Chapter 1
Introduction

Clay science is multi-disciplinary area; the scientists who work in this area come from diverse backgrounds with very diverse interests. The diversity of the nature of clay science is also reflected by the existence of a variety of scientific journals, books, and patents. Several of the available records such as Handbook of Clay Science, edited by Bergaya et al. (2006) provides information on the fundamental structure and surface properties of clay minerals, their industrial and environmental applications as well as analytical techniques, and the teaching and history of clay science. *Applied Clay Mineralogy* by Murray (2007) discusses about the occurrences, processing and application of kaolins, bentonites, palygorskite-sepiolite, and common clays.

Most of the available review papers just only compilation of the published literatures. This book is intended to provide a critical review of recent studies on the utilization of clay minerals and its modified forms for the water remediation purpose. The structures of clay minerals and their utilization for removal of hazardous compounds from gas and water environment are discussed in Chap. 2. The modification of clay minerals using various kinds of modifying agents such as acids, base, and surfactants is discussed in Chap. 3, while Chap. 4 deals with the adsorption isotherm models which widely used to represent the experimental adsorption data of various hazardous substances on clay minerals. The temperature dependent forms of several isotherm models are also presented in this chapter. The extension of single component isotherm to multicomponent system and its modification are also discussed. The kinetic studies of the adsorption hazardous substances onto clay minerals are described in Chap. 5. The comprehensive discussions about the physical meaning of kinetic parameters of the widely used kinetic models are also presented in this chapter. Chapter 6 describes various analytical instruments commonly employed for the characterization of clay minerals.

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1.1 Water Pollution

An environmental problem arises whenever there is a change in the quality or quantity of any environmental factor which directly or indirectly affects the health and well-being of man in an adverse manner. In this modern world we face very serious environmental issues that need special attention to make the environment friendlier to human. Presently, the global warming is the greatest environmental and humanitarian crisis. Clean and renewable energy is the second big issues after climate change. Water degradation and shortage, severe industrial pollution, and diminishing biodiversity are also other big environmental issues. Increasing human population at faster rate resulted in over consumption, leading to poverty and other environmental problems.

Water is an important and indispensable part of the cosmos and it plays a critical part in the proper operation of the earth's ecosystems (Ali and Gupta 2006). The water shortage has already become the daily problem for almost 1/6 of the world's population. It is also predicted that by 2025, more than 30 % of the world's population will experience water scarcity and more than 60 % will experience clean water problems due to contamination of water and water pollution. Water pollution caused by industrial activities is likewise a major global problem that demands very serious attention, therefore, the evaluation and revision of water resources and water usage policy are also required.

The contaminants enter the water environments through various ways. It can enter directly from direct discharge of industrial effluents, wastewater treatment facilities, refineries, etc. The contaminations of soil, groundwater, and the atmosphere via rain water also contribute to water pollution. Water pollution often creates severe problems for human and environment, such as poisonous drinking water, poisonous food animals, unbalanced river and lake ecosystems that can destroy the biological diversity, etc.

The presence of heavy metals in water cause serious health problems to human. Although several adverse health effects of heavy metals have been known for a long time, exposure to heavy metals continues, and is even increasing in some parts of the world, in particular in less developed countries (Jarup 2003). In view of the human health impacts, each metal imparts different effects and symptoms. Heavy metals are persistent, and therefore, very difficult to eliminate naturally from the environment, even at a presence of trace amounts. Table 1.1 lists the common heavy metals found in water environment as pollutants and its impact on human health (Febrianto et al. 2009; Arief et al. 2008).

Other pollutants commonly found in water environment are dyes, antibiotics, biocides compounds, aromatic organic compounds, and etc. As coloring agents, some dyes are resistant to degradation and their presence in water dyes might be harmful to human beings and hazardous to aquatic organisms. Even at very low concentration, the presence of dye in water is visible and could reduce aquatic diversity by blocking the passage of light through water. The presence of antibiotics and biocides compounds in the water stream cause severe environmental problems. Some of these chemicals have toxic nature toward algae and other lower

Table 1.1 Heavy metals and its impact on human health

Heavy metal	Impact on human health
As(V)	Damage to skin, eyes, and liver, may also cause cancer
Cd(II)	Provoke cancer, kidney damage, mucous membrane destruction, vomiting, diarrhea, bone damage, itai-itai disease, affect the production of progesterone and testosterone
Cr(III)	Allergic skin reactions and cancer in the digestive tract and lungs
Cr(VI)	Headache, nausea, severe diarrhea, vomiting, epigastric pain, hemorrhage, provokes cancer and has an adverse potential to modify the DNA transcription process
Cu(II)	Liver damage, Wilson's disease, insomnia, brain, pancreas, and myocardial damage
Hg(II)	Damage to the nervous system, kidneys, and vision, protoplasm poisoning
Mn(II)	Triggers neurotoxicity, low hemoglobin levels, and gastrointestinal accumulation
Ni(II)	Dermatitis, nausea, chronic asthma, coughing, bronchial hemorrhage, gastrointestinal distress, weakness and dizziness
Pb(II)	Anemia, damage to the kidneys, nervous system deterioration, damage the ability to synthesize protein
Zn(II)	Irritability, muscular stiffness, loss of appetite, nausea, depression, lethargy, neurologic signs such as seizures and ataxia, and increased thirst

organisms which can bring about indirect effect in long terms toward ecological sustainability and some bacteria are becoming more resistant to the exposure antibiotics or biocides. Some aromatic organic compounds are important materials in the chemical process industries and usually used as the raw materials or as the solvents. Most of these chemicals are classified as dangerous chemicals and several of them are carcinogenic and/or mutagenic substances. In several less developed countries, all of these compounds are major pollutants in the water streams.

Currently, several technologies are available for the remediation of contaminated water, such as aerobic and anaerobic biological treatments, photocatalysis, advanced chemical oxidation, membrane separation, and adsorption process. Among those available technologies, the adsorption process is economically viable and highly effective across a wide range of pollutant concentrations.

1.2 Role of Clay Minerals in Environment Protection

Clay minerals are one of the most abundant materials in the earth. These minerals play important role in the development of human civilization. For the environment protection, the clay minerals have been used in the disposal and storage of hazardous chemicals. Clay minerals have the catalytic capability to neutralize certain organic hazardous chemicals. As the liners of hazardous chemical storage, one of the most important characteristics of clay minerals is the adsorption capability. As the base liners, the clay minerals must be able to prevent any leakage of hazardous substances into the subsoil or the environment. The capability of clay minerals to retain hazardous substances depend on their cation exchange capacity (CEC) since the process of retaining toxic materials mainly occurs by the adsorption or ion exchange.

Due to its high cation exchange capacity, clay minerals are very effective for the adsorption of cations from the solution, therefore these materials are widely used for the removal of heavy metals from the solution. Clay minerals The uptake of heavy metals by clay minerals involves a series of complex adsorption mechanisms, such as direct bonding between metal cations with the surface of clay minerals, surface complexation, ion exchange, etc. Although the most of clay materials are negatively charged (Churchman et al. 2006), due to their high surface area and pore volume, these materials still can adsorb organic and non-ionic substances in significant amounts. Churchman et al. (2006) mentioned that in their natural state the clay minerals are hydrophilic and in the aqueous solution usually they have low adsorption capacity toward small non-ionic organic compounds. The adsorption capacity of natural clay minerals can be enhanced by modification using various kinds of acid, base, salts, surfactants and other organic or inorganic chemicals. Through this modification the clay minerals become hydrophobic and organophilic, and it will enhance the uptake of small non-ionic organic compounds. Details of modification using various kinds of chemicals are discussed in Chap. 3.

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