the contributions and assistance of many people. I am foremost indebted to my students at Dartmouth College, who persuasively led me to consider environmental fluid mechanics as an integral discipline. Numerous colleagues, too many to permit an exhaustive list here, have made detailed and invaluable suggestions that have improved both the contents and presentation of this textbook. Special thanks go to Edwin A. Cowen, Carlo Gualtieri, Heidi Nepf and Thomas Shay, among many others.

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