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Research paper

## The mineralogical, geochemical, and thermophysical characterization of healing saline mud for use in pelotherapy

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### ABSTRACT

With a rich spa and wellness heritage, Slovenia now boasts fifteen registered natural health resorts and spas. Certain locations feature the traditional use of the Sečovlje Salina mud, or “fango.” This study represents the first investigation of the mineralogical, geochemical and thermophysical characteristics of this mud. The healing saline mud samples were characterized by very fine, sandy, medium silt in which the mud fraction greatly dominated over the sand fraction. The mineral fraction was predominantly composed of an amorphous phase, followed by quartz, calcite, illite/muscovite, gypsum and halite, albite, and clinocllore and pyrite. The results of XRD analysis with oriented preparation identified smectite, chlorite, interstratified layers of smectite/illite, and kaolinite mineral components. The contents of the major and trace elements of saline muds were comparable to their mean concentrations in surface sediment from the Central Adriatic Sea. The samples had a high cation exchange capacity, yet low total organic carbon, total nitrogen, and total sulphur content. The concentrations of select trace metals were in the range of that found in other healing saline muds. Additionally, the physical properties of the mud (i.e., density, specific heat, thermal conductivity, and viscosity) were measured. This study contributes new knowledge about natural peloid characteristics and their quality criteria related to wellness and therapeutic purposes.

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### 1. Introduction

One of the most valuable natural and cultural heritage sites in Slovenia, the Sečovlje Salina Nature Park (KPSS) is an important tourist attraction on the Slovenian coast. While providing a home for numerous indigenous species of flora and fauna (Kaligarič and Škornik, 2006; Sovinc, 2012; Škornik, 2008), the KPSS also preserves the tradition of salt production. With written references dating back to the second half of the 13th century, the area has contributed to the traditional manual harvesting of salt in crystallization basins, and thus to other products produced in the area, including those within the food, cosmetics, and therapeutic purposes.

Slovenia has 15 certified natural health resorts (Horvat, 2010) located in untouched natural environments that practice the centuries-old tradition of thermal treatments and experience in the fields of

balneology, climatology, and thalassotherapy. The history of these coastal spas dates back to the Middle Ages, when Benedictine monks from the monastery of Saint Lawrence began to use seawater, brine, and mud from the nearby Piran Salina in the effort to cure a range of diseases (Vrtačnik Garbas, 2005). In the second part of the 19th century, the Consortium of Piran Salina (Consorzio delle saline di Pirano) introduced medical treatments that utilized concentrated sea water from the shores of the Bay of Portorose. By July of 1897, the town Portorose became known as “Kurt Ort,” meaning a health resort with official approval (Brezovec, 2012). The success of treatments using natural substances from the Piran salt pans significantly contributed to the development of the area as a health resort, as well as to coastal tourism. During the Austrian monarchy (later Austro-Hungarian Monarchy), natural healing factors such as sea air, saline mud, concentrated seawater, and bathing in warm water represented the most important attractions of the Austrian Littoral (Austrian Riviera), which included the Slovenian coastal town of Portorož and its surroundings (Kavrečič, 2009).

At the beginning of the 20th century, the natural healing factors of the area were discussed by Dr. Orazio Pupini in his book «Portorose in Istrien klimatischer Kurort, See- und Solbad» (Pupini, 1910), and one

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of the most beautiful hotels on the Adriatic coast, the Grand Hotel Palace (Brezovec, 2012), was opened (in August of 1910, later renovated in 1954, 1975, and 2008). Today, in addition to the coastal climate, seawater, brine, salt, and algae, the saline mud or “fango” from the Sečovlje Salina is one of the most widely utilized natural medicinal aids in the coastal health resorts of Talaso Strunjan and LifeClass Hotels & Spa. In May of 2013, the open-air Thalasso Spa Lepa Vida opened in Sečovlje Salina Nature Park, where saline mud and brine (“mother water”), salt, and seawater are used in thalassotherapy which represents an important part of European centers (Charlier and Chaineux, 2009). In 2013, the saline (salt-pan) mud and brine from the Sečovlje Salina were recognized as natural healing substances by the Slovenian Ministry of Health.

In recent years, several studies on the thermophysical characterization of peloids have been carried out in different countries. For example, Knorst-Fouran et al. (2012) have described the properties of the Dax peloid (TERDAX®) and its evolution when mixed with thermal and mineral water, and Pozo et al. (2013) have studied the physico-chemical properties of various Spanish peloids in comparison. In Portugal, Rebelo et al. (2011, 2015) studied the rheological and thermal characterization of peloids made up of select Portuguese geological materials, as well as their mechanical properties, such as consistency and abrasiveness. Quintela et al. (2015) studied the clay sediments of Caldeira da Ribeira Grande in Azores Islands, and Cara et al. (2000) and Veniale et al. (2004) have published much data on Italian peloids made with different types of thermal water. Suárez Muñoz et al. (2015) have studied the river sediment and final peloids of the San Diego de los Baños Thermal Center (Pinar del Rio, Cuba), and da Silva et al. (2015) published the characterization of Peruibe mud in Brazil. In Croatia, several publications have examined peloids from Makirina and Morinje Bay (Komar et al., 2015b; Miko et al., 2007, 2008; Šparica et al., 2005; Vreča and Dolenc, 2005). Recently, ten Iranian bentonites have been studied and evaluated for use in pharmaceutical applications (Modabberi et al., 2015).

Each of the above studies has shown the most important properties linked to thermotherapy to be density, specific heat, thermal conductivity, and rheological behavior. Despite the long traditional use of fango in Slovenia, there is a lack of scientific studies on the quality and uses of Sečovlje healing saline mud (peloid). The present study, the first of its kind, takes a multidisciplinary approach to its examination of this natural peloid.

## 2. Materials and methods

### 2.1. Sampling site and sampling strategy

The Sečovlje Salina (Fig. 1) belongs to the Northern Adriatic Piran Salinas, which include the still active Strunjan Salina and the already abandoned Lucija Salina. The Sečovlje Salina spans roughly 650 ha and is situated in Piran Bay along the estuary of the Dragonja River (SW Slovenia).

In November of 2012, two samples were collected from the Sečovlje Salina for physico-geochemical and thermal analyses, i.e. the first from the pilot study maturation pan [Sample A] and the corner of a shallow channel around the selected crystallizing basin [Sample B], respectively. According to the oral traditions of salt workers, the latter is characterized as the best healing saline mud of the salt pans. Mud in a shallow channel was exposed to natural conditions (without mixing) and processes occurring in the crystallization basin, including special water regimes and other processes connected to salt production. Sample A was the product of a year-long maturation of marine sediment (from Piran Bay, Northern Adriatic) in a selected (open) canal under the natural conditions of Sečovlje Salina (Fig. 1). The “virgin” marine sediment was permanently covered with marine water or brine depending on the current water regime and salt production processes in the Salina. The material was mixed at irregular intervals in the open air. The samples were collected in plastic containers and immediately carried to the laboratory, where they were processed and analyzed in accordance

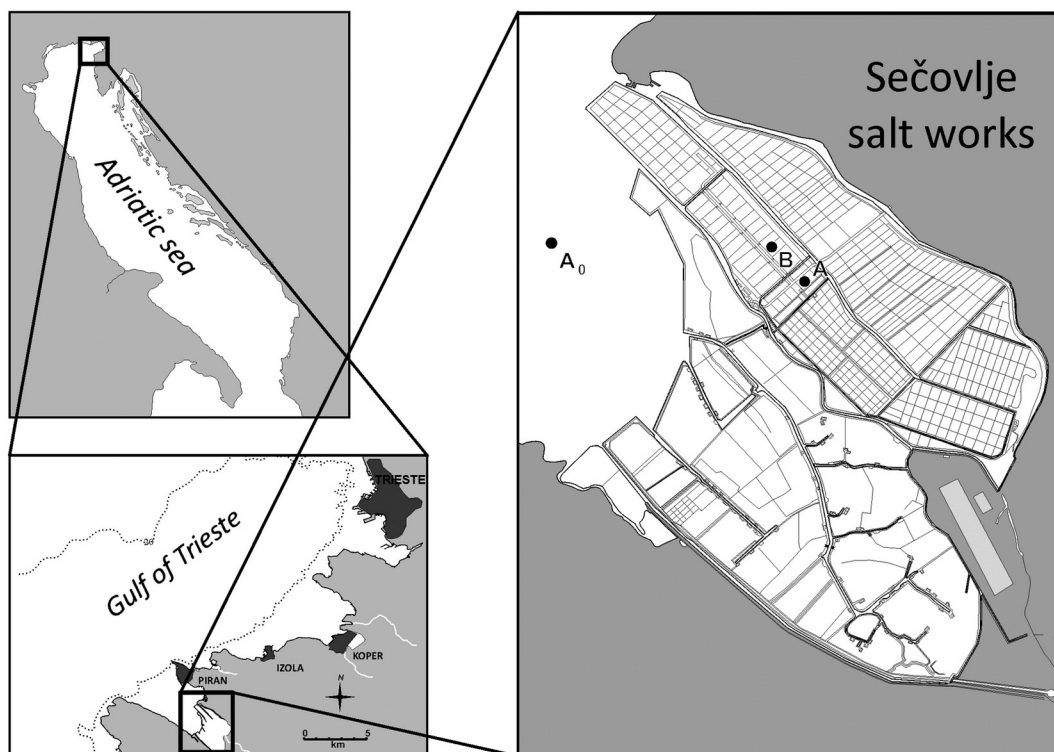


Fig. 1. The Research area of Sečovlje Salina Piran Bay (Northern Adriatic), with the sampling sites of sample A ( $A_0$ : virgin marine mud location, A: maturation site) and sample B (B: sampling and maturation site).

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