Bentonite and Its Impact on Modern Life

Don D. Eisenhour¹ and Richard K. Brown²

INTRODUCTION

Bentonite is a rock term used to describe natural clay materials that are composed primarily of the clay mineral montmorillonite. The characteristics of montmorillonite that underlie the commercial value of bentonite are its submicrometer crystal size, sheet-like structure, large surface area (up to 800 m²/g), significant negative layer charge (≈120 meq/100 g), and associated counter-balancing exchangeable surface cations (Güven 2009 this issue). The hydration energy of the exchangeable cations gives bentonite a strong affinity for water. These characteristics result in interparticle forces that are significant in determining the bulk physical properties of the clay, including its significant sealing, swelling, and adhesive characteristics.

The unique properties of bentonite were recognized and exploited at least 3000 years ago in ancient Greece and Cyprus (Robertson 1986). Prior to about 400 BC, bentonite from the Greek island of Kimolos became widely used throughout the Mediterranean to clean or “full” wool and as a component of soap for use in bathing. These uses of Kimolian bentonite were so highly regarded that they are well documented in the writings of Aristophanes (405 BC). Bentonite from this same deposit is still mined today for use in detergents. In practices similar to those of ancient Greece, Native Americans used bentonite to clean animal hides. Later, early American settlers used it to clean clothing and as axle grease for wagons during the westward migration of the 1800s.

Until the end of the 19th century, bentonite appears to have been used in small quantities, primarily for cleansing and medicinal purposes (Robertson 1986; Reinbacher 2003). However, during the 20th century, the uses for bentonite, as well as the volume of bentonite consumed, increased dramatically (Fig. 1) (Eisenhour and Reisch 2006; Wan 2008).

This growth in consumption has been accompanied by significant changes in exploration, mining, and processing techniques.

BENTONITE USES

Worldwide bentonite consumption has increased steadily since the early 1900s, as has the number of locations in which it is produced. Recent production statistics (Table 1) reveal that significant quantities of bentonite are being produced in at least 23 countries, with lesser amounts from many more (USGS 2008).

From a commercial standpoint, there are two primary types of natural bentonite, sodium and calcium. Na-bentonite is characterized by its ability to absorb large amounts of water and form viscous, thixotropic suspensions. Ca-bentonite, in contrast, is characterized by its low water absorption and swelling capabilities and its inability to stay suspended in water. Each type of bentonite has its own unique applications.

Metal Casting

Metal casting is among the most important current uses of bentonite. Engine blocks, brake drums, transmission housings, manhole covers, street drains, brass water fittings, cast-iron pans, and more are produced from foundry molds containing bentonite (Fig. 2). In most ferrous and many nonferrous foundries around the world, bentonite is used as a bonding agent in a process known as green sand

---

¹ Amcol International, 2870 Forbs Avenue
Hoffman Estates, IL 60192, USA
E-mail: deisenhour@amcol.com

² Wyo-Ben Inc., PO Box 1979
Billings, MT 59103, USA
E-mail: rbrown@wyoben.com

---

This growth in consumption has been accompanied by significant changes in exploration, mining, and processing techniques.

BENTONITE USES

Worldwide bentonite consumption has increased steadily since the early 1900s, as has the number of locations in which it is produced. Recent production statistics (Table 1) reveal that significant quantities of bentonite are being produced in at least 23 countries, with lesser amounts from many more (USGS 2008).

From a commercial standpoint, there are two primary types of natural bentonite, sodium and calcium. Na-bentonite is characterized by its ability to absorb large amounts of water and form viscous, thixotropic suspensions. Ca-bentonite, in contrast, is characterized by its low water absorption and swelling capabilities and its inability to stay suspended in water. Each type of bentonite has its own unique applications.

Metal Casting

Metal casting is among the most important current uses of bentonite. Engine blocks, brake drums, transmission housings, manhole covers, street drains, brass water fittings, cast-iron pans, and more are produced from foundry molds containing bentonite (Fig. 2). In most ferrous and many nonferrous foundries around the world, bentonite is used as a bonding agent in a process known as green sand
molding. Here, it is mixed with sand, coal, and a small amount of water to form a mixture that is packed around a pattern made in two halves. Once the shape is formed, the patterns are removed, the two halves of the mold are fitted together, and molten metal is poured into the open mold cavity. After the metal has solidified and partially cooled, the sand is shaken off and the metal cast is further cleaned and machined. The sand and clay mixture is then recycled to form another mold. New sand, clay, coal, and water are continually added to the recycled mixture as old materials are destroyed and removed. Both Na- and Ca-bentonites are used in this process, either individually or as blends. The type and amount of bentonite used depends on the metal being cast, the size and complexity of the casting, and the type of molding equipment. Other additives such as starch and wood flour may be used to modify the molding sand properties. When compared with other binding materials, the adhesive characteristics of bentonite provide a superior bond for sand in the mold prior to, during, and after the molten metal is poured, making metal casting rapid, highly flexible, and cost-effective (Sanders 1973). Natural Na-bentonites from the United States are known to perform particularly well in foundry applications and are widely used for this purpose. The metal casting industry is estimated to be the primary consumer of bentonite, accounting for approximately 25% of all worldwide production.

**Pet-Waste Absorbents**

Prior to the 1980s most pet litter products were composed of sand or nonclumping clays. Litter boxes containing these products were difficult to keep clean and required frequent changing to keep them fresh. In the late 1980s Na-bentonite was discovered to be ideal for making clumping cat litter. Na-bentonite encloses pet wastes in clumps of absorbent clay, which can be scooped easily and completely from the litter box, decreasing the amount of litter wasted and keeping litter boxes clean and odor-free. The development of clay-based litter, and particularly clumping litter, has contributed significantly to the acceptance of cats as indoor pets.

Over the past decade, the annual consumption of clumping cat litter has more than doubled. Pet-waste absorbents now account for approximately 25% of bentonite production in the United States and Europe. Pet litter is perhaps the most widely recognized application for bentonite because of its direct use by consumers.

**Drilling Fluids**

Na-bentonite has been used in drilling fluids for oil and gas exploration since the 1920s (Fig. 3). It is also a principal component in fluids used for drilling small-diameter holes for water, mineral exploration, and environmental-monitoring wells. In addition, it is used in the relatively new technique of horizontal directional drilling to place utility cables and pipelines under buildings, streets, highways, and environmentally sensitive areas without the need for expensive and disruptive surface trenching (Fig. 4). These fluids are particularly suitable for drilling applications because of their ability to lubricate the drill pipe and cutting head, and suspend drill cuttings so they can be easily removed from the borehole (Darley and Gray 1988). The bentonite in the fluid also functions to limit loss of the fluid into the soil and rock around the drill hole. In non-water-based drilling and in many emulsion-based fluids, organically modified bentonites offer many of the same properties.

**Iron Ore Pelletizing**

Development of the iron ore pelletizing process in the late 1950s brought about the worldwide use of abundant, low-grade iron ore for making steel. Critical to that development was the use of natural Na-bentonite as a binding agent. In this process, the ore is first finely ground to liberate the iron oxide from the host rock. Unfortunately, the fineness of the resulting powdered iron ore concentrate creates handling problems during shipping and during processing at the blast furnace. These problems are solved by mixing a small amount of bentonite and water with the finely ground iron ore concentrate and then passing the mixture through a pelletizer to produce spherical pellets about 1 cm in diameter (Fig. 5). These pellets are dried and then sintered. After cooling, the hardened pellets can withstand long-distance transport and handling without breaking. The pellets also allow gas flow through reduction furnaces in the steel-making process. In some cases, iron ore concentrates mixed with bentonite are compacted under high pressure to make briquettes. Approximately 20% of global bentonite production is consumed in iron ore pelletizing.

**Bleaching and Clarifying**

During the last century, Ca-bentonites have increasingly been used to clarify and decolorize, or “bleach,” animal, vegetable, and mineral oils (Torok and Thompson 1972; Robertson 1986; Diaz and Souza-Santos 2001). Animal and vegetable oils contain many impurities, such as gums, phosphatides, trace metals, and free fatty acids, that can produce undesirable oxidation products and reduce product shelf life. Bleaching clays remove many of these substances, as well as color-producing compounds such as chlorophyll, xanthophylls, and carotenes. Ca-bentonites are particularly effective as bleaching clays after they have been treated with acid to improve their porosity. Because of their superior bleaching properties, worldwide production of acid-activated bentonites now exceeds several hundred thousand tons per year.

---

**Table 1**: **BENTONITE: WORLD PRODUCTION, BY COUNTRY**

<table>
<thead>
<tr>
<th>Country</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>146,845</td>
<td>163,028</td>
<td>243,590</td>
<td>283,000</td>
<td>300,000</td>
</tr>
<tr>
<td>Australia</td>
<td>145,000</td>
<td>265,000</td>
<td>223,000</td>
<td>200,000</td>
<td>220,000</td>
</tr>
<tr>
<td>Brazil, beneficiated</td>
<td>198,981</td>
<td>226,874</td>
<td>221,035</td>
<td>221,100</td>
<td>220,000</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>146,000</td>
<td>225,000</td>
<td>181,000</td>
<td>200,000</td>
<td>220,000</td>
</tr>
<tr>
<td>China</td>
<td>2,000,000</td>
<td>2,000,000</td>
<td>2,000,000</td>
<td>2,000,000</td>
<td>2,000,000</td>
</tr>
<tr>
<td>CIS</td>
<td>750,000</td>
<td>750,000</td>
<td>750,000</td>
<td>750,000</td>
<td>750,000</td>
</tr>
<tr>
<td>Cyprus</td>
<td>144,859</td>
<td>155,717</td>
<td>150,000</td>
<td>150,000</td>
<td>150,000</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>199,000</td>
<td>201,000</td>
<td>186,000</td>
<td>220,000</td>
<td>220,000</td>
</tr>
<tr>
<td>Egypt</td>
<td>50,000</td>
<td>50,000</td>
<td>50,000</td>
<td>50,000</td>
<td>50,000</td>
</tr>
<tr>
<td>Germany</td>
<td>478,796</td>
<td>404,549</td>
<td>352,374</td>
<td>350,000</td>
<td>350,000</td>
</tr>
<tr>
<td>Greece</td>
<td>950,000</td>
<td>950,000</td>
<td>950,000</td>
<td>950,000</td>
<td>950,000</td>
</tr>
<tr>
<td>Iran</td>
<td>140,528</td>
<td>193,046</td>
<td>200,000</td>
<td>200,000</td>
<td>200,000</td>
</tr>
<tr>
<td>Italy</td>
<td>474,000</td>
<td>475,000</td>
<td>446,000</td>
<td>470,000</td>
<td>470,000</td>
</tr>
<tr>
<td>Japan</td>
<td>425,945</td>
<td>455,282</td>
<td>421,629</td>
<td>420,000</td>
<td>420,000</td>
</tr>
<tr>
<td>Mexico</td>
<td>464,056</td>
<td>564,015</td>
<td>425,630</td>
<td>420,000</td>
<td>420,000</td>
</tr>
<tr>
<td>Morocco</td>
<td>67,700</td>
<td>85,400</td>
<td>85,400</td>
<td>80,400</td>
<td>80,400</td>
</tr>
<tr>
<td>Poland</td>
<td>31,648</td>
<td>66,143</td>
<td>86,331</td>
<td>85,000</td>
<td>85,000</td>
</tr>
<tr>
<td>Slovakia</td>
<td>74,938</td>
<td>73,273</td>
<td>70,000</td>
<td>70,000</td>
<td>70,000</td>
</tr>
<tr>
<td>South Africa</td>
<td>145,060</td>
<td>55,859</td>
<td>139,833</td>
<td>32,878</td>
<td>32,878</td>
</tr>
<tr>
<td>Spain</td>
<td>103,174</td>
<td>156,760</td>
<td>105,000</td>
<td>110,000</td>
<td>110,000</td>
</tr>
<tr>
<td>Turkey</td>
<td>831,146</td>
<td>850,000</td>
<td>925,000</td>
<td>950,000</td>
<td>950,000</td>
</tr>
<tr>
<td>Ukraine</td>
<td>300,000</td>
<td>300,000</td>
<td>300,000</td>
<td>300,000</td>
<td>300,000</td>
</tr>
<tr>
<td>United States</td>
<td>3,770,000</td>
<td>4,550,000</td>
<td>4,710,000</td>
<td>4,940,000</td>
<td>4,940,000</td>
</tr>
<tr>
<td>Others</td>
<td>262,324</td>
<td>284,054</td>
<td>378,178</td>
<td>230,622</td>
<td>230,622</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>12,300,000</td>
<td>13,500,000</td>
<td>13,600,000</td>
<td>13,700,000</td>
<td>13,700,000</td>
</tr>
</tbody>
</table>

---

1 Data summarized from USGS Minerals Yearbooks (USGS 2008). See source for additional footnotes. All data are in metric tons.
2 All years for China production estimated from Industrial Minerals, June 2006.
e Estimated p Preliminary r Revised
Na-bentonite has a long history of use as a fining agent for clarifying wine and juice. Fining is a process in which an adsorptive substance is introduced into the liquid to remove suspended proteins and other organic colloids that would otherwise precipitate or create haze when the liquid is chilled (Fig. 6). Because of their small size and solubility, these undesirable materials are difficult to remove by conventional filtration. The large surface area and high negative charge of montmorillonite makes bentonite ideal for adsorbing positively charged compounds, such as proteins, and removing them through flocculation.

**Desiccant**

Bentonites are known for their ability to absorb moisture from air. Desiccant-grade bentonites contain Ca$^{2+}$ and Mg$^{2+}$ as the dominant exchangeable cations and always have high montmorillonite contents with high layer charge. It is not uncommon for desiccant-grade bentonites to have cation exchange capacities exceeding 130 meq/100 g. Although Ca–Mg-bentonites have little swelling capability in water, they function well as desiccants because of the greater first and second shell hydration energies of Ca$^{2+}$ and Mg$^{2+}$ cations relative to Na$^+$ (Güven 1992).

**Paper Making**

Bentonite is widely used in combination with cationic polymers to flocculate cellulose fibers during paper making. The use of bentonite improves several key processes on the wet end of paper machines, including solids retention, drainage rate, and uniform sheet formation (Langley and Holroyd 1990). The addition of only 0.2 wt% bentonite can increase paper production by as much as 30% in a paper mill. Acid-activated bentonites are used in making carbonless copy paper, which is typically composed of three sheets. The upper surfaces of the middle and lower sheets are coated with clay, which serves as a solid acid that reacts with microencapsulated dyes fixed on the undersides of the upper two sheets. When pressure is applied to the top sheet, the microcapsules of colorless dye break and react with the acidic clay to form a permanent colored dye.

**Environmental Sealants**

The unique ability of bentonite to absorb water, swell many times its dry volume, and yield extremely low water permeability makes it an excellent sealant for environmental applications. Coarse-screened, natural bentonite products, often called chips or gravel, were developed for use in sealing casings when wells are completed and for filling boreholes and subterranean cavities when wells are abandoned. Bentonite chips can rapidly sink through standing water and, once in place, they swell to apply significant pressure against the cavity walls, forming a secure seal. Water-filled boreholes up to 500 meters deep have been sealed successfully in this fashion.

Where free space in a well is limited and bentonite chips are not practical, pumpable, high-solids bentonite grouts may be used. These products are prepared from bentonite that has been specially modified to delay onset of gelling when they are mixed with water, allowing them to be emplaced while still in a fluid state. Bentonite grouts may also be injected under high pressure directly into soil to fill pores and form a low-permeability seal for building foundations and other subterranean structures.

A variety of granular and powdered bentonite products have been developed for sealing landfills, sewage lagoons, and decorative ponds. These applications are described in detail by Gates et al. (2009 this issue).
Na-bentonite has been used since at least the mid-1940s to create low-permeability in situ barriers to groundwater movement and to form in situ foundations for buildings in a practice known as slurry trench construction (Fig. 7). In this process, bentonite slurry is placed in a trench during excavation so that it is constantly kept filled. As water from the slurry seeps out of the trench into the soil, the bentonite forms a thin film on the walls of the trench. This retards further water movement, allowing the hydrostatic pressure of the slurry against the bentonite film to stabilize the trench walls. With this practice, trenches can be excavated to depths of a hundred feet or more, even through highly unstable soils. Bentonite mixed with soil, cement, or other backfill materials, depending on the requirements of the project, may then be placed in the trench. Such barriers have routinely been used to form stable, low-permeability cores during the construction of earth-filled dams. The Wanapum Dam on the Columbia River in southern Washington State, USA, is an excellent example of this construction method. This technique is also widely used to form low-permeability barriers around hazardous waste sites to contain contaminants until site remediation is completed. Where concrete is used as the backfill, an in situ foundation wall can be created without the need to excavate large holes, set forms, and then backfill around the outside of the foundation. This practice is commonly used for construction of new buildings in congested urban areas.

Bentonite-based products are also used in boring tunnels for highways and subways, and for installing pipelines to transport drinking water, storm water, and sewage. In these applications, bentonite is used in tunnel-boring machines to stabilize the excavation face, lubricate the machine as it moves through the earth, and seal the tail of the machine to prevent flooding where boring is performed below groundwater level.

**EXPLORATION AND MINING**

The increasing rate at which bentonite has been consumed over the past hundred years and the significant proliferation of applications in which it is being used have required that greater attention be paid to mining, grading, and blending practices. Bentonite is relatively common, with known occurrences on every continent except Antarctica. However, the properties of the montmorillonite in bentonite, as well as the quantity and types of accessory minerals present, can vary widely from deposit to deposit, even within the same geographical location. Understanding the broad range of physical and chemical properties inherent in bentonite has become increasingly important to meet today’s market requirements.

Most commercially significant bentonite deposits were formed by the devitrification of volcanic ash that fell into shallow oceans or brackish ponds and lakes (e.g. Knetchel and Patterson 1962; Elzea and Murray 1990; Christidis and Huff 2009 this issue). These deposits often cover large areas and may consist of several layers, representing multiple volcanic eruptions. While deposits of this type are most often found in Cretaceous marine sediments, commercially important deposits of Tertiary or younger age also occur locally in some areas.

Some bentonite deposits formed by hydrothermal groundwater alteration of felsic host rocks, commonly rhyolite. However, these hydrothermal deposits are limited in scope and commercial significance. Other bentonite deposits have resulted from erosion and redeposition of primary deposits. These deposits often have little or no value because they contain significant quantities of other minerals and organic compounds as contaminants.
Many bentonite deposits are identified where they have been exposed at the ground surface by erosion. The layers, or beds, of bentonite are often quite obvious because of their unique surface texture, which results from swelling and shrinking of the clay as it undergoes repeated cycles of wetting and drying. Lesser-swelling Ca-bentonite deposits are often characterized by an alligator hide appearance, while Na-bentonite deposits are frequently characterized by a pronounced popcorn texture (Fig. 8).

Commercially viable bentonite deposits are typically 0.5 to 5 meters thick but may exceed 30 meters in some locations. A detailed knowledge of the physical and chemical characteristics of the clay in each deposit is important to meet the diverse quality criteria for each of the many end uses for bentonite. These physical and chemical data are gathered from pre-mine drilling and testing, as well as from samples taken following overburden removal. In this way, the different qualities of bentonite within a bed are identified, selectively mined, and stockpiled.

Exploration data, together with information on soils, vegetation, wildlife, local land use, and archeological, cultural, and groundwater resources, are used to develop detailed mining and reclamation plans. In most countries, these plans are then submitted to regulatory agencies for review and approval. To ensure that reclamation is completed, a bond or other form of financial assurance is typically required before mining can begin.

Bentonite is usually extracted by surface mining. Bulldozers and tractor-scrapers are used to remove the overburden material; the topsoil and subsoil are stockpiled separately so they can be replaced during reclamation. The remaining overburden above the clay is then removed and stockpiled. After the clay has been extracted from the pit, the overburden, subsoil, and topsoil are replaced, and the surface is contoured to blend with the surrounding terrain and reestablish drainage through the area. In a practice known as cast-back mining, materials removed from one pit are placed directly into an adjacent pit to minimize the disturbed area. This practice also minimizes the need for stockpiles and shortens the time required for reclamation. With this technique, it is not uncommon for a pit to be opened, closed, and seeded within a year.

Reclaimed mine areas are monitored until self-sustaining plant communities have been established and the reclamation goals have been met. In many cases, well-planned and well-executed reclamation has improved habitat for wildlife, compared to pre-mining conditions. Creative ways in which this can be achieved include using topsoil-rich areas to assist in reclaiming topsoil-poor areas, and creating local ponds and wetlands where none previously existed.

**PROCESSING**

Following removal from the mine, bentonite is hauled to a processing plant and stockpiled by quality. At the plant, clays of different qualities are frequently blended during processing in order to achieve more consistent finished-product quality. Common bentonite processing steps include extrusion, drying, milling, screening, air classification, centrifugation, agglomeration, acid leaching, and cation exchange. The specific processing methods employed depend both on the nature of the crude bentonite and its intended end use. In general, processing is designed to maximize the dispersibility of the clay, increase its surface area, alter its surface chemical properties and, in some cases, increase its montmorillonite content. These goals, and thus the steps to achieve them, are often interrelated.
The surface area of bentonite is greatest when the individual montmorillonite sheets are fully delaminated and dispersed. Mechanical shear is one method used to delaminate montmorillonite. This is typically accomplished either by high-speed mixing, when the bentonite is in a fluid state, or by high-pressure extrusion, when the bentonite is in a semisolid state. Delamination may also be facilitated by modifying montmorillonite surfaces through cation exchange. In one common approach, Na-carbonate (Na₂CO₃) is added to bentonite to produce a Na-rich clay. The water dispersibility and colloidal stability of the clay are improved when exchangeable divalent surface cations, such as Ca²⁺ and Mg²⁺, are replaced by univalent cations, e.g. Na⁺ and Li⁺ (Güven 1992).

Although sodium exchange improves dispersibility in water, it is of little benefit in weakly polar and nonpolar liquids, such as toluene or mineral oil, where the driving force for dispersion is largely entropic rather than enthalpic. Where dispersion of clay in nonpolar fluids is required, hydrophilic Na-bentonites are transformed to hydrophobic organobentonites by exchanging the surface cations with positively charged organic species, most commonly quaternary amines. Organobentonites are widely used in the development of clay–polymer nanocomposites, which are described in more detail by Carrado and Komadel (2009 this issue).

Production of high-value products for use in paint, ink, cosmetics, pharmaceuticals, and nanocomposites requires bentonites to be purified by removing nonclay contaminants. This is often accomplished by dispersing the clay in water and then passing it through a continuous centrifuge. In addition, various oxidation, reduction, and magnetic separation processes have been developed to improve purity.

FUTURE TRENDS

Demand for bentonite for use in iron ore pelletizing, drilling, and metal casting is expected to remain strong as the BRIC (Brazil, Russia, India, and China) economies continue to show potential for growth. Clumping cat litters are also expected to show sustained growth as USA and European consumers continue to move away from nonclumping litters and consumers in BRIC countries, and elsewhere, adopt the use of pet litters for the first time.

Consumption of bentonite for civil engineering and environmental sealing applications is expected to increase as the global focus on environmental responsibility continues to advance. Research on nanoscale clay–plastic composites is expected to accelerate, as materials science increasingly focuses on nanoscale interactions among materials. Active areas of development include lightweight automobile parts, low-permeability food-packaging films, and high-performance sporting equipment.

Other ongoing developments include the use of bentonite as a functional ingredient in cosmetics, as a carrier for pesticides to improve efficacy and reduce usage, in insulating compounds for electrical components, in electrically conductive compounds for use in grounding systems, as barrier materials for storing nuclear waste, and for removing contaminants from wastewater. The past decade has seen a significant rise in research on clay minerals and their role in animal and human health (Williams 2009 this issue). Clay minerals have long been reported to have healing properties, but their true efficacy and the mechanisms by which they work are only now being investigated in detail.

Mining and processing technologies will also continue to develop to keep pace with the new applications and increased demand for bentonite. In mining, particular attention is being paid to more efficient mining methods that require less time and allow greater selectivity over the qualities of clay that are obtained. New production methods are also constantly being sought to improve production rates and decrease cost while maintaining a high level of quality control. In addition, new production processes are constantly being developed to manipulate the physicochemical characteristics of the clay in order to meet existing and new market demands.

The unique properties of bentonite are certain to make it an increasingly important and sought-after material in the years to come, whether for energy production, human health, nanotechnology, or some yet-to-be-identified application.

ACKNOWLEDGMENTS

We thank J. Elzea Kogel and H. Murray for constructive reviews and D. Bain for his guidance in preparing the manuscript.

REFERENCES


Reinbacher WR (2003) Healing Earths: The Third Leg of Medicine. 1st Books, USA, 244 pp

Robertson RHS (1986) Fuller’s Earth – A History of Calcium Montmorillonite. Volturna Press, Hythe Kent, UK, 421 pp


