CHARACTERISTICS OF THE SILICA SLURRY AT THE BOTONG SECTOR OF THE BACON-MANITO GEOTHERMAL PRODUCTION FIELD

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Abstract

The highly concentrated amorphous silica (≈ 1400 ppm) in Botong geothermal brine, a major concern in the cold injection scheme (CIS) of the fluid collection and disposal system (FCDS), was collected by dropping the fluid's temperature and precipitating colloidal silica in a huge baffled thermal pond (TP-1). The collected silica slurry samples from 19 lanes of the TP-1 were characterized chemically, physically, and microscopically.

Physical characteristics of the slurry has similarity to pure water except in gel strength, 4.0 in 10 minutes. The slurry contains amorphous silica of about 98.7 % pure in terms of SiO_2. Sedimenter and TEM analyses showed that the colloidal sizes of silica precipitates are < 5 μm. Tests using a refrigerated centrifuge showed satisfactory separation of the gel from its corresponding brine medium at 4000 rpm for 5 minutes.

These results will be further used for evaluation, proper handling, and storage of the accumulated silica to be produced during the operation of the BacMan-II power plant.

1.0 INTRODUCTION

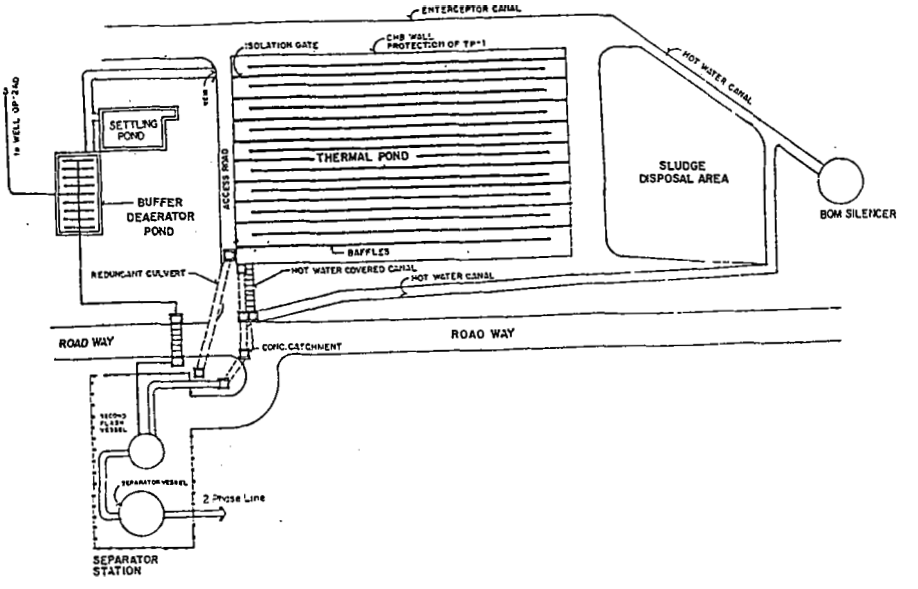
The physical and chemical characterizations of Botong silica slurry is part of the FCDS-CIS research program for BacMan II geothermal sector. In this activity, the slurry profile was evaluated in order to decide on its proper handling and disposal.

Part of the Botong FCDS (Fig. 1) is the large baffled thermal pond, TP-1 which is used for the deposition of the highly concentrated silica slurry generated by OP-3D and OP-4D wells. The hot separated brine from the flashed vessel is collected into this pond and allowed to cool down to facilitate silica polymerization and precipitation (PNOC-EDC, 1993). The separated brine then flowed towards the buffer or deaerator pond (BP or DP) and heated up to deaerate prior to reinjection to OP-2RD (Solis, 1991). These processes were tested during the initial effluent disposal system (EDS) experiment from 21 April to 12 May 1994.

Slurry samples were collected from each lane of the TP-1, for the next six days after the testing. The slurry samples analyzed in this report are those collected on 17, 18, and 19 of May 1994. Sixteen (16) of the samples collected were already contaminated with rainwater and mud from the surroundings. A total of 19 samples were collected for three (3) successive days. These were stored in opaque plastic containers and undergone physical and chemical analyses in the laboratory.

Representative amount of all the even number lanes were combined and coded as **ELC,** so as the odd number lanes, **coded as OLC.** A total of **21** samples were prepared including the **two** lane combinations for physical and chemical characterizations.

Fig 1 SCHEMATIC DIAGRAM OF BOTONG LOW TEMPERATURE INJECTION SCHEME



2.0 METHODS OF PREPARATION AND *ANALYSIS*

The methods of preparation and analysis issued by the geothermal silica collection and disposal committee were modified and used for the silica slurry samples.

2.1 Sample Collection and Storage

Approximately **17** liters of silica slurry from each lane of the thermal pond were collected (except lane **20)** and stored in separate opaque screw-capped 5gal plastic containers. Samples for three **(3)** lanes (L1, **10,** and **19)** were collected **on** day 1, ten **(10)** lanes **(L2-8, 13,** and 15) on day **2,** and six **(6)** lanes (L11, **12, 14** and **16-18)** on day **3.**

2.2 Sample Preparation

The hot silica slurry is a homogeneous mixture of supersaturated brine and silica. Upon cooling, it formed a heterogeneous mixture of brine, suspended silica, and silica gel. The gel is denser than its corresponding brine medium. This property, in addition to the polymeric character of suspended amorphous silica, helped in facilitating fast separation and easy decantation of the slurry.

The sample preparation procedure reported by Baltazar (1994) was used for the slurry. Decantation was applied instead of filtration due to the large volume of the sample. Decanted silica gel was spread in a wide shallow plastic basin and air dried with the help of a dehumidifier. Drying took around 6-10 days for one (1) liter of sample. The product is white to grayish flakes of solid silica mixture.

Air-dried samples were partially ground using agate mortar and pestle and washed four times (4x) with ddH_2O (1g:7 mL). Soluble inorganic solids of the air-dried samples is about 49 %. With this remarkable value, washing is suggested to be always part of the sample preparation. Analyzed chloride concentrations of the filtrate in the last washings range from 150-500 ppm. Chloride monitoring was done to determine the effectivity of washing procedure on the dry samples. This could be found useful in the processing of silica slurry for commercial purposes. Washed samples are either air or oven dried depending on the requirement of analysis. The end product is white amorphous fine solids.

2.3 Petrochemical Analysis

The methods of petrochemical analysis were applied to silica slurry samples. Samples were analyzed for LOI, SiO_2, Fe, Cr, Au, Ag, Cu, Pb, As, Ca, Na, K, Mg, and Mn. The techniques involved in the analysis are gravimetry, AAS, and W-VIS spectroscopy.

2.4 Physical Properties

The physical properties which were determined from the slurry samples are density, funnel viscosity, and gel strength. The methods used are those applied for mud rheological properties. The colloidal particle sizes were also studied using a sedimenter at Standard and Testing Division-DOST. Separation test was conducted using the refrigerated centrifuge at 4000 rpm and 25 °C.

2.5 Microscopical Analysis

Preliminary studies on the morphology of silica polymer were undertaken using microphotography and transmission electron microscopy (TEM) techniques. The results were correlated with the sedimenter data.

3.0 RESULTS AND DISCUSSION

The samples collected from the TP-1 is part of the slurry produced during the 12-day continuous discharge in Botong. During the testing, much of the brine and considerable amount of suspended silica polymers were reinjected to OP-2RD. Slurry samples collected during the second and third days were already contaminated with rainwater and mud from the surrounding area. The majority of materials deposited in the TP-1 are accumulated amount of silica and trace elements.

3.1. Physical Analysis

The homogenized slurry including the lane combinations, ELCand OLC, were analyzed for density (D), funnel viscosity (FV), and gel strength (GS) (Table 1). The results were compared to water as the standard. The slurry density has an average value of 1.07 kg/L. Funnel viscosity of the

slurry is relatively low and has minimal contribution to the nature of the sample. Gel strength is slightly significant which can be attributed to the polymeric character of the silica gel. This is expected to contribute slight difficulty during the collection, disposal, and processing of the slurry.

Table 1. Physical Properties of Botong Silica Slurry

Sample	D (kg/L)	FV (s/qt)	GS (10 min)
silica slurry	1.07	32.63	4.0
ELC/OLC	1.06	32.00	4.0
H2O	1.00	28-32	0

Results of centrifugation testing is illustrated in figure 2. Various concentrations of the slurry were tested for separation at 4000 rpm at 25 "C for 5 minutes. Satisfactory separation was achieved while the analyzed centrate contains about < 50 ppm of total suspended silica.

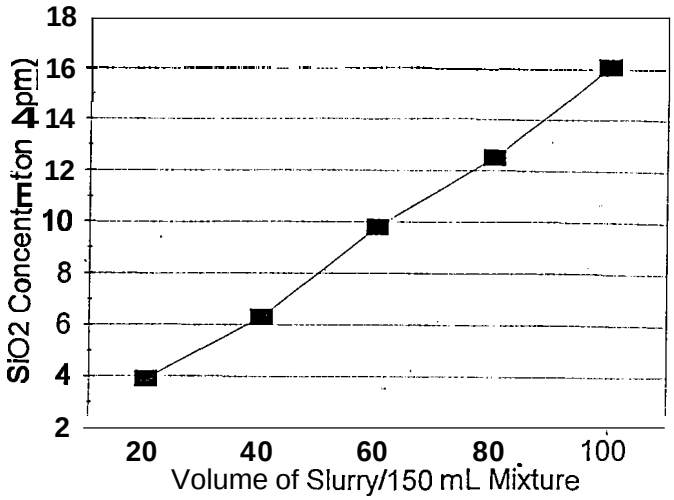


Fig. 2. Centrifugation results of various silica slurry concentration at 4000 rpm for 5 minutes. (25 "C)

3.2 Chemical Analysis

The chemical data provided information that is useful for the proper handling of waste either for disposal or for commercial purposes. The major concerns are the high purity of silica and concentrations of toxic elements and precious metals.

Pure silica was found at about 4.7 % of the slurry which has an average purity of 98.7 % (Table 2). Moisture free sample was found to contain volatile components (reported as LOI) of 0.213 %. Other inorganic components found in the sample were also reported in percent values.

Table 2. Average Percentage by Weight Composition of Botong Silica

Analyte	Slurry	Washed-Dried Solid
H2O	90.0638	0.0638
Si02	4.7267	98.70
SIS*	4.0340	--
LOI	0.2130	--
Fe	0.0047	0.0983
Na	0.0151	0.3153
K	0.0029	0.0612
Ca	0.0068	0.1420
Mg	0.0012	0.0254
Mn	0.0009	0.0198
Zn	2.295×10^{5}	0.0015
Total	99.07	99.43

* SIS= soluble inorganic solids

Average gold, silver, and copper concentrations of the washeddried solids are listed in Table 3. Concentrations of the mentioned metals in lane 1 are significantly high.

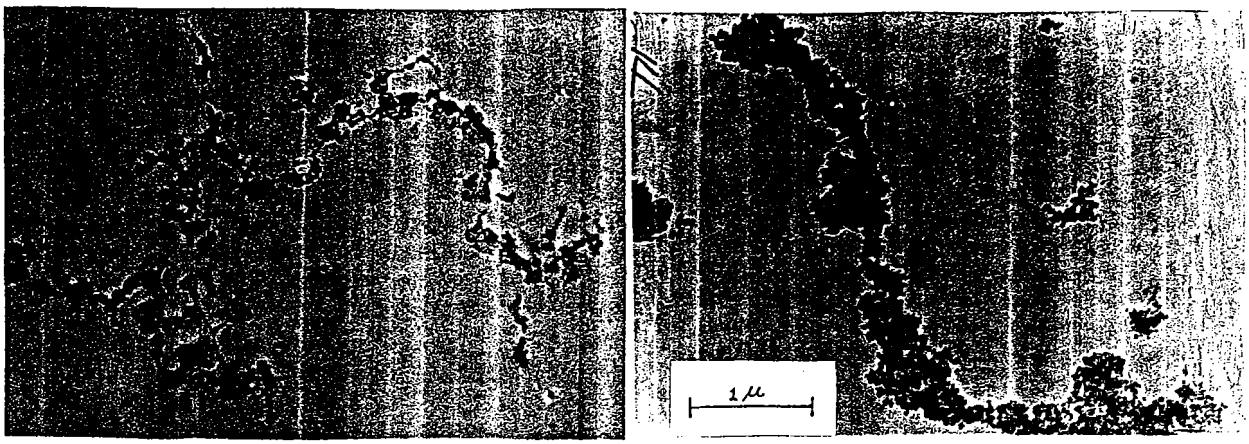
Table 3. Average Percentage Precious Metal Composition of Washed-Dried Solid

Metal	Concentration (ppm)	Lane 1 (ppm)
Au	1.22	10.82
Ag	1.31	12.46
cu	22.13	193.78

Arsenic concentration of washeddried solid samples is significant at 170 ppm. This concentration is hazardous and environmentally alarming. Safety precautions must therefore be exercised in handling the slurry.

3.3 Microscopical Analysis

The colloidal aggregates of polymeric silica were viewed under light microscope and TEM. The structures of the colloids are shown in photos. As discussed earlier the silica colloids are all less than 5 μm. Consistency in the structure of silica aggregates were observed in both figures. Colloidal silica particles (TEM) was measured to about 30 nm.



a) Photomicrograph of colloidal silica (10X) b) Electronmicrograph of colloidal silica

4.0 CONCLUSION AND RECOMMENDATION

In this activity, the collected samples from the thermal pond were cumulative amount of the 12-day discharge, and therefore the chemistry obtained is very specific to the slurry obtained Analyses results were partly influenced by the undetermined degree of contaminations brought about by rainwater and mud Other parameters such as pH, temperature, and polymerization/deposition rate per lane were not determined due to some problems encountered at the site. The results therefore can not be used fully in the assessment of the slurry and silica processes along the TP-1.

The data however, shows high acceptability of the density and silica purity. The slurry de0nsities at different lanes are very close to each other even at different water compositions. Density is therefore predicted to be within the observed range at any given time of discharge.

Based on the problems experienced during the test, it is suggested that further testing be done to obtain all the needed data. Additional parameters, sampling frequency, and sampling points are also recommended. These will be useful in proper assessment and evaluation of the Botong FCDS, possible control of silica polymerization and TP-1 lane utilization, and handling/disposal management of silica.

Electron microscopy study of the colloidal particles is also recommended for colloid profile at different pH and temperature. Particle size analysis using a sedimenter is also suggested. This could give us ideas on the size distribution of silica which is useful for commercial purposes.

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