地すべり地帯における水抜きボーリングおよび平野部における井戸管と揚水管に形成するバイオマットの研究

氏　　名	髙橋　直人
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論文審査委員（主査）	田崎　和江（自然科学研究科・教授）
論文審査委員（副主査）	加藤　道雄（自然科学研究科・教授），神谷　隆宏（自然科学研究科・教授），奥野　正幸（自然科学研究科・教授），笹川　一郎（日本歯科大学・教授）

Summary

The well efficiency declines because of the damages of the clogging of screens by forming of microbial mats. At landslide areas, the reddish-brown microbial mats formed in drainpipes for a short period such as within three years after the construction. In this doctoral thesis, the damage situation in such an institution by microbial mats formed by iron bacteria, and examined growth environment of iron bacteria on drainpipes at landslide areas in Niigata prefecture. At same point of view, well and riser pipes at Fukui city and Kanazawa city are examined.

In several landslide areas of Niigata prefecture, the reddish microbial mats were more remarkable in areas mainly containing clays than sandstone areas. These microbial mats formed with iron bacteria, such as *Toxothrix trichogenes* and *Leptothrix ocheracea.* The reddish microbial mats of iron bacteria suppress clogging of screens and the growth of specific species occurs to corrosion of screen in the well at Fukui plain.

As for the microbial mats of drainpipes, well and riser pipes in Niigata, Ishikawa and Fukui prefecture, the environmental difference of the oxidation / reduction was clear. Microbial mats included iron bacteria, alga and cyanobacterium, and reduction characteristics lived apart. The formation of microbial mats is caused by a difference of existence forms of the Fe of a little groundwater environment such as pH, Eh. In conclusion, when deciding the positions and materials of drainpipes in landslide areas and well pipes in the future, more concrete plans should come with serious consideration concerning about characteristics of groundwater environments and microbial mats.

Abstract

Various microorganisms inhabit hydrosphere and lithosphere on the Earth. The

structures formed by microorganisms are so-called microbial mats (biomats). They are observed frequently in groundwater and sometimes form yellow, reddish-brown or dark-brown microbial mats. Iron bacteria are bacteria which multiply by oxidizing dissolved ferrous iron and accumulate the resulting ferric oxide in the cells. Several wells in Fukui and Ishikawa prefecture resulted in poor efficiency because of the damages or clogging the screens with microbial mats. At some landslide areas in Niigata prefecture, the reddish-brown microbial mats formed in drainpipes and water catchments well for a short period such as within three years after the construction. This deteriorates the function of some drainpipes seriously. In this doctoral thesis, the damage situation in such an institution by microbial mats formed by iron bacteria, and examined growth environment of iron bacteria on drainpipes at landslide areas in Niigata prefecture. At same point of view, well and riser pipes at Fukui city and Kanazawa city are examined.

In the first section, several cases of microbial mats formation at Yamanaka, Irishiokawa and Ohirota landslide area in Niigata prefecture are focused, because these landslides are typical types in eastern Japan. In a landslide place of Niigata prefecture, the microbial mats were more remarkable in areas mainly containing clays than sandstone areas. The microbial mats were seen in the aquatic environment where the oxidation-reduction potential (Eh) was in the range of +165 to +244 mV and the concentration of dissolved oxygen (DO) was in the range of 2.7 to 7.4 mg/L. In addition, more microbial mats were formed around the part in the range of about 0 to 15 meters from the aperture mouth of drainpipes, while less microbial mats were formed in the deep part of drainpipes. The formation of microbial mats was remarkable under the condition where the reductive groundwater was exposed to the atmosphere and suddenly changed into an oxidation state. The microbial mats were formed by iron bacteria, such as *Toxothrix trichogenes* and *Leptothrix ocheracea.* However, the microbial mats are formed completely within several months to one year at Ohirota landslide area in Niigata prefecture. High pressure water is the only way to wash off the microbial mats at this moment.

In the second section, several cases of microbial mats formation at M1-well in Fukui city are focused because this well is a typical type in Fukui plain. The well efficiency declines because of the damages of the clogging of screens by forming of microbial mats. From the viewpoint of microbiology, this study is conducted to explain the troubles caused by reddish

microbial mats. The geological structure of Fukui plain mostly consists of alternating layers of clays and gravels. There are five or six aquifers in Fukui plain, the groundwater samples are collected from three aquifers. Many of wells in Fukui plain draw groundwater from these aquifers. The suspended matters in groundwater were observed by differential interference microscope and episcopacy fluorescence microscope. The microbial mats of iron bacteria suppressed screen clogging and the propagation of specific species resulted in corrosion of screen. The groundwater quality and the condition of iron bacteria growth varies depending on their aquifers. It is clarified that the symbiosis of iron bacteria and the propagation of specific iron bacteria caused different types of well obstacles at M1-well in Fukui plain.

In the third section, several cases of microbial mats formation at riser pipes in Kakuma campus of Kanazawa University, Ishikawa prefecture are focused. Bluish green Zn-S- and yellowish brown Fe- microbial mats were found on outer surfaces of well riser pipes the microscopic observation and XRF chemical analysis revealed that the formative conditions of microbial mats differ in depth due to stationary and pumping groundwater levels. Bluish green microbial mats formed in 61.6 - 75.6 m depth were characterized by high content of Zn and S. The microbial mats mainly consist of spherical fine particles of several μm in size. A small amount of coccid- and bacilli-form bacteria were found in the aggregation. While, yellowish brown microbial mats formed in 30.8 - 61.6 m depth and were characterized by high content of Fe, Ca, P, Si and Zn. The microbial mats mainly consist of spiral materials that were metabolized from an iron oxidizing bacterium, *Gallionella ferruginea*. Harp-like materials metabolized from another iron oxidizing bacteria, *Toxothirix* spp. were also found below 56 m in depth. A large amount of coccid-, bacilli- and filamentous- form bacteria were found in the assemblage of the metabolic materials and the number of filamentous- form bacteria increased with depth. TEM observations and FE-TEM-EDX elemental maps revealed that some spherical particles on the cell surface of bacteria in the bluish green microbial mats are rich in Zn and S stick, suggesting that Zn exist as sulfide. The other adhesion materials consisted of Fe, Si, O, and Zn were also formed around cell wall. The bacteria in the bluish green microbial mats might be tolerant to heavy metal Zn. The formation of microbial mats was influenced by different Fe forms which depended on the groundwater environment factors such as pH and Eh.

As for the microbial mats of drainpipes, well and riser pipes in Niigata, Ishikawa and

Fukui prefecture, it becomes clear by difference of the oxidation / reduction environment. Microbial mats included iron bacteria, alga and cyanobacterium, and reduction characteristics lived apart. At the place covered with green microbial mats including alga and cyanobacterium, the pH of groundwater was 6.0 to 7.0 and the oxidation-reduction potential showed more than +300mV. At the place covered with reddish / yellow -brown microbial mats formed by iron bacteria, the pH of groundwater was 6.0 to 7.5 and the oxidation-reduction potential showed a range of +130 to +300mV. At the place covered with bluish microbial mats formed by reductive bacteria, the pH of groundwater was 7.0 to 8.2 and the oxidation-reduction potential showed less than +100mV. The microbial mats were completely formed again in several months to one year. Both dead and surviving iron bacteria could form microbial mats.

In landslide areas, the necessity of maintenance was pointed out in important geological features comprising clays. In such areas, reddish / yellow-brown microbial mats formed by iron bacteria deteriorated the function of drainpipes. Therefore, more efficient maintenance of drainpipes in landslide areas is possible and necessary. In conclusion, when deciding the positions and materials of drainpipes in landslide areas and well pipes in the future, more concrete plans should come with serious consideration concerning about characteristics of groundwater environments and microbial mats.

学位論文審査結果の要旨

本学位論文に関し、平成19年2月2日に第1回審査会議を開催、面接審査を行った際、論文の内容について討論した。さらに、2月5日に行われた口頭発表の後に第2回審査会を開き、協議の結果、以下のように判定した。本論文は、新潟県内の地すべり地の水抜きボーリングや、石川・福井県内の深井戸のバイオマット形成事例を示し、地質・地下水質との関連や形成状況について検討を行った。地下水は年間を通して安定した水量・水質を得られるという理由から、上水道水源として広く用いられているが、施工後鉄細菌バイオマットにより井戸取水部の閉塞により取水量が減少し、井戸水が懸濁するなどの現象が見られる。また、地下水は地すべりなどの土砂災害の発生とも関連しており、地すべり地では豪雨・融雪時に浸透した地下水を排水するための水抜きボーリングが施工されているが、バイオマットにより孔口が閉塞してしまうものがある。その結果、バイオマットの種類や形成状況を決定する要素として、Ehの他に地下水中のFeやMn濃度が重要な要素となっている点が明らかになった。地下水のEhが+300mV以上の酸化的な環境下では、珪藻による緑色バイオマットが、Ehが+100～+300mVの環境下では、鉄細菌による赤褐色バイオマットが、Ehが+100mV以下の還元的な環境下では、還元性細菌による青緑色バイオマットが形成されていた。高圧水噴射による洗浄で、一時的にバイオマットは除去できるが、効果は数ヶ月程度しか持たず、1年後には孔口が再び閉塞する状況が観察された。本研究の結果に基づき、予めバイオマットの形成が起こりやすい箇所を特定すれば、将来より効率的な施設の維持管理を行うことが可能である。以上の研究結果は博士（理学）に値するものと判定した。