氏　　名	HARTWIG CLAUDIA
授与した学位	博　士
専攻分野の名称	環境学
学位授与番号	博甲第４８６７号
学位授与の日付	平成２５年　９月３０日
学位授与の要件	環境学研究科　資源循環学専攻 （学位規則第５条第１項該当）
学位論文の題目	Study on physical and chemical clogging phenomena during artificial recharge of groundwater （人工涵養における物理的及び化学的な目詰まりに関する研究）
論文審査委員	教授　西垣　　誠　　教授　鈴木　茂之　　准教授　小松　　満

学位論文内容の要旨

Open loop heat pump systems (OLHPS) are valid methods for energy storage and groundwater management due to their high efficiency and low costs. But when injecting water into the aquifer, clogging occurs. Clogging can be divided in three major causes; biological, chemical and physical clogging. In this study, chemical and physical clogging was investigated in order to make application and maintenance of OLHPS more practicable even in developing countries. Iron in groundwater is a major cause for chemical clogging due to its elusive chemistry by contact with oxygen. Expensive iron removal methods in practice impel to device us to explore alternative cheap and eco-friendly materials for iron removal from groundwater practicable in developing countries. In present study, wooden charcoal was used and compared to fine sand and volcanic ash in order to evaluate the filtering potential of filter material. The column experiments were conducted in an upward flow mode by minimizing oxygen contact with water. Wooden charcoal was highly efficient material when compared with the other filtering materials (fine sand and volcanic ash). In an additional field test, with wooden charcoal and layers of gravel, middle and fine sand at the inlet and the outlet, filled pilot filter was tested under realistic operational conditions. The treated water was then used to lower the temperature in a room of 18.9 m² and was re-injected into the aquifer. The results showed that the used wooden charcoal is capable of adsorbing and removing dissolved iron from groundwater under anoxic condition. In the field tests the wooden charcoal filter showed higher performance than in the laboratory. However, if the higher performance of the on-site wooden charcoal filter is taken into account, an adsorption capacity of 2.2 – 3.3 g/L material is possible, which means a 36%-53% efficiency of the Ferrolite MC3 filter. Furthermore, suggestions are made for installation and maintenance of the filter under field conditions. Iinvestigations on physical clogging regarding the particle mobilization was carried out in laboratory experiments under controlled environmental conditions. One- and two-dimensional experiments were conducted in order to determine the critical hydraulic gradient. The one-dimensional horizontal-flow column experiments showed that not only the fine colloidal particles of the soil were mobilized, but also the larger particle ranging between 0.25 and 2 mm were moved by velocity forces. Experimental results showed that when the bigger particles were mobilized by velocity forces, the finer particles were pushed aside and thus fine particles accumulated in the areas near the injection port. In addition, wooden charcoal is thought to be a good fertilizer for agricultural use; however, the survival of plants is firstly strongly dependent on phosphate availability in the soil. In order to investigate the plant survival strategies, a study was carried out using different Brassica cultivars, which are known to survive even in low-P soils. Phosphate (Pi), influences virtually all developmental and biochemical processes in plants; however, its availability and distribution are widely heterogeneous. However, even total P is abundant in the lithosphere; elusive soil chemistry of Pi renders the element the most dilute and the least mobile in natural and agricultural ecosystems, resulting in P deprivation due to its low mobility and high fixation capacity in the soil. Using a soil low in P with or without P fertilization, Brassica cultivars showed substantial genetic diversity in P-utilization efficiency (PUE), P efficiency (PE), P-efficiency ratio (PER), and P-stress factor (PSF). Cultivars producing greater root biomass accumulated greater total P contents, which in turn was related negatively to PSF and positively to shoot and total biomass. Plant survival and reproduction rely on efficient strategies in exploring culture media for P.

論文審査結果の要旨

一般的に地下水の熱利用に関してはクローズシステムとオープンシステムがある。前者は地下水を揚水したりしたいために、現在では比較的有効な地下水の熱利用システムとして普及しつつある。しかし、そこで利用できるエネルギーは限られたものである。後者のオープンシステムは、地下水を揚水して地下水の熱を利用するシステムで、大量のエネルギー利用が可能である。しかし、揚水した地下水を再び地盤内に涵養しないと、地盤沈下等の地下水障害が生じる。揚水した水を地下に涵養する際には、今日でも多くの課題が残されている。本研究の中心課題は、揚水した地下水を涵養する時の「目詰まり」をどのように回避するかである。本研究で得た結果を以下に列挙する。

(1) 地下水への人工涵養で課題となる物理的目詰まりに対して、涵養時の注水井 の水位と地下水位と差である「注入水位差」が大きくなると，注入している帯水層内の細粒子が注入井から帯水層の方向に移動するため、注入導水勾配が小さくなる所で目詰まりが生じる．この物理的な目詰まり現象を回避するには大きな「注入水位差」を与えないことである．この限界の水位差を「許容水位差」と提案し、原位置でそれぞれの涵養しようとする帯水層に対して、この「許容水位差」を注入前に求めておくことがきわめて重要であることを明記した。

(2) 地下水への人工涵養でもう一つの重要な課題である化学的目詰まりについての研究を行った。具体的には、揚水した地下水に含まれる鉄イオンやマンガンイオンが空気の酸素と結合して生じる酸化鉄等の沈殿物を生じさせない方法として次の3つの手法を提案した．

  (a) 注入水中の鉄イオン等を除去する方法，(b)地下水中から鉄やマンガンイオンと注入前に除去する方法

  (c) 揚水した地下水を空気に触れささないで涵養する方法

上記の研究成果は地下水のモデル化に大きく貢献するものである。よって、本研究は博士（環境学）を授与するに値すると判断した。