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APPLICATION OF NANOFILTRATION MEMBRANE FOR REMOVAL OF VOCS AND HEAVY METALS IN GROUNDWATER, RATCHABURI, THAILAND

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The presence of toxic contamination in groundwater has become a concerning issue. Since groundwater is the main source of fresh water that is used for domestic, agricultural, and industrial activities, contamination can result in health issues for humans and animals. Sources of groundwater contamination are from both geogenic origins caused by dissolution of minerals in aquifer, and anthropogenic origin due to high expansion of urbanization, agricultural production, and industrialization. One of the areas affected by groundwater contamination is located in Namphu and Rangbua subdistict, Ratchaburi province, western Thailand. According to the site investigation results performed by the Department of Groundwater Resources, Pollution Control Department, and other environmental government agencies in 2014, the groundwater in the area is contaminated with volatile organic compounds (VOCs) and heavy metals. The pollutant source was identified as leakage from landfill and industrial waste recycling activities which are located upstream. The villagers living downstream were not able to use this contaminated groundwater. However, the methods for improving groundwater quality have not been determined.

The objective of this study was to define the hydrochemistry of contaminated groundwater and examine the efficiency of nanofiltration membrane for removal of pollutants in groundwater as well as the potential implementation of the membrane. Hydrogeological characteristics of the study area is comprised confined aquifer which consist of massive limestone, meta-sandstone, mudstone, and quartzite which is 20-80 meters below surface and unconfined aquifer consists of clay, sandy clay, silty sand, and weathered rock 3-8 meters thick. Depth to water is approximately 1-6 meters. The chemical property of groundwater at the site was $Ca\text{-}HCO_3$ type with high total hardness. The distance of groundwater contamination extended from the landfill area to 1 kilometer downstream from the source. The analytical results of groundwater samples reported that the highest vinyl chloride concentration (2,170 µg/L) was detected in the monitoring well at the landfill in July 2020. The contamination of vinyl chloride and benzene was also detected in shallow wells located in the southeast of the landfill area. Moreover, the heavy metals concentration including nickel was 0.36 mg/L and manganese was 10 mg/l which are higher than groundwater standards. The concentration of the pollutants fluctuated depending on seasonal variables that control water table in aquifer and biodegradation of organic compounds occurring in subsurface environment. Although the industrial waste recycling activities have been suspended since 2018, the contaminants are leaking from the source and flow to the discharge area. Several technologies for groundwater remediation such as the implementation of permeable reactive barriers, pump and treat, or bioremediation could be applied to the site. The processes to clean up subsurface environments includes many steps and can be quite costly to improve water quality for desired standards. Instead of remediating aquifer conditions as a long-term solution, household filtration solutions are cheaper and simpler to achieve. The alternative method to treating groundwater in situ is the implementation of membrane filtration technology to produce safe drinking water for household use.

The pressure-driven membrane processes including microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO) have been widely used in municipal wastewater treatment as well as household scale. Nanofiltration (NF) is a relatively recent development in membrane technology with characteristics that fall between ultrafiltration and reverse osmosis (RO). In this study, we investigated the potential for removal of chlorinated volatile organic compounds and heavy metals from groundwater. The chemicals of concern were cis-1,2-dichloroethylene, vinyl chloride, benzene, nickel, and manganese. A hand operated filtration system developed by the International Environmental Research Institute (IERI), Gwangju Institute of Science and Technology (GIST), Republic of Korea, pumps water at low pressure through microfiltration and nanofiltration membranes to remove contaminants. The membrane module is composed of spiral-wound type with

polyamide thin-film composite Nanofiltration membrane. The module is cylindrical shape of 101.6 cm long and 6.4 cm diameter, and the membrane surface charge is negative with monovalent rejection (NaCl) of 85-95%. The filtration experiments were conducted at a pressure of 0.4-0.6 MPa, which yielded flow rates of approximately 2 L/min. To examine the nanofiltration membrane efficiency, groundwater samples were extracted from four monitoring wells by using a submersible pump with low flow rate, and were used as feed water. The samples were measured for pH, temperature, and electrical conductivity at the site and were collected in bottles for laboratory analysis. Permeate samples were collected for laboratory analysis, and the field parameters were measured. In addition to nanofiltration, an activated carbon filter was used in this experiment to compare the removal rates of pollutants.

According to laboratory results, the maximum concentration of pre-treatment samples were as follows; cis-1,2-dichloroethylene 6 µg/L, vinyl chloride 25 µg/L, benzene 6.9 µg/L, nickel 0.026 mg/L, and manganese 0.53 mg/L. The removal efficiency of the filters was calculated for each parameter of interest. The results indicated that the nanofiltration membrane performs better with contaminant removal than the activated carbon filter. The nanofiltration maximum removal efficiencies for 1,2-dichloroethylene, vinyl chloride, benzene, nickel, and manganese were 97, 99, 98, 99, and 99%, respectively. The activated carbon filter removal efficiencies for 1,2-dichloroethylene, vinyl chloride, benzene, nickel, and manganese were 97, 75, 96, 62, and 2%, respectively. Based on the findings, nanofiltration membrane could be recommended for VOCs and heavy metals removal in the study area. However, the treatment efficiency is dependent on several factors, including pretreatment requirements, influent water quality and the lifespan of the membrane, which needs to be investigated more in details. The Nanofiltration membrane (NM) is generally used for two to three years, but it depends on the input water quality. Therefore, it is recommended to increase the replacement cycle of NM by frequently replacing the relatively cheap pre-filter. The water filtration with the NM is entirely operated by manpower so that the users can save the cost for fuel or electricity. It also reduces the burden of hiring skilled experts and using expensive chemicals required by other treatment processes such as oxidation, precipitation, and adsorption. However, it is necessary to discuss how to control the effluent concentrated with pollutants after filtration. Further research to determine the maximum concentration of VOCs and heavy metals in the feed water should be performed before applying this treatment method to large scale.

Widespread implementation of these nano filtration systems provides the opportunity for Thailand to achieve the Sustainable Development Goals (SDGs) related to “Clean Water and Sanitation” (Goal 6). The presence and regular maintenance of these filtration systems in households and villages would provide local communities ample access to clean water. This clean water can be used for drinking and improved sanitary conditions for people who would otherwise have difficulty obtaining it.

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