Celso Gomes
Michel Rautureau *Editors*

Minerals *latu sensu* and Human Health

Benefits, Toxicity and Pathologies

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Preface

Humankind has used natural mineral resources for millennia, which have been central to the technological progress of human societies by providing mineral-based materials and their derivatives that shape the everyday lives of humans.

Human survival and development are dependent upon natural resources, water, land, forests, and minerals. Minerals are present, although not always very apparently, in every car, plane, bicycle, computer, TV set, cell phone, lamp, tile, brick, tableware, plaster, pigment, paper, cement, and glass. In fact, humans live side-by-side with minerals. Minerals are also present as fundamental constituents in the human body, as well as in pharmaceutics and cosmetics that humans use for healthcare and well-being. Minerals are essential to humans and other organisms and microorganisms.

This book is intended to be an updated and comprehensive academic review on both positive and negative interactions of minerals *latu sensu or* minerals *l.s.* regarding living quality for quality of life. As a rule, researchers do overweigh the negative interactions. On the contrary, this book seeks a harmonious balance of both categories of interactions.

To accomplish the main target of this book – a holistic approach to *minerals* and *humans* general and specific interactions – a broad concept of mineral was adopted, the concept of mineral *latu sensu* (mineral *l.s.*).

The comprehensive concept of mineral *latu sensu* (mineral *l.s.*) encompasses within other concepts presented ahead, the two most trivial: the concept of mineral *strictu sensu* (mineral *s.s.*) or mineral *itself* – natural, inorganic, solid, and crystalline product which is an important component of rocks and soils – adopted as so, for instance, in Earth sciences, soil sciences, and materials science; and the concept of *mineral* – chemical element of natural and inorganic origin, as a rule metal and metalloid, which is an important component of the human body, food (solid and liquid), and pharmaceuticals – adopted as so, for instance, in medical sciences, pharmaceutical sciences, and nutritional sciences.

All the chemical elements of natural origin and inorganic nature shown in the periodic table can be constituents of both *minerals s.s.* and *humans*. Also, very close relationships are known between *minerals s.s.* and *humans*. Both *minerals s.s.* and

humans are chemical systems built with the same fundamental blocks – the natural chemical elements – although in different concentrations. Also, both *minerals* and *humans* follow processes of formation, growth, and duration, and sooner or later they disappear, since they are imperfect natural beings characterized by inherited and acquired defects and disorders. In *humans*, such defects and disorders could be expressed as diseases of more or less severity, imperfections that could be found in the genetic code. In *minerals*, such defects and disorders mean physical and chemical instability leading to alteration, transformation, and disappearance.

The general and comprehensive concept of mineral, the concept of *mineral l.s.* adopted in this book, allows to encompass the following particular concepts:

1. The *natural, inorganic, solid*, and *crystalline chemical elements* or *compounds* that participate: in the composition of rocks and soils, and can be present too dissolved or suspended in both mineral water and air; some of these minerals, particularly those suspended in respirable air and being either naturally or anthropogenetically produced, can cause serious diseases such as *silicosis* and *asbestosis* depending upon concentration and exposure duration in the respiratory system; other such minerals can play positive functions in *pharmaceutics* and *cosmetics.*
2. The natural, inorganic, solid, and crystalline compounds that undergoes man-made physical and chemical modifications, and is able to change, in a controllable mode, its natural physical and chemical properties assumed to be important for certain industrial applications, situation exemplified by the processes: delamination, intercalation, pillaring, and acid or alkaline activation being performed in certain clay minerals.
3. The bio-essential *chemical elements* of natural origin that, in the ionic form, are constituents of the solid food of either vegetable or animal nature being created in soil, which being named *macronutrients* or *mineral salts* and *micronutrients* or *oligominerals* are the main suppliers and carriers of minerals for human nutrition and wellness.
4. The *chemical elements* that in ionic form are constituents of potable mineral water which are currently called *minerals*, their decisive conditioning of human health and living quality being well established; mineral water that can be used for therapeutical purposes, for instance in *crenotherapy*, *hydrotherapy*, and *thalassotherapy.*
5. The *chemical elements*, also currently called *minerals*, which mostly enter as oligoelements into the formulations of the so-called *mineral supplements*.
6. The *nanominerals* characterized by nanosizes, exemplified by some types of *clay minerals*, which are actually investigated and used for the controlled and sustainable delivery of pharmaceutics.
7. The *biominerals* classified as either *bio-essential* for some human physiological systems such as bones and teeth, or *pathological* since they can cause pathologies such as *lithiasis* – urinary, salivary, renal, and biliary – due to the formation of the so-called *calculi* or *stone.*
8. The *special clays*, natural associations of minerals dominated by the so-called *clay minerals* – hydrous phyllosilicates – which are being used since Antiquity

as cosmetic products and as therapeutic materials in both internal and external applications, for instance those called *geophagy*, and *mud therapy*, and *pelotherapy.*

9. The hybrid mineral-organic complexes, such as clay-drug hybrid materials and clay-drug delivery systems, which are considered of paramount importance in the field of biomedical research and applications.
10. The *special sands*, such as those of biogenic carbonate minerals, those of radioactive minerals yielding radon gas evolution, and those of naturally heated volcanoclasts, which are used under the form of sand baths, either outdoors in the natural environment or indoors inside spa facilities in a therapeutic application named *psammotherapy.*
11. The *chemical elements* of natural and inorganic origin usually called *metals*; some could participate in the composition of *metalloproteins* and of *metalloenzymes* acting as catalysts in the health essential metabolic reactions; some others could be used too, for instance, in *disease diagnosis* and treatment in *cancer therapy.*
12. *Synthetic minerals* that can be used in pharmaceutics and cosmetics.

Very early on it is admitted that since the beginning of antiquity, man first empirically and much later on the basis of scientific principles and methods discovered that certain natural products, which later came to be called *minerals*, when ingested or applied topically had curative or healing effects on certain diseases of digestive and dermal conditions, such as alleviating ailments and gastric intoxications, healing wounds and stopping bleeding; some minerals could also have beneficial effects on skin care and treatment, both cosmetic and dermocosmetic.

It is well established that minerals participate in the constitution of all living beings and can condition the quality of the natural life support systems: soil, water, and the atmosphere. There are four sources for the human intake of minerals: food, soil, water, and air. Also, there are three pathways for the human intake of minerals: ingestion, inhalation, and skin absorption.

In humans, some minerals, depending on their bioavailability, can play three main positive roles:

1. Provide structuring in the formation of bones and teeth.
2. Help the maintenance of normal heart rate, muscle contraction and conduction of the nervous system, and acid–base balance.
3. Regulate cellular metabolism by being part of enzymes and hormones that control cellular activity.

Also, in humans, some minerals can play negative roles, which in certain circumstances can lead to pathological consequences, all caused by different exposure to potentially toxic minerals, the more or less severity of the pathologies mainly relying on both dose and exposure duration.

Humans have identified that certain minerals bearing lead (Pb) and mercury (Hg) can be the cause of diseases named *plumbism* or *saturnism* and *mercurosis* or *hydragirism*, respectively, which can be lethal. Progressively, humans found also that

several diseases or pathologies are due to other minerals *s.s*. such as *silicosis*, *asbestosis*, *baritosis*, *siderosis*, *berylliosis*, and *talcosis*. Also, it became well established that mineral toxicity can be attributed to the excessive exposure to certain minerals in the elemental form as in the cases of As, Cd, F, and Se, which, being present in food and in drinking water, can cause the pathologies *arsenicosis*, *cadmiosis*, *fluorosis* and *selenosis*, the more or less severity of the pathologies being mainly related to both dose and exposure duration.

In general, minerals toxicity exposure involves processes that follow three pathways: ingestion, inhalation, and dermal absorption. Solid food of vegetable or animal origin and created in soil, as well as potable mineral water, are via ingestion the main suppliers/carriers of minerals in the elemental form for human nutrition and good or bad health.

In potable mineral water, which is essential for life, although condition of health quality depends upon its chemical and microbilogical composition, minerals are, as a rule, either dissolved in the elemental form (Na, K, Ca, Mg, Fe) or suspended in extremely fine particulate form (clay, oxides/hydroxides, organic matter).

Minerals l.s. are the fundamental constituents of the natural environment where humans live, and they use minerals for their survival and living quality. Naturally, both positive and negative interactions do occur between minerals and humans, and in the last two decades, the studies on these subjects have been dealt with within the sphere of action of the emergent scientific field called Medical Geology.

Research on medical geology in the search for relationships between the environment, the geologic environment in particular, and human health should involve a large number of areas of knowledge and specialties. Effectively, the diagnosis, prevention, and personalized treatment of a disease related to the geological environment can only be achieved through a wide interdisciplinary collaboration involving people with professional training in diverse scientific areas, such as medicine, geology, biology, biochemistry, biophysics, mineralogy, geochemistry, hydrogeology, hydrochemistry, ecology, environment, food chemistry, nutrition, toxicology, pathology, epidemiology, etiology, territory planning, and economics.

To be used by man, minerals require, first, to be extracted from the earth by mining and quarring processes, second to be submitted to physical and chemical processing. Mineral extraction, inherently irreversible and unsustainable, and mineral processing, as a rule, produce more or less serious impacts, both on the environment and on human health. For instance, underground water contamination caused by heavy metals and atmospheric contamination by metal-bearing dust are the major problems arising from mining and metallurgical processing. The rising public awareness of these impacts justifies the recycling, whenever possible, of mineral-based wastes.

In 16 chapters, this book intends to be a holistic approach to the knowledge, both historical and actual, of the benefits and hazards involving the diverse interactions between *minerals l.s.* and *humans*.

The aim of this book is to provide students and researchers worldwide with updated scientific data, generic and specific, of both positive and negative interactions of *minerals l.s.* on the *quality of life*. In fact, this book intends to gather, using

an integrative mode, most of what is presently known of the significant contributions provided from various scientific and technological sources about the aforesaid interactions referred to. The scientific, historical, and technical references thoroughly disclosed in this book, although numerous, are certainly incomplete. Therefore, our best excuses for the missing references.

This book is particularly addressed to upper-level undergraduate, graduate, and postgraduate students and researchers doing studies and research, specifically in geological, biological, chemical, materials, environmental, pharmaceutical, and medical sciences.

The specific field of clay science being a subject of common interest to all the aforesaid sciences deserves a particular development in this book. Clay and clay minerals, within all minerals, and due to their ubiquity, diversity, and crystalochemical specificities, as well as to specific physical, chemical, and physicochemical properties, are the most acknowledged along the human history for various health benefits, first on an empirical basis, and later on a scientific basis.

Clay and clay minerals whenever used for therapeutics and cosmetics are currently part of formulations which are administered both orally and topically in various forms, such as patches, pastes, tablets, powders, capsules, emulsions, suspensions, creams, and ointments, and for such purposes, they had undergone little or much scientifically and technically sound processing and modification. However, particularly since the last decade and as output of scientific and technical developments, the so-called hybrid mineral-organic complexes, such as *clay-drug hybrid materials* and *clay-drug delivery systems*, are becoming matters of extensive biomedical research and application, either as formulation additives, or as drug carriers using a variety of routes, including oral, transdermal, and local administration.

Aveiro, Portugal — Celso Gomes
Orléans, France — Michel Rautureau

Citations

"We're well aware that every creative work is imperfect and that our most dubious aesthetic contemplation will be the one whose object is what we write. But everything is imperfect. There's no sunset so lovely it couldn't be yet lovelier, no gentle breeze bringing us sleep that couldn't bring yet sounder sleep."
Fernando Pessoa (1888–1935) – Portuguese poet, writer, and philosopher. *In*: *The Book of Disquiet*, Assirio & Alvim editors, 1st edition 1998.

"The poet Leopoldo Lugones affirms the friendship of man and stone. I want to refer to another more essential and mysterious friendship, the friendship of man and water. Most essential, because we are made not of flesh and blood, but of time, of fugacity, whose immediate metaphor is the water, and already Heraclitus of Ephesus has said so.**"**
Jorge Luis Borges (1899–1986) – Argentine poet, writer, and philosopher. *In:* the book entitled *Atlas*, topic "As Fontes," Quetzal editors, 1st edition 2018.

"Let men, made up of flesh and blood, not complain about the brevity of life, for the stones also die, and also everything that has happened has passed, and everything that is passes too.**"**
Padre António Vieira (1608–1697) – Portuguese preacher, writer, and philosopher. *In*: the book entitled *Antologia e Aforismos*, Telos editors, Porto, 1997.

"We only know exactly when we know little; as we acquire knowledge, doubt arises." "Knowing is not enough, we must apply." "Willing is not enough, we must do."
Johann Wolfang von Goethe (1749–1832) – German writer and scientist.

"Look deep into nature, and then you will understand everything better."
Albert Einstein (1879–1955) – German-born theoretical physicist and Nobel Prize winner.

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Chapter 1
Introduction: Targets and Concepts

Celso S. F. Gomes

Abstract It is known for centuries that minerals *latu sensu* (*minerals l.s.*) play decisive roles in both human health and living quality, naturally first on an empirical basis and later on a scientific basis. When ingested or applied topically, some minerals are reckoned for having curative effects on certain diseases of the digestive forum and dermal conditions, such as alleviating ailments and gastric intoxications, healing wounds, stopping bleeding, and skin care and treatment. In turn some minerals may be deleterious for the human health, even lethal depending on the exposure concentration and time. In the 16 chapters of this book, historical and scientific information, generic and specific of the positive and negative interaction of minerals in the human health, is disclosed. A holistic approach to these subjects is the main target of the book, and to fulfill this approach, a comprehensive concept of mineral has been adopted, the concept of mineral *latu sensu* (mineral *l.s.*) that has been presented in the Preface and thoroughly exemplified along this chapter.

1.1 Introduction: Targets and Concepts

This book is intended to be an updated and comprehensive academic review on both positive and negative effects of minerals *latu sensu* or minerals l.s. regarding human health and living quality. As a rule, researchers do overweight the negative interactions. On the contrary this book seeks a harmonious balance of both interactions.

To accomplish the main target of this book - a holistic approach to *minerals/humans* general and specific interactions -, a broad concept of mineral has been adopted, the concept of mineral *latu sensu* (*minerals l.s.*).

The comprehensive concept of mineral *latu sensu* (*minerals l.s.*) encompasses within other concepts ahead presented, the two most trivial: the concept of mineral *strictu sensu* (*minerals s.s.*) or mineral *itself* – natural, inorganic, solid, and crystalline product which is an important component of rocks and soils – adopted as so, for

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instance, in Earth Sciences, Soil Sciences and Materials Science; the concept of *mineral* – chemical element of natural and inorganic origin, as a rule metal and metalloid, which is an important component of the human body, food (solid and liquid), and pharmaceuticals -, adopted as so, for instance, in Medical Sciences, Pharmaceutical Sciences and Nutritional Sciences.

All the chemical elements of natural origin and inorganic nature shown in the Periodic Table can be constituents of both *minerals s.s*. and *humans*. Also, very close relationships are known between *minerals s.s*. and *humans*. Both *minerals s.s.* and humans are chemical systems built with the same fundamental blocks – the natural chemical elements – although in different concentrations. Also, both *minerals* and *humans* follow processes of formation, growth and duration, and sooner or later they disappear since they are imperfect natural beings characterized by inherited and acquired defects and disorders. In *humans* such defects and disorders could be expressed as diseases of more or less severity, imperfections that could be found in the genetic code. In *minerals*, such defects and disorders mean physical and chemical unstability leading to alteration, transformation and disappearance.

The general and comprehensive concept of mineral, the concept of *minerals l.s*. adopted in this book, allows to encompass the following particular concepts of mineral:

1. The *natural, inorganic, solid and crystalline chemical element* or *compound* that participate in the composition of rocks and soils, and can be present too dissolved or suspended in both mineral water and air; some of these minerals, particularly those suspended in respirable air and being either naturally or anthropogenetically produced, can cause serious diseases dependent upon the exposure in the respiratory system, such as *silicosis* and *asbestosis*; other of these minerals can time play positive functions in *pharmaceuticals* and *cosmetics*;
2. The natural, inorganic, solid and crystalline compound which underwent man-made physical and chemical modifications able to change its natural physical and chemical properties with importance for certain industrial applications; such situation is well exemplified by cation exchange, delamination, intercalation, pillaring, acid or alkaline activation performed in certain clay minerals;
3. The bio-essential *chemical elements* of natural origin that in the ionic form are constituents of the solid food of vegetable or animal origin created in soil, which being named *macronutrients* or *mineral salts* and *micronutrients* or *oligominerals* are the main suppliers/carriers of minerals for human nutrition and wellness;
4. The *chemical elements* that in ionic form are constituents of drinking mineral water and currently called *minerals*, being well established their decisive conditioning of human health and living quality too; mineral water that can be used in therapeutics, such as *crenotherapy, hydrotherapy*, and *thalassotherapy*;

5. The *chemical elements*, also currently called minerals that enter mostly as oligoelements into the formulations of the so-called *mineral supplements*;
6. The *nanominerals* characterized by nanosizes, exemplified by some types of *clay minerals*, which are actually investigated and used for the controlled and sustainable deliver of pharmaceuticals;
7. The *biominerals* classified as, either *bio-essential* for some human physiological systems such as bones and teeth, or *pathological* since they can cause pathologies such as *lithiasis* – urinary, salivary, renal and biliar -, due to the formation of the so-called *calculi* or *stone*;
8. The *special clays*, natural associations of minerals dominated by the so-called *clay minerals* – hydrous phyllosilicates -, which are being used since the Antiquity as cosmetic products and as therapeutic materials in both internal and external applications called *geophagy, mudtherapy* and *pelotherapy*, respectively;
9. The *special sands*, such as: those of biogenic carbonate minerals, those of radioactive minerals yielding radon gas evolution, and still those of naturally heated volcanoclasts, which under the form of sand-baths are used, either outdoors in the natural environment or indoors inside Spas facilities, in a therapeutic application named *psammotherapy*;
10. The *chemical elements* of natural and inorganic origin usually called metals; some could participate in the composition of *metalloproteines* and *metalloenzymes* acting as calalysts in the health essential metabolic reactions; some others could be used too, for instance, in *disease diagnosis* and in *cancer therapy*;
11. *Synthetic minerals* that can be used in pharmaceuticals and cosmetics.

Very early, it is admitted that since the dawn of Antiquity, man first empirically and much later on the base of scientific principles and methods has discovered that certain natural products which later came to be called *minerals*, when ingested or applied topically had curative or healing effects on certain diseases of digestive and dermal conditions, such as alleviating ailments and gastric intoxications, healing wounds and stopping bleeding; some minerals could also have beneficial effects on skin care and treatment, both cosmetic and dermocosmetic.

The use of minerals for therapeutic purposes it is acknowledge since the earliest cultures, such as Ancient China, Mesopotamia (3000–2000 B.C.) with references on the famous Nippur clay plates or boards (~2500 B.C.), through Ancient Egypt with references on the famous *Ebers papyrus* (~1500 B.C.), Ancient Greece and Rome.

The plates or tablets of Nippur, Mesopotamia, listed clays as remedies for healing wounds and stopping the "body fluxes." The *Ebers papyrus*, the world's oldest medical text, listed clay as a mineral remedy for ailments such as diarrhea, dysentery, tapeworm, hookworm, wounds, and abscesses. Early also, still in antiquity, man discovered that some minerals, when extracted and processed from mines, could act as real poisons, naturally by inhalation of dust then generated [Hippocrates (460–355 B.C.) and Galen (131–201 B.C.)].

Poisoning caused by lead (Pb), mercury (Hg), and arsenic (As), called *plumbism* or *saturnism*, *mercurosis* or *hydrargyrism*, and *arsenicosis*, respectively, were common occurrences among the Romans.

By the Middle Ages, the illness caused by mineral dust was sufficiently recognized to be mentioned by Georg Bauer (1494–1555) whose pen name was the Latinized Georgius Agricola, in the book *De Re Metallica* published in 1556, in Latin, cataloging in 12 chapters labeled Books I to XII the state of the art of mining, refining, and melting metals. Georgius Agricola devoted his activities to study the relationships between mining and medicine.

The most poisonous minerals known in the Greek and Roman times were the minerals of *arsenic* (As), both *orpiment* (As_2S_3) and *realgar* (AsS), which could be lethal when inhaled. Solutions of these minerals, without smell and taste, were intentionally used as poisons. Later, it was identified that *mercury* (Hg) minerals and *lead* (Pb) minerals were equally strongly toxic.

Minerals and metals in particular are present in our daily lives, although the vast majority of us do not realize it. Really, we can't live without them. Within minerals the so-called industrial minerals and rocks, also called *non-metallic minerals* despite not being sources of metals, some are herein identified as aggregates (sand, gravel), clay (kaolin, bentonite, fibrous clay, ball clay, fuller's earth, heavy clay), limestone, dolostone, talc, feldspar, quartz, bauxite, asbestos, etc., participate in fundamental applications depending on their physical and chemical properties, in industries, such as construction, cement, ceramics, plastics, glass, refractories, paper, paints, rubber, fertilizers, pesticides, absorbents, cosmetics, pharmaceuticals, etc. (Kogel and Trivedi 2006). Other minerals, the so-called metallic minerals, are the source of metals, some herein identified: iron ores, copper ores, gold ores, zinc ores, rare-earth ores, etc.

As a matter of curiosity it is interesting to know that in the manufacture of a "smartphone," a machine or commodity so common and important these days, 40 metals are utilized. In a smartphone, the major metals are Cu (13.7 g), Ag (0.189 g), Au (0.028 g), and Pd (0.014 g). In 2015, Samsung produced 83.2 million smartphones, and Apple produced 61.2 million smartphones, which required 7913 tons of copper and 16 tons of gold. Other eight essential metals (Y, La, Ce, Pr, Nd, Gd, Tb, and Dy) belonging to the so-called group of rare-earth elements (REEs) commonly referred to as lanthanides, which are characterized by unusual physical and chemical properties, in particular magnetic and optical properties, are utilized in a smartphone. Some REEs are essential to the manufacture of smartphones, tablets, and computer flat-panel screens, and also in computers hard disk drives, special alloys, fluorescent and LED lightings, catalytic converters, medical imaging devices, etc.

There are 15 REEs which are classified into two groups: light REEs (La, Ce, Pr, Nd, Sm, Eu, and Gd) and heavy REEs (Tb, Dy, Ho, Er, Tm, Yb, Lu, and Y). The REEs commonly occur together in the Earth's crust in carbonatites, alkaline igneous rocks, ion adsorption clay deposits, and monazite-xenotime-bearing placer deposits.

Magnets based on Nd-Fe-B are the strongest permanent magnets so far known. Ce and La are being investigated as anticancer agents. A review of REE

applications, occurrence, exploration, and environmental impact can be found in USGS (2014) and Balaram (2019). Actually, REE market supply is much dependent on China (controls 95% of the global market, southern China being the world's primary source of REEs, extracted from ion adsorption clay deposits); the reason why REEs are "critical" or "strategic" mineral resources is its high potential of supply-side risk or supply vulnerability (Elements v.8 (5), 2012; Géochronique Juin 2008). Presently, besides REEs, other minerals in the elementary form such as lithium (Li) and cobalt (Co) are considered "critical" too.

Material science, minerals and their derivates included, and health sciences are presently within all sciences, the most relevant and productive, both scientifically and technologically. Some metals and metalloids, even as trace elements, are being used in some of today's most sophisticated medical applications.

Actually, the decarbonation of the global economy – required by the so-called climate crisis – and the new wave of technological evolution featuring artificial intelligence (AI) and 5G networks fuel the race to secure uninterrupted access to critical minerals. Electrification is seen as the way forward for various sectors. Transportation – responsible for over 20% of the global emissions during the last decade – is expected to transition to alternative energy vehicles with expanding share of electric vehicles (Evs). The push toward Evs seems unstoppable. The Netherlands has pledged to ban the sale of petrol and diesel cars by 2025, and the UK and France by 2040. China is targeting zero-emission cars as 12% of new car sales by 2020.

Since the beginning of the twenty-first century, the production of lithium (Li), metal indispensable to high-tech, green economy and the defense industry, began to grow rapidly in order to meet the demand for lithium-ion batteries. However, Li resources are highly concentrated in South America, especially in Argentina (14.8 million tons), Bolivia (9 million tons – of largely untapped resources), and Chile (8.5 million tons). Because of their dominant position, these three countries have become known as the "lithium triangle" (Kalantzabos 2019).

According to the *Portuguese Mining Bulletin – Special Edition Lithium* (2017–18), Portugal is the EU country with the largest lithium reserves concentrated in the northern and central areas, Li mainly occurring in the minerals *spodumene*, $LiAl(SiO_3)_2$, and *lepidolite*, $Kli_2Al(Si_4O_{10})(F,OH)_2$.

Cobalt (Co) is also a key metal and ingredient in batteries for smartphones, laptops, and electric cars. However, the dominant producer is the Democratic Republic of Congo, which currently accounts for more than 60% of the world's cobalt mine production and boasts by far the largest reserves in the world.

The discovery of metals, naturally extracted from certain minerals, was a key factor for the development of civilizations and the establishment of the first empires by military forces. The metals copper (Cu) and tin (Sn) were the first metals used by man who, as soon as he knew how to produce the alloy called bronze, made it possible to manufacture efficient tools to use in agriculture, and at the same time lethal weapons. Small groups of men with bronze swords succeeded in defeating armies armed with pieces of stone, bone, or stick. Later, in the East, around the thirteenth century B.C., metallurgical techniques allowed the production of iron armaments,

resulting in a new civilization leap that in Europe was only felt many centuries later. The civilization leaps due to the discovery of bronze and iron were equivalent to the civilization leap that many centuries later had been due to the discovery of gunpowder and firearms.

The increasing concern of modern societies with the interactions between the environment and health, in particular through the geological processes and products, justified the emergence in the last two decades of the scientific field called "Medical Geology," mainly focused on the negative or hazardous effects of minerals themselves and natural chemical elements, despite their fundamental and paramount importance for both good health and living quality.

Duffin et al. (2013), Duffin (2017), and Hoch (2017) show the historical connections between geology and medicine. Duffin (2017) produced a brief but concise historical backdrop on the historical links between medicine and geology initiated with a reference to the *Dictionary of Assyrian Chemistry and Geology*, in which Claredon Thompson (1936) mentions 120 mineral drugs cited in the clay tablets excavated from the King Ashurbanipal of Assyria's Library, at Nineveh, and whose links continued with references to the contributions of the Egyptian, Greek, Roman, Arabic, and Medieval and Renaissance schools.

Within the first minerals utilized by man for curative purposes, it should be enhanced the so-called medicinal earth or medicinal terra (*terra* from Latin), also known as *terra sigillata* or *terra sellada,* particularly exploited in certain volcanic islands of the Aegean Sea. *Medicinal earth* was commercialized and utilized since the antiquity up to the eighteenth century. Each one of those islands produced its own *medicinal earth* named according to its provenance: *Lemnian earth* from the Lemnos's island; *Cimolian earth* from the Kimolos's island; *Samian earth* from the Samos's Island; and *Melos* or *Milos earth* from the Melos's or Milos's island.

Lemnian earth, a famed medicine from antiquity to post-Medieval times being used as an antidote to snake bites or to any poison internally taken and to cure ulcers and dysentery, was firstly used in the Greek island of Lemnos in around 500 B.C. The clay torches were crushed into a powder and taken with liquids or made into paste and smeared on parts of the body. The worldwide increased demand inspired a host of counterfeits and imitations. The need of an increased supply leads to the survey of new sources of similar medicines, which particularly in Medieval and post-Medieval times were discovered, prepared, and commercialized in Hungary, France, Germany, Malta, Sienna, and Silesia.

With the progressive evolution of the knowledge acquired by man, he came to know that the *medicinal terra* is a geological material to which was given the name of clay. Some types of clay, to which were already recognized in the twentieth century, specific medicinal properties and functions and scientific and commercial names too, as well as other pharmacological preparations based on *minerals*, have been included in pharmacopeias, from the first that appeared in the sixteenth century to the contemporaneous ones, as active substances or as excipients, in one case and another with different functions. As a rule, the therapeutic activity of clay takes place by oral and topical pathways. Orally the following functions are highlighted:

gastric anti-acidity, gastrointestinal protection, anti-diarrheal, antianemic, laxative, homeostatic, and dietary supplementation.

Geophagy, particularly through ingestion of the so-called edible clays, is a good example of the internal use of minerals for curative purposes. The internal uses of minerals, *clays* and *clay minerals* in particular, and their benefits and risks will be disclosed in this book.

Topically, the following antiseptic, anti-inflammatory, disinfection, dermal protection, and sun protection functions of minerals are highlighted. *Mud therapy* and *pelotherapy* are good examples of the external use of curative minerals in the form of poultices, patches, and facial masks. The topical uses of minerals, clays and clay minerals in particular, and their benefits and risks will be also disclosed in this book.

Today we know that *minerals* and the *human body* are chemical systems which have in common many of their elemental constituents, the natural chemical elements, classified as metals, metalloids, and gases. Life, living beings, and biodiversity much depend on the relationships that could be established and developed between these elemental chemical constituents. Therefore, the development of Pharmacology has been parallel to the development of Chemistry and also to the development of therapeutics as a competence of medicine.

Evolution has been so remarkable that presently in many pharmaceutical formulations, the minerals as natural products have been replaced by the so-called synthetic analogs produced in laboratories and industries even though from natural products (minerals included) but having improved properties, for example, the degree of purity. Naturally, the participation of *minerals* in pharmaceutical formulations requires them to undergo previous industrial and laboratory processes used in the so-called pharmaceutical technology.

Today we also know that *minerals*, in the broad concept of mineral *latu sensu* (*mineral l.s.*), term adopted in this book, occur in the whole natural environment:

1. In rocks and soils, both in the form of mineral itself, that is, as natural, inorganic and crystalline solid, considered *mineral stricto sensu* or *mineral s.s*, and in the elemental free form, considered the *chemical element* of natural origin constituting the *minerals s.s.*, and which in the natural environment occur either solvated or fixed to the surfaces of inorganic and organic compounds;
2. In mineral waters, dispersed and suspended in a colloidal form of the *mineral itself* or *mineral s.s.* (it is the case of nanoclay), and/or in a solution in the elemental form;
3. In the air, dispersed in the form of *mineral itself* or *mineral s.s.*, and/or in the elemental free form or fixed to aerosols.

The concept of mineral *latu sensu* or mineral *l.s.* encompasses the two aforementioned forms, natural inorganic and crystalline solid and natural solid chemical element. Minerals in the natural environment can occur in these two forms. We well know that the names of some natural inorganic and crystalline solids and natural elements sometimes coincide; they are the cases, for instance, of *gold* (Au), *silver* (Ag), *copper* (Cu), *iron* (Fe), *sulfur* (S), and *carbon*-I, the so-called native element minerals.

The mineral forms referred to as the natural chemical elements can occur free and dispersed in rocks, soils, water, and air. Also, in this book, the concept of mineral *l.s.* comprises too some natural associations of minerals *s.s.*, as are the cases of certain types of *clay* to which man since the antiquity had recognized their healing properties.

Mineral water from the surface or from underground reservoirs and used for human consumption is itself essential for life due to the "minerals" it contains dissolved and in the elemental and ionic form, as cations and anions. Such justifies the generalized designation "mineral water."

There is general and specific information on the historical evolution of the use and effects, both positive and negative, of minerals on the human health. Information exists too on the sources – food, water and air, and pathways – ingestion, inhalation, and dermal absorption, which rule the availability and the incorporation of minerals in the human body, and supplemental information exists on the application and function of minerals in terms of human health, exemplified as follows: Campbell Thomson (1936); Duffin (2013); Gomes (2003, 2012, 2013, 2015a, b, 2017); Gomes and Silva (2003, 2006, 2007, 2010a, b, c, 2012); Hall and Photos-Jone (2008); Macgregor (2013); Photo-Jones et al. (2017); Rautureau et al. (2010, 2017); Retsas (2016); Teixeira (2009, 2016); Viseras et al. (2019).

All natural and inorganic chemical elements or "minerals" are present in the human body, and a significant number of them reckoned as essential to human health are classified as major, minor, and trace elements. Such elements could be good, tolerable, or toxic for human health depending on the individual dose. In particular, *mineral toxicity* due to dose excess or deficit will be enhanced. Also, minerals *s.s.* whether present as fine particles suspended in the air that is inhaled can cause severe pathologies, such as *silicosis*, *asbestosis*, *siderosis*, and *talcosis*.

Information about the use of some *minerals* as active substances and as excipients in pharmaceuticals is disclosed, the use of those *minerals* being dependent upon their specific crystallochemical properties.

As active substances in pharmaceuticals, *minerals* can perform important specific functions, such as gastric antacid, gastrointestinal protection, anti-diarrhea, laxative, antianemic, antiseptic and disinfectant, dermatological protection, solar protection, cosmetics, abrasive and mitigator of dental sensitivity, ocular congestion relieve, nutritional supplement, means of diagnosis and treatment, immobilizer in orthopedy and mold in odontology, contrasting mean in pathology diagnosis, and hemostatic agent.

In turn, as excipients in pharmaceuticals, minerals play the following main functions:

1. Improvement of organoleptic properties (taste and color);
2. Improvement of physicochemical properties (viscosity, dispersibility, suspendability, and thickness);
3. Facilitation of preparation and conservation of formulations (dilution, lubrification, and desiccation);

4. Facilitation of the release of the active drug ingredient in a particular site inside the organism.

Also, as excipients, minerals perform important specific functions, such as lubrication, taste correction, disintegration, dilution, binding or aggregation, pigmentation, emulsifying, thicknessing, and carriers for the controlled release of drugs.

Yet, there is significant information about the minerals utilized in cosmetics. In the manufacture of cosmetics, thousands of chemicals can be used. A typical cosmetic product could contain anything from 15 up to 50 ingredients. Most cosmetics contain a combination of at least the following functional ingredients: water, emulsifier, preservative, thickener, emollient, color pigment, fragrance, and pH stabilizer.

Also, interesting information exists on *metals*, natural elements constituents of the Earth's crust which are released from *minerals s.s.*, some of them that, in small amounts, are needed in the human body participating in the composition of *metalloprotein*s (generic term for proteins that contain metal ions as cofactors) and *metalloenzymes* (enzyme proteins that contain metal ions as cofactors), both fundamental for life and health.

In the Earth's crust, there are, in the native state, near 30 chemical elements, mainly metals, few being metalloids and gases. Native elements, native metals, and native metalloids can occur as native *minerals s.s*. The chemical native element or native metal iron (Fe) forms the native mineral α-Fe named *ferrite*. This example could be extended to the native metals Co, Ni, Pt, Ir, Pd, and Rh of group VIII in the Mendeleev's table, to the metals gold (Au), silver (Ag), and copper (Cu), to the metalloids As, Bi, and Sb of group V, and yet to the metalloids S, Se, Te, and C (native minerals *diamond* and *graphite*) of group VI.

Metals are of paramount importance for human health. For instance, the metal iron (Fe) is a constituent of hemoglobin; the metals copper (Cu), zinc (Zn), and manganese (Mn) are constituents of enzymes; and the metal chromium (Cr) is a cofactor in the regulation of sugar levels. Some other metals, as are the case of the so-called heavy metals, such as lead (Pb), cadmium (Cd), and mercury (Hg), can be deleterious to human health.

Metals can be intake from environment by organisms, man included, through ingestion of water, solid food, and plants. Metals can be taken from the environment by plants, through the roots and leaves. Metals can be taken from inhalation of dusts, gases, and aerosols. Metals can be bio-accumulated up the food chain. Therefore metals, those good or bad for human health, are included in this book into the concept of *mineral latu sensu* (*mineral l.s.*). Still regarding the *concept of mineral*, it is important to note that the concept varies from the Earth Sciences to the Pharmaceutical Sciences, to the Medical Sciences and to the Nutrition Sciences.

"Inorganic solid whose constituent chemical elements have their own ordered organization, and that is formed in the natural environment without human intervention" – this is the concept of *mineral* adopted by the specialists in Earth's Sciences, Materials Science, and Soil Science, and corresponds to the concept of *mineral stricto sensu* (*mineral s.s.*). The proper three-dimensional and ordered organization

of the chemical element constituents of minerals is specific to the so-called natural crystals, and almost all *minerals s.s.* are *natural crystals*.

Otherwise, the specialists in Medical Sciences, Pharmaceutical Sciences, and Nutrition Sciences, in general, call minerals "The chemical elements of natural and inorganic origin that are essential to man's life and quality of life." However, it should be noted that in Pharmaceutical Sciences, the concept of *mineral* is effectively double, covering the aforementioned chemical elements and some natural inorganic solids, the latter being part of the so-called active substances and excipients, both components of the so-called pharmaceutical formulations.

Also, in the Medical Sciences, in addition to the chemical elements above recalled, the mineral designation is also applied to the so-called biominerals formed in the human body by cell division, and which are both *bio-essential* (constituents, for instance, of the bones and teeth) and *pathological* (constituents, for instance, of kidney stones and gallstones). And, it is well known that minerals participate in the constitution of all living beings and that they condition the quality of the natural systems which are life supporting: soil, water, and atmosphere.

In humans, *minerals* play three main roles:

1. Provide structuring in the formation of bones and teeth;
2. Help in the maintenance of normal heart rate, muscle contraction, conduction of the nervous system, and acid/base balance;
3. Regulate cellular metabolism by being part of enzymes and hormones that control cellular activity.

Minerals can also have deleterious effects on humans. It is known that a good part of the human diseases is related to the minerals of both geogenic origin and anthropogenic origin present in the natural environment that serves as habitat for the man. It is well-acknowledged that some diseases are related to lifestyle, others are due to the action of pathogens (viruses and bacteria), and several others are genetically dependent. Also, it has been effectively demonstrated that in the natural environment man's exposure to certain geological materials and processes can be a cause of disease, some of which can be lethal, for example, excessive exposure to certain potentially toxic natural elements such as arsenic, lead, cadmium, mercury, selenium, fluorine, uranium, and radon, which may be present, either in the soil particularly affixed to clay particles and utilized by the plants which are at the base of the food chain, or in the water, or yet in the air.

The importance of the so-called nanominerals and nanomaterials in Pharmacy and Therapeutics will be dealt with in this book. *Nanominerals* also play important functions in the field of *nanomedicine* defined as the science and technology of diagnosing, treating, and preventing disease and traumatic injury, of relieving pain, and preserving and improving human health, using molecular tools and molecular knowledge of the human body.

Nanomedicine embraces five main sub-disciplines which are in many ways overlapping and are underpinned by common technical issues: *nanomaterials and devices*, *analytical and imaging tools*, *novel therapeutics and drug delivery systems*, *clinical applications*, and *safety and toxicological issues* (*environmental*,

manufacturing, and *clinical use*) (ESF-European Medical Research Councils report, 2004). Nanominerals such as *carbon nanotubes*, *halloysite nanotubes*, *allophane*, and *imogolite nanospherules* and *tubules* have been thoroughly investigated as drug delivery systems. Also, minerals ever since have been used in cosmetics, and currently under the form of *nanominerals*, they are incorporated in several cosmetic products, such as creams, powders, emulsions, sunscreens, lipsticks, bathroom salts, and toothpastes.

Experience shows how important are the roles of *clay* and *clay minerals* for human health, the reason why one chapter of book is dedicated to clays and clay minerals and to their crystallochemical properties that could justify both positive and negative interactions on human health. Clays are one of the oldest earth materials used for healing purposes in the traditional medicine, and they continue to be applied in modern life for the treatment of various topical and internal ailments. Effectively clays are mineral resources and not *minerals s.s*. As a matter of fact, clays are aggregates of different minerals, which as a rule have associated non-mineral substances, such as organic matter and amorphous iron oxyhydroxides. Clays and clay minerals can be used *unmodified* (natural or synthetic) or *modified* (composites such as *clay-drug hybrids*, *organoclays*, *clay-polymer hybrids*, and *hydrogels*).

Nanostructured materials can be produced by the intercalation of organic molecules, such as proteins, enzymes, peptides, carbohydrates, nucleic acids, lipids, and polymers, within the interlayer spaces or other internal spaces of clay mineral structures, taking advantage of clay minerals' specific physicochemical properties, such as high specific surface area, electric charge, and reactivity.

Smectite clay minerals (*montmorillonite* and *hectorite*), fibrous clay minerals (*palygorskite* and *sepiolite*), and kaolin clay minerals (*kaolinite* and *halloysite*) are the mineral species most utilized in biomedical and pharmaceutical applications. *Biomolecules*, either negatively or positively charged, can be immobilized, stabilized, and preserved on the basal and edge surfaces, or in interlayer spaces or microchannel spaces of clay mineral particles.

Experience has shown how positive, important, and unique is the role of certain natural or modified clay minerals in controlled drug release systems, as well as in the field of biosensors (e.g., *enzymatic biosensors*) and in the field of *regenerative medicine* or *regenerative tissue engineering*.

New trends on developments of controlled drug release based on clay-drug hybrid systems take into account the kind of administration route (oral, topical, transdermal), hoping to be deployed to specifically targeted parts of the human body (organs or cells). In general, clay-drug hybrid systems seemed to be very effective and to work well in vitro, and not so well in vivo. Hence, some challenges still remain for researchers.

Great advances are being made in the field of polymer nanocomposites based on both clay and clay minerals for various applications in automobiles, packaging, aerospace, and agriculture sectors. The required modification of clay particles involves the application of physical and/or chemical methods, always aiming at the achievement of stronger interaction among clay particles and modifying agents. The

so-called organoclays, obtained by intercalating some organic molecules into the structure of certain clay minerals, particularly in those belonging to the smectite group, have promising potential on the biomedical and pharmaceutical fields of application.

In the biomedical field of applications, clays are used in pharmaceutics (both as active ingredients in the case of drug carriers and as excipients), cosmetics (sun screens and topical care), biomaterials (scaffold, hydrogel, foam, film), biosensors (electrochemical), and medical devices (patches, implants, medical plastics). In fact, recent research reinforces the promising potential on the biomedical and pharmaceutical fields of application.

As active substances or ingredients, to certain types of natural clay of green or blue colors that bear reduced transition metals such as Fe^{2+}, Cu^{2+}, and Zn^{2+}, are being attributed bactericidal properties, and in the last decade, the significant investigation being carried out has confirmed such properties relative to various pathogenic bacteria and has tried to identify the mechanism of the microbicide action and to establish the methodologies for both internal and external (topical) applications. Clay bactericidal character does not exist if clay is in the dry state – only when clay is in the hydrated state, for instance, in the paste state, microbicide action exists. Such microbicide action creates high expectations when both public health and science are becoming more and more apprehensive and engaged relatively the increasing resistance of bacteria to antibiotics.

Specific clays and clay minerals have proved to be valuable in the treatment of bacterial diseases, including infections for which there are no effective antibiotics, such as *Buruli ulcer* disease caused by *Mycobacterium ulcerans*, and multi-drug resistant infections. Dozens of scientific articles can be found in the literature describing and investigating the mechanisms of action of the so-called killer clays, which can be a possible new answer to "superbug" infections. "Superbugs" are pathogens or disease-causing microorganisms resistant to multiple antibiotics, and such antibiotic resistance is presently a matter of major public health concern. One example of "superbug" is the methicillin-resistant *Staphylococcus aureus* (MRSA). "This serious threat is no longer a prediction for the future," states a World Health Organization report. "It's happening right now in every region of the world and has the potential to affect anyone, of any age, in any country."

Topical antimicrobial therapy emerges as an attractive route for the treatment of infectious diseases due to the increased resistance to oral-administered systemic antimicrobial therapy (Lam et al. 2018).

Microbes are essential components of most environments on Earth, being present for instance, in the geomaterials, such as soils, clays, and mineral waters. Minerals provide microbes with nutrients, energy, and livable habitats, and microbes intervene in mineral weathering and diagenesis through their effects on mineral solubility. By contrast, microbes can form *minerals* as a by-product of either their surface reactivity toward soluble metals or as a consequence of their metabolism. The so-called microbiome is an essential component of the human body, and it can contribute to human health and disease. The importance of the interaction *microbes* and *minerals* has been reckoned particularly in the last decades; the so-called

Geomicrobiology became a very interesting field of research. Some microbes are reckoned by their economically useful capabilities, as is the case of the bacterial species of the phyla *Actinobacteria*. It is also known that in certain environments, conditions, and doses, the *minerals* can benefit or affect both the quality of the soil where the animal or vegetable food raises and is produced and the quality of the water and air that the man eats and breathe, respectively.

In the soil and water, minerals can occur in the elemental form which is the bioavailable form and, when in balanced contents, may be essential for sustained and sustainable animal and plant life. For example, it is now widely accepted that the type of soil, which is very much determined by the types of minerals it contains, is a factor that, together with three other factors, caste, climate and winemaking, are essential factors for commercial success, complexity, and originality of a wine, current consumer product. It is the soil that feeds the strains.

Different soils provide different wines even if the grape variety is the same. From this fact the concept of terroir has appeared. Since the 1980s, several studies have emphasized the importance of *rocks'* and *minerals'* quality and quantity in the land where the vine grows. In general terms, granite, shale, limestone, and clay or clay soils decisively influence the final complexity of the wine and its differentiation, which are still influenced by the differentiated varieties of the rocks mentioned above, because there are several granites, shale, limestone, and clays. For example, among clays, there are differences in terms of composition granulometry, mineralogical, chemical and also other properties such as adsorption and water fixation, plasticity, and cation and anion exchange.

If the levels of some bio-essential elements are deficient in the water and in the animal and plant food, the deficiency can be compensated for by the controlled consumption of the so-called mineral supplements for animals (man included) and, for plants deficiency, can be compensated for by the addition to the soil of fertilizers in whose composition the soil chemical elements were deficient.

Mineral water is essential to life, to human body, and to human health. Experience has shown the existence of healing waters, and according to their specific physicochemical properties, they are used in the treatment of specific diseases. The amazing diversity of *mineral waters* used for drinking is definitively due to both the quality and quantity of dissolved minerals, as is clearly shown in the book *Drinking Water Minerals and Mineral Balance: Importance, Health Significance, Safety Precautions* (Rosborg I (editor), 2015, Springer).

Concerning *mineral water*, there is a worrying concern about the increasing exposure of subterranean aquifers, whose mineral water can either be collected for human consumption or perhaps used in *thermalism*. Chemical and microbiological contaminations of anthropogenic origin, although there are aquifers in which, for natural reasons, high concentrations of toxic chemical elements, metals, and/or metalloids occur, make improper the use of water for human consumption. Thermalism is an important economic activity in many countries, including Portugal, with obvious effects on the health and well-being of users. In Portugal, the concepts, objectives, means, and techniques, both fundamental and complementary, of thermalism

are established in the so-called Law of the Thermalism, the Decree-Law No. 142/2004 of 11 of June that defines Thermalism as being:

"The use in Thermal Stations or Thermal Centres or yet Thermal spas of natural mineral water (deep circulation water characterized by the stability of its chemical, physicochemical and microbiological properties), and other complementary means for the purpose of prevention, therapy, rehabilitation or well-being."

In the so-called health resort medicine, the use of *thermal mineral waters* for therapeutic purposes is an important component of the *Medical Hydrology*, a scientific field that covers scientific and technical domains dealing with the medicinal use of mineral water (spring water and natural mineral water), methods of application, and solutions.

Thermalism includes *crenotherapy* practices taken place inside the facilities of thermal resorts, or thermal spas, or yet health resort medicine spas, practices that involve the use of certain natural mineral waters or spring waters showing differentiate chemical composition (bicarbonate sodium, gasocarbonic, sulfate calcium, bicarbonate sodium sulfide, chlorinate, etc.), differentiated degree (greater or lesser) of mineralization (hypersaline, mesosaline, and hyposaline), and also differentiate temperature at the emergence site (hot and cold). Such waters of more or less underground deep circulation are considered medicinal products, being used for internal applications (ingestion and inhalation) and/or topical applications (various baths and hydrotherapy), waters that are generally of a more or less deep circulation (Teixeira 2009, 2016).

Crenotherapy may also involve the topical applications of the so-called curative or therapeutic muds and of the so-called cosmetic muds, which are referred to, respectively, as *therapeutic peloids* and *cosmetic peloids* if the natural mud is matured and modified in an artificial environment, and it is recommended to be applied and supervised by medical or cosmetic training professionals.

The therapeutic application of *peloids* is called *pelotherapy*. Inside of the bathhouses, or balnearies, thermal baths, or spas of the thermal resorts, the liquid phase of the mud/peloid being applied is necessarily the *natural mineral water* used in these resorts. The so-called thermal baths, for example, were introduced by the Romans in many European countries; after having passed through a decadence period, they were revived by the Arabs in the case of the Iberian Peninsula.

Thalassotherapy is another interesting economic activity that uses, for therapeutic purposes, naturally occurring highly mineralized seawater or other products from the sea such as mud, salt, sand, algae, and aerosols. In Portugal, for instance, thalassotherapy is practiced in *thalassotherapy centers* (included or not in hotels) and in *thalassotherapy spas* (all hosted in hotels), however still without legal accreditation in what concerns the quality of resources (human and technical) and methods being employed due to the lack of specific legislation. Also, in Portugal, thalassotherapy is practiced in thalasso spa and even in thalassotherapy centers where the use of seawater could be classified as for well-being and not really therapeutics. The *therapeutic thalassotherapy* is distinctive from the *crenotherapy* in terms of the nature of the raw materials being used, the type of pathologies treated, and the methodologies used in the treatments.

Specific legislation deplorably does not exist for the thalassotherapy practiced in Portugal, unlike what happens for the thalassotherapy practiced in France, Tunisia, and Spain. However, specific legislation exists for the crenotherapy practiced in Portugal, ruled by the Decree-Law No. 142/2004, known as the Law of Thermalism.

Minerals *l.s.* can have adverse effects on the human health, effects that in some circumstances can be lethal. Such aggressive effects can be attributed to some minerals *s.s.* or to some natural chemical elements. In the first case, the situation could be represented by *microcrystalline silica*, *asbestos*, and *talc*, present in the air that man needs to breathe, all minerals with origin either natural or anthropogenic (wind-driven dusts, mining works, or ore processing works), eventually causing pathologies called *silicosis*, *asbestosis*, and *talcosis*, respectively; in the second case, some minerals in the elementary form, such as Pb, As, Hg, Sb, Cd, and F, and other elements present in soils, in water (particularly dissolved in underground water), or in air (volcanic gas, industrial gas emissions) can be toxic for man.

Minerals are involved in another process of naturotherapy called *psammotherapy* or *arenotherapy*, yet another economic activity that uses, for the treatment of pathologies of the musculoskeletal forum or simply in wellness practices, baths of the so-called special sands. An example of *psammotherapy* is the case of the traditional biogenic carbonated sand baths that take place in the island of Porto Santo of the archipelago of Madeira, in the natural environment and with the sand exposed to solar radiation, taking care that the sand temperature is not over 41 °C. Natural or artificial heating is essential to produce sweat which, in the interface of human body/sand due to its acid pH, dissolves and turns free Ca, Mg, Sr, and other elements to interact with the body.

At the moment, sand baths also can already take place in bathhouses/balnearies, being the sand heated inside the spa by artificial heating. There are also examples of sand bathing or *psammotherapy* practiced in certain countries, as is the case of places in southern Japan where the sand of volcanic nature is naturally heated by exposure to the volcanic heat, and the case of certain beaches of Guarapari, in Victória do Espirito Santo district, Brazil, where health benefits are assumed to be related to the *radon* emitted from the radioactive monazite-rich sands.

There is an important medical area in which *mineral analogs* or *analogous* play important roles having both positive and negative effects on the human health, such as the so-called biominerals, classified into two groups: bio-essential and pathological. Minerals play equally important and positive roles in the human body through the so-called biomaterials, in the form of metal alloys, special ceramics, and bioactive glasses. It is now possible to manufacture human tissues and organs using the so-called tissue engineering, and stem cells are essential raw materials for this purpose.

The interdependence between pharmacy and therapeutics involving minerals is of course strong, the minerals being the common fundamentals and connecting bridges between two scientific and technical areas which are recognized as so important to health, a reason for the authors of this book to seek to present evidence of this interdependence, both positive and negative. *Minerals* have been used ever since as drugs and in drugs preparation, in accordance with the pharmacopeias, and

in which participate *minerals latu sensu* (or *minerals l.s.*), the concept of mineral defined in this same chapter further on. *Geopharmacy*, a secular practice that began with the empirical use and processing of natural substances or drugs of mineral, animal, and plant origin, in modern and contemporary times, has progressively incorporated the growing scientific knowledge that has led to the development of molecular chemistry and the industrial processing of drugs purely synthetic.

In turn *geotherapeutics* is defined as being the scientific domain that within the scope of the Medical Sciences studies prescribes and supervises the use of the *minerals l.s.* for therapeutic purposes. *Geotherapeutics*, which began with the empirical use in antiquity of *minerals*, *metals*, and *clays* (called *medicinal earths* or *medicinal terras*), is a practice which continued until the nineteenth century and was eclipsed in the twentieth century because of the spectacular developments of molecular medicine and the corresponding progress of the pharmaceutical industry. From the foregoing the existence of basic and functional relationships between *geopharmacy* and *geotherapeutics* is clear as expressed through the use of *minerals l.s.*, both in the composition of drugs and in therapeutics, in any of the situations in view of the benefits of the state of human health.

On the *Geological Sciences* side, knowledge about *minerals l.s.* is fundamental, provided in particular by sciences such as mineralogy, geochemistry, and hydrochemistry. On the *Health Sciences* side, the knowledge of *minerals l.s.* is fundamental, in particular for physiology, nutrition, epidemiology, etiology, toxicology, pharmaceutical technology, and clinical medicine. It should be noted that both *geopharmacy* and *geotherapeutics* can be included in the recently emerging scientific field called *Medical Geology*, which targets comprise studies of the properties, benefits, and risks of *minerals l.s.* in *public health*, matters that will be further developed in the following chapters.

Finally, the accomplishment of the broad and specific objectives of this book much had benefited from the complementary contributions of specialists in different scientific fields: geology, chemistry, physics, engineering, medicine, public health, and pharmacy Along the years, experience has shown that in science any great scientific advances require interdisciplinary contributions. Also, along the course of their professional careers, the authors have produced scientific books and articles, most of which related to the subjects dealt with in this book are reported as bibliographical references at the end of the chapters and of some sub-chapters.

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