A Novel Hybrid Photocatalytic System for water purification: application to groundwater remediation and aquifer recharging

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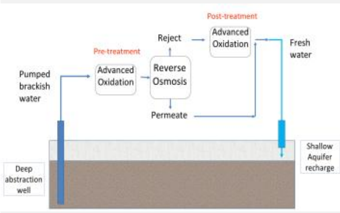

A novel hybrid remediation system has been developed, incorporating a photocatalytic reactor coupled with Reverse Osmosis (RO). The system was constructed and operated in pilot scale, in order to ensure the recharge of a nearby aquifer with pure and desalinated water. The system is remotely monitored and operated, so as to be tested and operated in remote locations.

Introduction

High water consumption, environmentally friendly waste disposal and conforming to local environmental authority regulations can render water management a costly and complicated task.

The scope of SUBsurface water SOLutions (SUBSOL) project is to establish a market breakthrough of subsurface water solutions (SWS) in order to provide answers to freshwater challenges in coastal areas worldwide. In the context of this project, full scale pilot systems, incorporating novel remediation technologies should be put in place.

The selected case study, (coastal site of the Schinias Natural Park) comprises of important ecosystems (coastal wetlands, sand dunes and a pine forest), but also accommodates greenhouses, requiring high quality water. Saltwater intrusion is a major issue in the upper aquifer. The intrusion of seawater in the upper levels of groundwater is a constant and escalating problem, occurring in numerous coastal areas where freshwater aquifers are being extensively pumped. Recharging the upper levels of groundwater aquifer with water originating from the lower karstic aquifer, can create a potential freshwater barrier to the continuous intrusion of saltwater into the shallow groundwater and refresh the wetland. Nevertheless, the quality of the pumped karstic groundwater, is of utmost importance to the success of the whole project, since the main goal is to reduce the overall inorganic and organic load and to provide the aquifer with water of high quality.

The groundwater of the area is known to be polluted by the use of pesticides (introducing organic pollution), fertilizers, while for most than 40 years, toxic liquid containing PolyChlorinated Biphenyls and PolyAromatic Hydrocarbons has been discharged illegally in the area. Soil remediation was limited and inadequate.

The objective in the area is a smart engineered aquifer recharge system via an optimized Pump & Treat system integrated with an Aquifer Storage and Recovery scheme. In this area this would include the abstraction of brackish groundwater from the deeper karst aquifer at a location close to the shoreline and direct treatment with Reverse Osmosis (RO) for desalination. RO is well established in removing inorganic and organic pollutants. Its main disadvantage however is the production of a concentrated flux, with increased amounts of organic and inorganic pollutants. Therefore, the integration of an Advanced Oxidation Process (AOP Photocatalysis) prior to RO would dramatically reduce incoming organic load of the RO and therefore of the concentrated reject flux.

In the context of the project, Greener than Green (GtG) Technologies Co. has introduced and implemented a series of novel remediation techniques in the flow of the pumped groundwater, before it is reintroduced in the wetland and the upper groundwater aquifer. These included a) a RO system, which drastically reduces the ionic content of the water and removes residual organic species of increased molecular weight and b) an AOP system for the degradation and possible mineralization of organic pollutants in the presence of inorganic ions, which are present in the rejected flux of the membrane filtration unit.

These techniques are remote monitored and operated, so as to be tested and applied in similar remote locations.

Methods

The RO unit was designed in collaboration with and produced by Lenntech BV (Delft, Netherlands). It was designed to process water of conductivity of about 4500 μS/cm and temperatures between 15 and 30°C and to produce an outflow of 200 μS/cm at 60 m^3/day. The RO unit includes the following process: Sand filtration, antiscalant dosing, 5 μm cartridge filter and Reverse Osmosis. A small by-pass line was also foreseen over the reverse osmosis plant, with manual regulation, in order to produce an increased outflow of up to 80 m^3/day, with slightly higher conductivity in the final product, by mixing the osmotic water produced with the feed water at a 3:1 ratio.

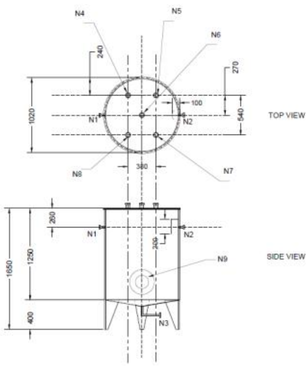

Fig. 1 AOP reactor design

Prior to that, an AOP unit was established (Figure 1), utilizing heterogeneous photocatalysis using titanium dioxide, TiO_2, as a catalyst, in order to confront organic pollution. The AOP unit was designed to use a grade 304 stainless steel tank of 1m^3, in which the slurry of the catalyst and the treated water will be illuminated for certain contact time. The number of tanks needed and consequently the contact time was determined according to the amount of pollution of the treated water, offering modularity in the system that can be modified to meet the needs. The selected photocatalyst was a novel material; it is photocatalytically active fumed titanium dioxide granules (>99,5%) with particle size of about 20 μm. Medium pressure lamps were used and their type and placement was designed and implemented (Figure 2). The UV Lamp Configuration max at 272 nm (UVC), UVT% : 99.65, lamp Length: 1 m, required power: 16 kw and catalyst loading: 300 mg/L (150-200 NTU). A cross-flow microfiltration (MF) process has been used for solid / liquid separation leading to a complete recovery of TiO_2 particles.

For the process of remote monitoring and control, a programmable logic controller (PLC) was employed connected to a virtual private network (VPN) by means of a laptop computer and a 4G mobile internet wireless router.

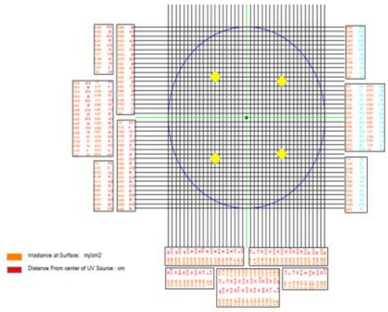

Fig. 2 AOP lamp placement calculations

Results

The proposed combined treatment module Figure3 and 4) in the case of Schinias includes the main components and treatment processes. Water (90 m^3/day) with salinity 1200-3000 μS/cm will be introduced in the AOP unit in order to decrease the total organic carbon possibly present in the feed. Part of the AOP outflow (70 m^3/day) is processed in the RO unit which produces 50 m^3/day water of low salinity (50 μS/cm) and 20 m^3/day of saline RO rejection water (16000 μS/cm). The outflow of the RO unit is combined with the remaining 20 m^3/day of AOP outflow (1200-3000μS/cm) to produce a total Unit outflow of 70 m^3/day at approx. 300-400 μS/cm.

The AOP unit included a tank with UV lamps which are introduced in the catalyst/water slurry and a continuous flow of air ensures the presence of conditions as well as proper mixing. The treated suspension undergoes filtration in a microfiltration unit with periodical back-washing steps, in order to recover most of the catalyst. The total organic carbon, pH and conductivity of the feed and the processed water were monitored throughout the process, using sensitive analytical equipment, in order to evaluate the efficacy of the whole process.

At the moment, the unit is continuously operated, producing water of TOC <0.5ppm, recharging the nearby aquifer with an approximate salinity of 200 μS/cm. Various inflowing solutions have been tested at different spiked TOC levels and TOC removal of 95% has been achieved in every case by changing the UV illumination, contact time or number of treatment cycles of the inflowing water.

Challenges rising from the operation of the unit are mainly related to the presence of inorganic ions, acting as radical scavengers throughout the AOP process and the separation of the solid catalyst with maximum efficiency, so as not to pose a risk to the RO membranes.

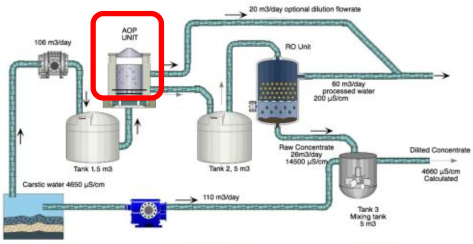

Fig. 3 Hybrid AOP / RO processing system

Fig. 4 Construction of the hybrid AOP system

Conclusions

An efficient integrated pilot scale AOP/RO system has been developed and constructed for the remediation and clean-up of a groundwater aquifer in Greece. The unit is continuously operated and monitored for maximum organic load remediation and salinity reduction, in order to recharge the nearby aquifer, without increasing the organic load of the RO reject flux. The project is under development and continuous data are gathered so as to maximize the efficiency of the unit.

Keywords: *hybrid photocatalytic reactor, reverse osmosis, TiO_2 slurry reactor, aquifer recharge*

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