公務出國或赴大陸地區報告提要　　類別：其他活動

出國或赴大陸地區報告名稱：
參加「2012 年新加坡國際自來水週研討會」　　含附件：■是 □否

出國計畫主辦機關：臺北自來水事業處
聯絡人：王詠民　　電話：2888-2119

出國人員姓名/服務機關/單位/職稱/電話
王詠民/臺北自來水事業處/陽明營業分處/幫工程司/2888-2119

出國類別：其他 ■1 出席國際會議 □2 表演 □3 比賽 □4 競技 □5 洽展 □6 海外檢測

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出國地區：
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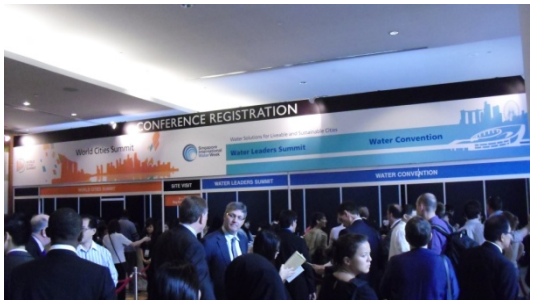
內容摘要：（300 至 500 字）

2012 年 7 月 1 日至 5 日於新加坡濱海灣金沙展覽會議中心舉行的第 5 屆「新加坡國際自來水週研討會暨展覽」是全球最重要的自來水產官學交流平臺之一，揭櫫主題爲永續的宜居城市，在維護永續充足的水資源，與新鮮的空氣和乾淨的環境，對適合人居的城市而言，均屬缺一不可，本屆研討會整合世界城市領袖論壇及乾淨環境峰會，以三合一形式同時同地舉行，共吸引了約 19,000 名來自全球 104 個國家地區的產官學界專家和專業人士參與。會議活動充份展現新加坡政府將新加坡打造成爲水的相關研究、技術和國際交流貿易樞紐的強烈企圖心。

本屆自來水週研討會除依循傳統舉辦各次主題的專題研討會外，另開辦規模驚人的國際自來水設備展，展示廠商除了有新加坡當地業者外，還包含來自臺灣等 16 個國家地區自來水設備廠商參展，共計 650 家一流的設備生產、製造公司和知名水務公司等參展，展示攤位超過 400 個。展覽展出內容涵蓋自來水有關之輸配水、給水、機械電氣、量測、水源取水、淨水、水質與維護管理等各領域。

出國人員參加本屆研討會，以海報論文發表形式發表「北投溫泉區自來水管材腐蝕檢測探討」(Water Pipes' Corrosion Inspection In Beitou Hot Spring Area)論文，除了提出在地極端區域管材受蝕狀況探討，同時在本屆國際自來水專業盛會中見習到其他國家地區的各類自來水創新解決方案。



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呼應研討會主題的兒童畫展

Water Pipes' Corrosion Inspection In Beitou Hot Spring Area

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Introduction

Xinbeitou Hot Spring Area (Fig. 1) is located in Datun Volcano Group. In administration, it is within Beitou District of Taipei City with an area of about 10 square KM. The last eruption is estimated some 200,000 years ago. The surface of this area is mostly covered by volcano rock in the thickness of 10 to 100 meters. The heat source of the hot spring in this area comes mostly from the geothermal activity of end period of volcanic activity. The main hot spring sources in this area are Green Sulfur Hot Spring of Hell Valley (Fig. 2) and White Sulfur Hot Spring of Sulfur Valley.

Hot spring of Hell Valley bursts out from the breaks of crust and forms natural hot spring pond in the valley and depressed area. The temperature of the hot spring at the efflux is between 70 ~100℃ and pH is at 1.5. The total dissolved solid (TDS) is about 20,600~24,260 mg/L, consists of 1,750 ~ 2,390 mg/L sulfates, 2,040 ~2,740 mg/L chlorinate and other chemical substances. The daily output hot spring is about 2,000 CMD. In the Hot Spring, the ions of sulfate and chlorine contents are very high, and it is termed as Acid Sulfate Chlorinated Hot Spring (or Green Sulfur Hot Spring, as commonly referred). The formation is hot water at the depth of terrain permeated into volcanic hot gas flow (sulfur, chlorine acid, carbon dioxide, sulfur dioxide, sulfur trioxide and hydrogen sulfide) and after acidized, it is later mixed up with ground water. Since it has very high content of sulfuric acid, it is of high acidity. Also, as it contains large number of chlorine ion, it is even more corrosive to metallic material. This Green Sulfur Hot Spring is the most corrosive hot spring in Datun volcano group.

Sulfur Valley was a mining area of sulfur and china clay in early period. The hot spring of Sulfur Valley is gas / water mixed hot spring and the hot gas is drawn out through gas well drilling and mixed with the cold surface water of Zhimin Brook by Dingbi Bridge. The temperature at the gas outlet of the gas well is above 100℃, and it is cooled down to 50℃ after mixing with surface water. The pH is at 3.5, the total Dissolved solid (TDS) is 188 ~ 502 mg/L and concentration of total sulfides content is 1.17 ~ 25.39 mg/L. The sulfate concentration is about 47.5 ~ 212 mg/L and concentration of chloride is about 19.3 ~ 55.7 mg/L and the output of hot spring is 5,000 CMD. It is acid sulfate spring, or commonly known as White Sulfur Hot Spring. White sulfur hot spring contents of minerals varied with the mixing water ratio. It is grey-yellow slightly transparent with thick sulfur smell. The corrosion to metallic material is light than Green Sulfur Hot Spring.

Xinbeitou Hot Spring Area had been tourist spot more than 100 years (Fig. 3 & 4) and is a nominated tourist attraction by many tourism guide, including Michelin Guide. Kagaya, a famous hospitality chain of Japan has their station in Xinbeitou Hot Spring Area. This Hot Spring Area is always jammed with visitors all year round. To meet the need of development of hot spring tourism, this region opened public tap water system since June 1911. From then on, it has been just over a hundred years now. In the early period, the water supply pipes' material was cast iron. The tap water pipe line material has been replaced by ductile iron pipe in 1990.

It is known from TWD Tap-Water Pipeline Equipment Geographic Information System Database (Fig. 5), the leak rate of Tap-Water Pipeline in Xinbeitou Hot-Spring Area is 21% higher than average of non-hot-spring area, especially in the hot spring supply of Green Sulfur Hot Spring and its basin. This is a spot centered at MRT Xinbeitou Station, neighboring Guangming Road, Zhongshan Road, Wunquan Road and Zhonghe Street. The corrosive leak rate of metallic pipe is higher than those of other materials (Fig. 6) It makes it necessary to conduct an investigation on the corrosion of Green Sulfur Hot Spring to tap-water pipeline, which includes soil corrosiveness evaluation and the corrosion test of metal component after immersing in local hot spring water (Fig. 7), so as to find the optimum measures to deal with it.

Fig. 1 Location of Xinbeitou Hot Spring Area

Fig. 2 Hell Valley, Origin of Xinbeitou Green Sulfur Hot Spring (with 2,000 CMD volume at pH=1.5 and 70~100℃)

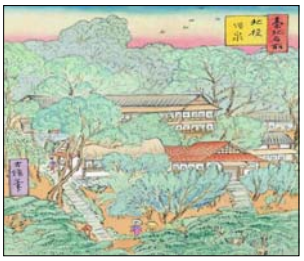

Fig. 3 1920 Painting recommending Xinbeitou Hot Spring as the tourist attraction of Taipei

Fig. 4 Tourist Guide Poster of Xinbeitou Hot Spring in 1930

The Way To Estimate The Soil Erosion Degree

According to AWWA/ANSI C105/A21.5-99 Appendix A, the corrosion property of soil can be evaluated in 10-point scale (as shown in Table 1). The method is giving different evaluation indices to the following 5 items of soil: 1) Specific Resistance, 2) pH, 3) Oxidation / Reduction Potential, 4) Content of sulphide and 5) Water content. The indices are then summed up. When the total scoring is higher than 10 points, it means that the soil can cause corrosion to underground Gray-iron and Ductile iron pipes and protection is required.

(1) Soil Specific Resistance: Soil specific resistance is the index of conductivity of soil and is the basic parameter in determining the corrosion of soil. Factors affecting soil specific resistance include the mineral composition, compactness, water content, composition and content of inorganic salt, content of organic matter and temperature of soil. Generally, when the specific resistance of soil is low, the corrosion of the soil will be high. According to ANSI/AWWA C105/A21.5, the specific resistance of soil has relationship with corrosion of soil as shown in Table 2.

(2) pH: pH represents the acidity of soil and the concentration of H+ ion will change the potential of metallic substance. When soil has pH less than 4, it is acid soil and is with strong corrosive power. Between pH6.5 and 7.5, the soil is regarded as neutral soil, and when there is sulphide existed, it will oxidizes and reduces can cause the potential to be minus, and it will be favourable for the existence and growth of sulphate reducing bacteria and results in corrosion of pipeline. When pH is between 8.5 and 1.4, the sedimentation of high concentration of soluble salt, specific resistance of soil will increase and corrosion will be held almost totally.

(3) Oxidation-Reduction Potential: Like specific resistance, oxidation – reduction potential of soil is also important index of corrosiveness of soil, which displays the oxygen content of soil. Generally, when it is low or at minus, it means the soil is in the status of anaerobic is favourable for the existence of sulphate reduction bacteria. The tendency of soil oxidation – reduction potential and bacteria corrosion is shown in Table 3.

(4) Content of Sulfide: With the existence of Sulphate (SO_4^{2-}), it will have cyclic reaction with iron and accelerate the corrosion reaction of iron. Also, when soil contains sulphate and sulphide, plus poor aeration, the environment will be most suitable for the growth of sulphate reduction bacteria. When there are existing sulphate reduction bacteria, the sulphate will be the final electron receiver and generate volume sulphides, which will depolarize anode of Fe metal and generate iron sulfide and deposit on the surface of anode. During the depolarization of anode, the hydrogen generated from surface of cathode will be consumed by sulphate reduction bacteria and accelerate depolarization of cathode and resulted in corrosion of metal.

(5)Water Content: From surface to underground this is the range of travel of surface water and, in the journey it is often accompanied with gas phase. Between liquid phase and gas phase in the soil, with the increase of humidity, O_2 and CO_2 will also increased and come up with effect on metal electrode potential and cathode polarization. Generally, the corrosiveness of soil increases with the increase of humidity until reaching certain critical humidity, and in excess of this critical point, the corrosiveness of soil will bend the trend down.

The Case of Soil Erosion Estimation

Table 4 shows the result of evaluation of soil corrosiveness at the point of broken tap-water pipe by MRT Xinbeitou Station, Guangming Road. The surface soil corrosiveness is evaluated at index of 4.5 points and the indices of soil at depth of 50 cm and 100 cm are evaluated to be 5.5 points; yet the soil beneath the pipeline is evaluated to be 16.5 points. Based on the Evaluation Standard of Appendix A to AWWA/ANSI C105/A21.5-99, when the total scoring is in excess of 10 points, the soil is corrosive to ductile –iron underground pipeline. So, the soil under the pipeline (evaluated at 16.5 points) is highly corrosive. This evaluation results is consistent to the results of visual inspection after evacuation of the site, i.e. the broken point of the pipe is exactly at 6 o'clock direction of the pipe (as shown in Fig. 8~10). Therefore, it is reasonable to infer that the penetration of pipeline is the result of corrosion of corrosive sulfide and sulfate accumulated in the soil that came from the seepage of hot spring water emitted by nearby hot spring hotel and leak of hot spring pipelines. This inference is supported by the results of soil chemical property analysis. The results is summarized as 25.5-28.5 ppm total sulfur above the pipeline, yet, same under the pipeline is as high as 69.5 ppm.

Table 4 Soil Corrosiveness Evaluation of §300 mm DIP Leak Point in Guangming Road, next to Xinbeitou MRT Station

Item	Evaluated points			
	Surface	50 cm underground	Above pipeline	Below pipeline
Soil specific resistance	0	0	0	8
pH	0	3	3	3
Water content	1	2	2	2
Oxidation – Reduction Potential	0	0	0	0
Sulfides (Total Sulfur , Sulfates)	3.5	3.5	3.5	3.5
Total points of corrosiveness evaluation	4.5	8.5	8.5	16.5

Fig. 5 Distribution of points of leak of tap-water pipeline of Xinbeitou Hot Spring Area in recent 10 years

Fig. 6 Excavation of Xinbeitou §300 mm DIP Leak Point

Table 1 Evaluation Standard of Soil Corrosiveness

Item	Test result	Evaluate points	Item	Test result	Evaluate points
Soil Specific Resistance (Ω-cm)	<1500	10	Oxidation – Reduction Potential (mV)	> +100	0
	1500-1800	8		+50 to +100	3.5
	>1800-2100	5		0 to +50	4
	>2100-2500	2		Negative	5
	>2500-3000	1	Burying depth and moisture	Poor draining Always wet	2
	>3000	0		Good draining Usually wet	1
pH	0-2	5		Excellent draining Generally dry	0
	2-4	3			
	4-6.5	0			
	6.5-7.5	0*	Sulfides	Yes	3.5
	7.5-8.5	0		Minimal	2
	>8.5	3		None	0

Note: With existence of sulfides and the oxidation-reduction potential is negative, the evaluation points of the box with * mark is 3.
(Source: AWWA/ANSI C105)

Table 2 relationship between soil specific resistance and corrosiveness

Specific resistance (Ohm-cm)	Soil corrosiveness
Below 500	Very corrosive
500 ~ 1,000	Corrosive
1,000 ~ 2,000	Moderately corrosive
2,000 ~ 10,000	Mildly corrosive
Above 10,000	Progressively less corrosive

Table 3 Relationship between Soil Oxidation-Reduction Potential and Bacteria Corrosion

Eredox Standard Hydrogen Cathode Potential (mV)	Bacteria corrosion tendency
＜100	Severe
100 ~ 200	Moderate
200 ~ 400	Mild
＞400	Nil

Fig. 7 Corrosion of SUS 316 and Ti bolts dipped in Green Sulfur Hot Spring for 3 months. (SUS 316 is corroded heavily and Ti bolt is in good visual appearance.)

Fig. 8 Corrosion of Xinbeitou §300 mm DIP pipe (Placed for 20 years and was asphalt coated from outside and leak repair has been done at the same place one year ago)

Fig. 9 Corrosion of Pressure Ring of Xinbeitou §300 mm DIP (Placed for 20 years and heaviest corrosion is found at 6 o'clock direction)

Fig. 10 Corrosion of SUS 304 Bolt of Xinbeitou §150 mm valve (Placed for 20 years and worst corrosion is found at 6 o'clock direction)

Conclusion

- In the area with acid hot spring, where soil is highly corrosive, soil corrosiveness evaluation shall be conducted firstly and establish related data base, so to facilitate the reference in adopting corrosion control measure and selection of pipe materials.
- In this project, we conducted external corrosion investigation of metal pipe buried underground in Xinbeitou Area, and according to Soil Corrosion Evaluation Standard in Appendix A to AWWA/ ANSI C105/A21.5-99, the soil corrosiveness index under tap- water pipeline is 16.5 as found in the soil corrosiveness analysis of Guangming Road, by MRT Xinbeitou Station. The soil is highly corrosive soil and can cause corrosion to metal underground metal pipeline, like cast iron and ductile iron pipe.
- Regarding the cast iron and ductile iron buried underground, the rate of corrosion is related to the nature of soil, environment and water quality; however, for the pipeline buried in area with Hot-Spring production or application, other than the damage caused through human factor, the pH value and sulfur content in the soil are playing the vital part.
- In order to prevent external corrosion of cast iron and ductile iron pipe, it is suggested to replace the asphalt corrosion control with synthetic resin coating, and for highly corrosive soil in hot-spring area, it is advisable to add PE film to protect. Certainly, breaking / damage of the film shall be prevented while laying the pipe.
- For the area with highly corrosive soil, plastic pipe, such as HDPE and PVC may be used to deal with corrosion.