Book Review

By Mark L. Maiello, PhD
Book Review Editor

The New Nuclear Forensics

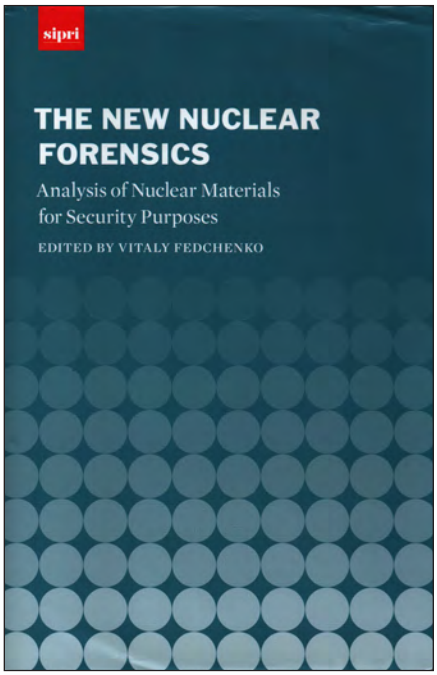
Edited by Vitaly Fedchenko

Hardcover, 290 pages
ISBN 978-0-19-873664-6
Oxford University Press, Oxford, UK, 2015

Here we have a text that fulfills its purpose well. It serves well as an introduction to nuclear forensics for those with a minimum of analytical and engineering background. If readers have some analytical chemistry or nuclear analysis capability under their belts so much the better, but in large measure, the book can be read with minimal knowledge in these areas. As a bonus, this text also provides a historical perspective of the field. Another unique contribution is the discussion of real-world applications of forensic techniques using recent events such as the North Korean nuclear tests.

This is an ensemble production with contributors hailing from across Europe and the United States. Swedish, Russian, Finnish, Hungarian, German, and American specialists have all contributed to a concise, well-constructed guide to the field. One can actually treat this text as a good read rather than a reference to be pulled down from the shelf when needed.

In the introduction, the editor Vitaly Fedchenko makes it clear that nuclear forensics has come of age. This term probably originated with the rise of nuclear smuggling in the 1990s as investigations sought techniques for evidentiary purposes in the prosecution of criminal cases. Attribution or the identification of a source of nuclear or radioactive materials and the route of transit of the materials are key components of nuclear forensics. He adopts the term "nuclear forensic analysis" because it more broadly encompasses the multiple techniques that in past years were used in isolation but now can be employed collectively for arms control, nonproliferation and intelligence work involving radioactive or nuclear materials.



The main elements of the field are explained in a very methodical way, allowing the novice to ease into the subject matter. Chapters 1 and 2 explain the field, carefully laying out such elements as its terminology and application. The "process" of nuclear forensics — essentially how it is conducted — is reviewed by explaining sample collection and characterization whereby the material is measured for physical size and subjected to elemental analysis. This is quite logically, followed up with the real meat of the process: the interpretation of analytical results.

Of the non-nuclear analyses utilized to achieve the goals of forensics, mass spectrometry in its many forms, is a key weapon in the arsenal. Though there is a brief explanation of the principals, the editor and his contributors do not waste much space explaining how the myriad mass-spec techniques work—one must look elsewhere for that. A diagram of the general principles is not to be found (probably considered too basic for the text), but this reviewer would have found it useful especially when the several mass spectrometry practices are discussed. Enough of these variants of mass spectroscopy are mentioned to warrant a fuller explanation of the overall method. A mass-spec technique comparison table somewhat along the lines of Table 3.1, which includes all forensic techniques, would have helped to elucidate and summarize application of this method. Of all the chapters in the book, Chapter 3 is perhaps the most difficult to follow. However, a lucid explanation of the *application* of mass-spec is made that will enlighten the reader as to the large role it plays in forensics.

The book flies higher afterwards. Chapters 4, 5, and 6 are where the radiological analyses hold the spotlight. Gamma-spectroscopy, nuclear signatures (uranium and plutonium), and radionuclide signatures provide the basic

foundation of nuclear forensics. Perhaps because of this, the principals of gamma spec are provided in a bit more abundance than was done for mass-spec. Detector types are discussed along with their capabilities and limitations. Competent discussions of the basic issues of gamma spectroscopy follow in turn: resolution of nuclide peaks, peak width, measurement time, and background radiation. A few brief words about airborne and underwater measurements are provided. They prove to be important in the later chapter on real-life attribution cases.

In Chapter 5, the processes that generate, transform, or modify nuclear material are discussed in the context of determining the history of the materials. The chapter is supplemented by twenty-one figures including electron microscopic images of uranium ore concentrates and fuel pellets. A good amount of effort was applied here to describe metallic uranium and plutonium because of its military use. Fuel pellets, which can be distinguished macroscopically and microscopically by the methods used to produce them, are also given their due.

A section is devoted to non-fissile materials commonly accompanying uranium, plutonium, and thorium. These elements may arise from processing of uranium oxide compounds or may accompany the feed material into the process. Rare earths and uranium oxide compounds follow a pattern unaffected by processing that allow the uranium to be traced back to a mine or geological location. Excellent figures accompany Chapter 5 that illustrate the dimensions, markings, and grain morphology of uranium fuel pellets from which manufacturers can be ascertained. Another parameter that can provide forensic evidence for attribution is the age of the nuclear material since it was chemically separated. Using both uranium and plutonium, it is explained how chemical separation during the manufacturing process removes the isotopes of decay and how new ingrowth can be utilized to determine the age of the uranium or plutonium. Even the age of uranium deposits can be estimated by using neodymium, lead or strontium isotope ratios.

We reach the post-explosion environment in Chapter 6. Despite the loss of most physical and chemical signatures by the explosion, the resulting radioactive materials in debris and fallout can be subjected to collection, characterization, and forensic interpretation that elucidate the history of the material. The chapter begins with the selection of "relevant radionuclides" used to calculate post-explosion doses to humans and to verify compliance with the Comprehensive Test Ban Treaty (CTBT) from the 2,391 known radioisotopes. The third section of this chapter is divided into ten categories that help determine the relevant radionuclides. It is an education on nuclear weapon debris. The categories include, of course, fission products and activation products, but also non-fission reaction products, residues, and tracers.

Clarity and insight mark this chapter. Tables 6.1 and 6.2 highlight a discussion of the twenty-one most important radionuclides utilized for estimating global average effective dose commitments from nuclear testing (Table 6.1) and the thirty-six deemed important for underground testing inventories in connection with France's Pacific testing from 1975 to 1996 (Table 6.2). This leads up to a discussion of the fallout particles needed to perform verification of nuclear detonations under the CTBT – the so-called "CTBT-relevant" nuclides. A simple but effective chart (Figure 6.1) illustrates a logical decision-making scheme utilizing the CTBT-relevant nuclides to determine treaty violations. The aforementioned ten categories define radionuclides associated with nuclear detonations, underground tests, underwater and atmospheric tests, and others defined by the manner in which the radionuclides are produced. The result is Table 6.3 — the forty-two particulate fission products relevant to international monitoring under the CTBT. A table of forty-two non-fission products compliments this (Table 6.4). This material is concisely and simply delivered to the reader in a manner that a novice to the field can benefit from immediately without confusion or the need for further research.

Chapters 7, 8, and 9 are excellent reads — truly interesting and extremely helpful in that they frame the historical background of nuclear forensics and then discuss real-world applications of its principles. The applied examples include discerning characteristics of Chinese nuclear weapons development and analyses of nuclear activities in Iran, Iraq, and North Vietnam. In Chapter 7, one finds a fascinating discussion of early environmental testing for German atomic bomb development including Nobel Prize winner Luis Alvarez' creation of a xenon-detection system and the collection of Rhine river water samples in 1944 by Manhattan Project foreign intelligence. As interesting are the revelations concerning the origins of soil testing to determine bomb yield credited to Herbert Anderson and Nathan Sugarman of the project's Metallurgical Laboratory. Through these efforts, Anderson discovered the glass created in the heat of atomic explosions from desert sand

(trinitite). The idea for airborne collection of bomb debris by a B-29 airplane, also the brainchild of Metallurgical Laboratory personnel and tested in 1945, is also discussed in these pages. The authors are not one-sided: a section is devoted to the development of debris analysis in the Soviet Union including Soviet investigations of U.S. tests.

The rubber really hits the road in Chapter 8. Here, Lars-Erik De Geer discusses the forensic efforts of the Swedish National Defense Research Establishment. Remote sensing (air sampling, both fixed and airborne), the principles of radionuclide fractionation, and studies of hot particles dominate the opening discussion of the chapter. De Geer then describes Sweden's rather impressive role in developing verification systems for the CTBT including its noble gas detection system. An interesting section applying Swedish-based forensics to "non-nuclear explosions" rounds out the chapter. These are events such as the 1983 nuclear-powered Cosmos satellite re-entry and the 1986 Chernobyl accident.

Appendix 8A is the "fun part" of the book. Swedish analyses of various nuclear tests are reviewed illustrating how and what forensics revealed about the past nuclear weapons tests of China. All told, the forensics of more than twenty tests are concisely reviewed.

With the basis of Chapter 8, the next logical effort is to describe recent forensic applications. This was taken on by Vitaly Fedchenko and Robert Kelley in Chapter 9, which includes the forensic analyses of North Korean enrichment and nuclear test efforts. A healthy amount of text is also devoted to the forensic efforts expended to investigate the 1990s era nuclear program of Iraq. This is all quite fascinating material some of which reads like a detective novel. There is an even a section titled quite mysteriously as "The Purple Sweater."

The New Nuclear Forensics is supplemented by a lengthy but welcome list of acronyms, a list of relevant measurement units, the chemical elements by atomic number, and a six-page glossary. There is an index and the references have been placed in footnotes. The book is more than adequately illustrated with high-quality black and white photographs.

A lean 290 pages, this work combines the technology and history of nuclear forensics into a very readable framework for those new and senior to the subject matter. There is also no question that the book will make a fine classroom companion or primary textbook, despite the lack of problems or questions to assign to future practitioners of this applied science. Its writing style and the breath of its coverage assure motivated student use. This is a sound, well-thought-out, and well-written addition to the nonproliferation literature.