COMPARISON OF LAND SUBSIDENCE CHARACTERISTICS IN CA MAU PROVINCE, VIETNAM AND JAPANESE LAND SUBSIDENCE AREAS

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ABSTRACT

The Mekong Group has investigated land subsidence in Ca Mau Province, Vietnam since November 2017. According to the uplifting phenomenon survey of the existing deep wells, the maximum uplifting rate of 2 cm/year was confirmed. Continuous monitoring of ground compaction and groundwater level at existing abandoned wells also showed the compaction occurs with lowering of groundwater level. The monitoring records indicate that the ground compaction occurs not only in shallow zone but also in deep zone. In Japan, the areas more than 2 cm/year of land subsidence rate have been regarded as active land subsidence areas. The lowland area of Tokyo is the worst with the maximum land subsidence of 450 cm by leveling survey. The lowest groundwater levels were recorded in mid-1960s, then the levels were rapidly recovered by strict regulation of groundwater pumpage. However, the ground elevation of the subsided areas is still lower than the mean seawater level. In northern part of Kanto Plain and Kanazawa Plain in Japan, land subsidence still occurs at present even after the reduction of total groundwater pumpage. The reason is seasonal fluctuation of groundwater level, particularly steep decline of groundwater level caused by excessive pumpage for snow melting purpose in Kanazawa Plain.

1. INTRODUCTION

The Research Group for Groundwater Contamination by Arsenic in the Mekong River Delta (hereafter, the Mekong Group) has carried out groundwater surveys in Dong Thap and An Giang provinces since 2008 with HCMC-IRG, VAST, Vietnam (AAN and Mekong Group, 2012). Since 2013, the study area has been expanded to the downstream areas of the Mekong River and the Bassac River (Sato et al., 2019). During the field investigations, we noticed uplifting phenomena of the casing pipes of deep wells caused by land subsidence in several places. In November 2017, we confirmed the occurrence of land subsidence by our field survey in Soc Trang and Ca Mau provinces. We selected Ca Mau Province as our study area and started detailed land subsidence survey from September 2018. In this paper, we summarize the characteristics of land subsidence in Ca Mau Province and compare with the characteristics of land subsidence in Japan.

2. CHARACTERISTICS OF LAND SUBSIDENCE IN CA MAU PROVINCE

The Mekong Group has started leveling survey since November 2017 to detect uplifting phenomenon of the existing deep wells at CM-01 site in central Dam Doi District, which is located about 21 km SSE of Ca Mau City. There two production wells for public water supply at CM-01 site, viz. left well (well depth more than 150 m) and right well (well depth about 150 m). We have conducted leveling survey twice a year and detected uplift rates of 1.3 cm/year at the left well and 0.8 cm/year at the right well. According to the one-year monitoring of compaction data at the left well (abandoned well) from September 2018 to September 2019, we found compaction (2.5 mm) from September 2018 until February 2019 and rebound (3.0 mm) from February 2019 until April 2019, although there were some measurement noises in the records (Nouchi et al., 2019). The reason of the rebound might be the suspension of groundwater pumpage at the right production well from 11 February 2019 and subsequent groundwater level rise around the well. We installed an automatic groundwater level sensor at the right well and started to monitor groundwater level from
25 September 2019. The static groundwater level on the day was -13.13 m from ground elevation. We will be able to analyze detailed relationship between land subsidence and groundwater level at CM-01 site from now onward.

We installed an automatic groundwater level sensor at CM-10 well in September 2018, which is an abandoned production well for public water supply having estimated well depth between 180 and 200 m. The well is located at the central part of Ca Mau City. According to the casing pipe observation, uplifting of 20 cm was recognized by color change of the pipe. We installed a compaction sensor in March 2019. According to the both records from March 2019 to September 2019, 5.5 mm of compaction occurred with 8.0 m of groundwater level decline at CM-10 well (Nouchi et al., 2019). The groundwater level on 25 September 2019 was -28.02 m from ground elevation. From the monitoring records, it is presumed that the groundwater level at CM-10 well is influenced by the groundwater pumpage of nearby operated pumping stations.

3. CHARACTERISTICS OF LAND SUBLIMATION IN JAPAN

In Tokyo, the first benchmark for levelling survey was installed in 1892, and land subsidence had already been noticed by 1920s (MoE, 2019). Before 1942, more than 200 cm of land subsidence was recorded due to the pumpage from deep production wells. The rate of subsidence was slow down during WWII, however, the subsidence rate increased again from 1950s to 1960s by the rapid growth of economy. The lowland area of Tokyo has the worst land subsidence record with the maximum amount of 450 cm by leveling survey. The lowest groundwater levels were recorded in mid-1960s, then the levels were rapidly recovered by strict regulation of groundwater pumpage by the central and local governments. However, the ground elevation of the subsided areas is still lower than the mean seawater level.

The areas more than 2 cm/year of land subsidence rate have been regarded as active land subsidence areas in Japan (MoE, 2019). Although the land subsidence in Tokyo had almost stopped around 1972, but the center of the subsiding area was shifted to the northern part of Kanto Plain. The land subsidence rate of Saitama, Ibaraki, Tochigi and Gunma prefectures ranges from 0.5 to 1.2 cm/year in 2017 (MoE, 2019). Cumulative land subsidence from 2013 to 2017 is also presented by MoE (2019). More than 8 cm of cumulative land subsidence for 5 years are observed in Kanto, Niigata and Kanazawa plains. The land subsidence occurred in Tokyo, Osaka, Noubi, and Chikugo-Saga plains are characterized by continuous compaction alluvial soft clay with lowering of groundwater level. After the reduction of groundwater pumpage by laws and regulations, the subsidence in these areas have almost stopped.

On the other hand, the land subsidence in northern part of Kanto Plain and Kanazawa Plain continues at present. The total amount of groundwater pumpage has been reduced, but the subsidence occurred in the season of groundwater level drop. In northern Kanto Plain, groundwater level declines in summer season for paddy irrigation. In Kanazawa Plain, groundwater use for snow melting purpose in winter has significantly increased then groundwater level sharply drops in snowing time. According to the groundwater level and land compaction monitoring data provided by Kanazawa City, ground compaction clearly occurs when groundwater level drops in winter. The ground is rebounded after winter, but the compacted ground is not fully recovered. Therefore, the land subsidence continues at a rate of 1 to 2 cm/year in recent years. It is characterized that the land subsidence in Kanazawa City occurs not only in alluvial soft clay, but also in stiff clayey layers of Pleistocene.

4. DISCUSSION

The continuous monitoring data of groundwater level and ground compaction are very important to clarify the mechanism of land subsidence and to identify subsiding layer. The compaction data at CM-01 site in Ca Mau Province indicate that the ground compaction occurs not only in shallow zone but also in deep zone, because the rebound was recorded after stopping nearby groundwater pumpage. Normally ground expansion is observed in pre-consolidated clayey layers.
with geologic age before Holocene. On the other hand, rebound is very small in alluvial soft clay because the clay normally shows plastic in nature and normal consolidation conditions. If it is possible to construct land subsidence monitoring wells with dual casing system, precise relationship between groundwater level change and ground compaction can be understood. In addition, if we have several such monitoring wells with different depths, depth-wise ground compaction and detailed characteristics of land subsidence will be revealed.

5. CONCLUSIONS

The Mekong Group has started to investigate land subsidence by field surveys including levelling survey of uplifting phenomena, land subsidence damage survey and continuous monitoring of ground compaction with groundwater level. From the investigation, it has been confirmed that land subsidence at the maximum rate of 2 cm/year occurs in Ca Mau Province. The monitoring records indicate that the ground compaction occurs not only in shallow zone but also in deep zone. It is necessary to continue these field surveys to understand the characteristic of land subsidence in Ca Mau Province. It is also recommended to install land subsidence monitoring wells with different depths to reveal precise characteristics.

REFERENCES