

Functional Treatment System for Water Used in Greenhouses*

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Abstract

Nutrient pH is related to the plant growth and nutrient components, but it is not easy to control the nutrient pH. In this study, based on the characteristics of the quartz porphyry, which create a pH-buffer and ion exchange actions due to its negative charge. Water production having pH-buffer action was investigated by an effective water treatment system (HITEC-TYPE). As the result, The pH of the nutrient was not rapidly changed, and was maintained in a stable condition at about 7.0 even with the addition of alkaline, and the EC was not reduced.

Keywords: pH-buffer, water treatment system, quartz porphyry, functional water

1. Introduction

Recently, nutriculture in greenhouses has been given attention for reducing labor, increasing efficiency, and creating higher quality. There are generally having some problems in nutriculture, such as the nutrient having a lower pH-buffer capacity compared with the soil, and it is not easy to maintain the nutrient on each plant growth term. Based on the protection of water quality, the development of innovative water circulation systems may contribute to the environmental protection, such as, nutrient and pathogenic fungus, etc., (Nakamura et al., 1997). In this study, a water treatment system, which may improve the function of water using an effectively negative charge of the silicate mineral (quartz porphyry), was constructed. This is to control the water environment on plant growth control in greenhouses, to investigate the mechanism of the colloid with charges in the water for function of pH-buffer action in the

nutrient.

2. Materials and methods

2.1 Mineral properties of tested quartz porphyry

The main chemical compositions of tested quartz porphyry are silica and aluminium oxide (Ishikawa et al., 1995). Feldspar was weathered accompanied with kaolinization, and part of the feldspar was changed into calcite. The structural materials are easy to ionize with the water contact. Fig. 1 shows a photograph taken by a scanning electron microscope of the particles, which passed through a 25×10^{-6} m sieve after crushing. They form microcrystalline, and part of them is microporous with a hole diameter of 100×10^{-10} m \sim $35,000 \times 10^{-10}$ m, and a hole number of about 83,000/cm².

2.2 Water treatment system

In order to enhance activities for a large quantity of water by using electrochemical energy, the water treatment system (HITEC-TYPE) shown in Fig. 2

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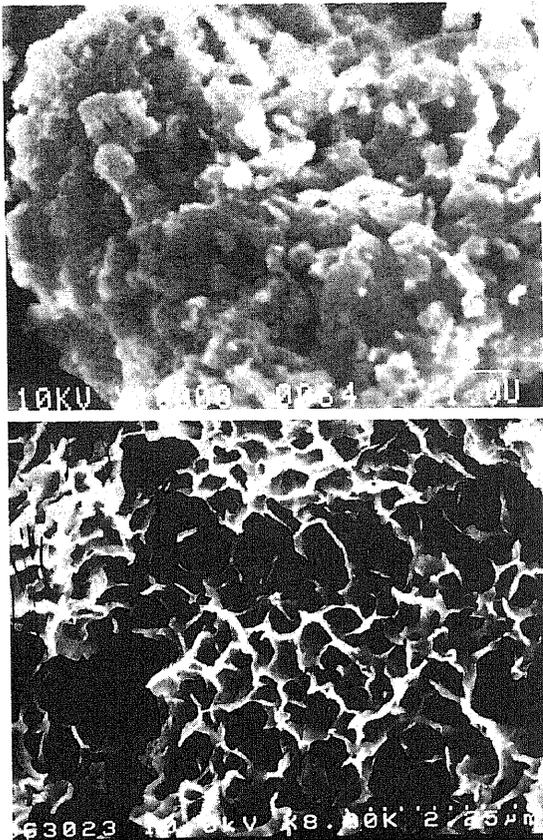


Fig. 1. Scanning electron microphotograph of powder particles

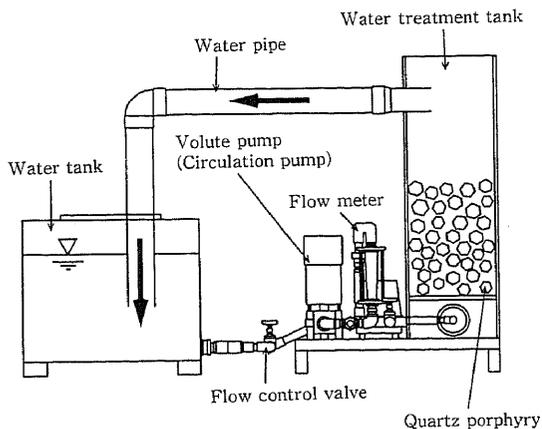


Fig. 2. Water treatment system (HITEC-TYPE)

was constructed as an experimental apparatus. This water treatment system can treat 200 liters of water. The way to treat the water is by pumping the water, thus allowing the water to pass through from the lower to the upper side in the water treatment tank, which contains quartz porphyry of 20 kg in weight. The flow rate can be controlled with a valve.

2.3 Quantitative analysis of water

In addition to hydrogen ion concentration (pH), electric conductivity (EC), for ion analysis of water, the spectrophoto method and atomic absorption flame emission methods were used. Also, the half-peak width of the spectrum by use of ^{15}O -Nuclear Magnetic Resonance Spectroscopy (AC-250 TYPE) was examined so that the change in the state of water was compared.

3. Results and Discussion

3.1 Immersion experiment

In order to reveal the pH-buffer action of the quartz phophyry immersed in water, the pH value of purified water was controlled to 4.0 and 10.0 with alkaline (NaOH) and acid (HCl). In this experiment, a quartz phophyry section and a zeolite section were provided. Each material (Table 1) of 100 g/dm^3 was placed into the pH controlled water, then the change of pH was examined at a constant water temperature condition of 25°C . It is obvious that at the controlled water of pH 10.0, the pH is 7.76 (after 12 hours), 7.62 (after 72 hours) for the zeolite section. The change of pH for the quartz porphyry section is remarkable and is 8.84 (after 4 hours), 7.28 (after 12 hours), and decreases to 7.09 after 48 hours. On the other hand, as for the controlled water of pH 4.0, the change of pH for the quartz porphyry section is slightly slower compared with that for the zeolite section. These phenomena are explained as follows. The end product of silicate minerals is $-\text{SiO}$ radical, which has ion combination, for acid water and for alkaline water

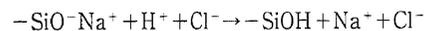


Table 1. Chemical properties

| | pH | | Exchangeable cation | | | | CEC (meq/100 g) | Degree of base saturation (%) |
|-----------------|--------------------|-------|---------------------|----------------|------------------|------------------|--------------------|-------------------------------------|
| | (H ₂ O) | (KCl) | (meq/100 g) | | | | | |
| | | | Na ⁺ | K ⁺ | Ca ²⁺ | Mg ²⁺ | | |
| Quartz porphyry | 6.1 | 4.5 | 0.06 | 0.13 | 1.10 | 0.28 | 2.37 | 66.2 |
| Zeolite | 8.3 | 6.4 | 64.35 | 28.92 | 48.71 | 3.70 | 105.90 | 137.6 |



The degree of base saturation of the zeolite is more than 100 %, and its pH is 8.3 (H₂O), 6.4 (KCl). This means that most cations compensating for the negative charge of the zeolite are the exchangeable cations such as Na⁺, K⁺, Ca²⁺ and Mg²⁺. On the other hand, the degree of base saturation of the quartz phophyry is 66.2 %, and its pH is 6.1(H₂O), 4.5 (KCl). As for the change of exchangeable cations (Table 2), Na⁺ and K⁺ ions increased, Ca²⁺ and Mg²⁺ ions decreased. Accordingly, it is suggested that the quartz phophyry has an additional negative charge (pH-dependent charge), and shows an ion exchange reaction which is similar to 1:1 type clay minerals, and the control of the charge on the pH of the surrounding solution can be accurately predicted.

Table 2. Change of exchangeable cations of quartz phophyry immersed in pH controlled water

| pH (-) | Na ⁺ (ppm) | K ⁺ (ppm) | Ca ²⁺ (ppm) | Mg ²⁺ (ppm) |
|-----------|--------------------------|-------------------------|---------------------------|---------------------------|
| 5.5 | 22.59 | 3.21 | 11.44 | 5.09 |
| 7.0 | 22.43 | 3.07 | 10.32 | 4.93 |
| 8.5 | 21.64 | 2.86 | 10.02 | 4.88 |
| Control | 21.56 | 2.46 | 12.43 | 5.78 |

3.2 Properties of water treated by a circulation treatment system

In order to investigate the activities of the circulation treated water, the tap water as raw water supplied to Miyazaki University was used. Table 3 shows the results of the analysis of the water treated at the flow rate of 0.045 m³/min. The dissolved ions

Table 3. Analysis of water treated by the circulation treatment system

| Section | Circulation time (min) | pH (-) | EC ($\mu\text{s}/\text{cm}$) | Na ⁺ | K ⁺ | Zn ²⁺ | Mn ²⁺ | Fe ²⁺ | Ca ²⁺ | Mg ²⁺ | NO ₃ ⁻ | PO ₄ ³⁻ | Cl ⁻ | Half-peak width (Hz) |
|---------|---------------------------|-----------|-----------------------------------|-----------------|----------------|------------------|------------------|------------------|------------------|------------------|------------------------------|-------------------------------|-----------------|-------------------------|
| A | 10 | 7.47 | 215 | 21.1 | 2.3 | 0.0 | 0.0 | 0.05 | 13.98 | 5.61 | 8.53 | 0.0 | 7.33 | 123 |
| | 20 | 7.64 | 216 | 21.2 | 2.3 | 0.0 | 0.0 | 0.06 | 13.95 | 5.52 | 5.80 | 0.0 | 7.34 | 114 |
| | 30 | 7.76 | 217 | 21.2 | 2.3 | 0.0 | 0.0 | 0.05 | 14.08 | 5.50 | 6.21 | 0.0 | 7.38 | 115 |
| | 40 | 7.81 | 217 | 21.1 | 2.2 | 0.0 | 0.0 | 0.07 | 14.17 | 5.49 | 8.38 | 0.0 | 7.35 | 111 |
| | 50 | 7.88 | 217 | 21.2 | 2.2 | 0.0 | 0.0 | 0.08 | 14.13 | 5.53 | 8.64 | 0.0 | 7.33 | 107 |
| | 60 | 7.89 | 217 | 21.1 | 2.2 | 0.0 | 0.0 | 0.07 | 14.27 | 5.51 | 7.74 | 0.0 | 7.31 | 104 |
| | Control | | 7.32 | 215 | 21.1 | 2.3 | 0.0 | 0.0 | 0.05 | 13.73 | 5.57 | 5.31 | 0.0 | 7.41 |
| B | 10 | 7.53 | 197 | 20.9 | 2.3 | 0.0 | 0.0 | 0.05 | 14.78 | 5.50 | 9.00 | 0.0 | 6.20 | 134 |
| | 20 | 7.79 | 199 | 21.1 | 2.3 | 0.0 | 0.0 | 0.06 | 14.96 | 5.50 | 7.97 | 0.0 | 6.18 | 119 |
| | 30 | 8.00 | 198 | 21.4 | 2.3 | 0.0 | 0.0 | 0.05 | 15.34 | 5.60 | 8.32 | 0.0 | 6.19 | 123 |
| | 40 | 8.06 | 197 | 21.5 | 2.3 | 0.0 | 0.0 | 0.05 | 15.10 | 5.50 | 9.08 | 0.0 | 6.21 | 119 |
| | 50 | 8.11 | 197 | 21.7 | 2.3 | 0.0 | 0.0 | 0.07 | 15.09 | 5.42 | 8.44 | 0.0 | 6.19 | 106 |
| | 60 | 8.19 | 198 | 21.8 | 2.3 | 0.0 | 0.0 | 0.06 | 15.15 | 5.47 | 7.52 | 0.0 | 6.19 | 106 |
| | Control | | 7.12 | 199 | 20.7 | 2.4 | 0.0 | 0.0 | 0.06 | 14.74 | 5.59 | 9.00 | 0.0 | 6.19 |

water temp.: 25°C

were changed slightly, especially the cation decreased, and the anion increased in spring (Section A). On the other hand, the results in summer (Section B) showed a reverse tendency as compared with that in spring. The pH increased to 7.9~8.2 at 60 minutes treatment when the pH of raw water was 7.1~7.3. The EC was not changed, but the half-peak width decreased gradually with the increase of circulation time. Therefore, it is suggested that the movement of water will be activated by this circulation treatment. The pH-buffer action of the nutrient (Ohtuka House A Prescription, 3/4 N) in the circulation treatment system was discussed. In this experiment, acid (1 N- H_2SO_4) and alkaline (1 N- NaOH) were used for pH control, and a quartz porphyry treatment section and a control section (not charged with quartz porphyry in the system) were provided. For each section, the nutrient (200 l, initial value; pH 6.23, EC 2.23 ms/cm) was always circulated, and as much as 50 ml acid or alkaline was added every 24 hours. It is clear that the pH of nutrient is rapidly decreased with the addition of acid at pH 6.0 or less, but for the quartz porphyry treatment section, the pH-buffer action worked and the pH increased with an addition of acid, even at pH 4.0. The change in EC with the addition of acid was small for both sections. Fig. 3 shows the result for the addition of alkaline. When the pH was more

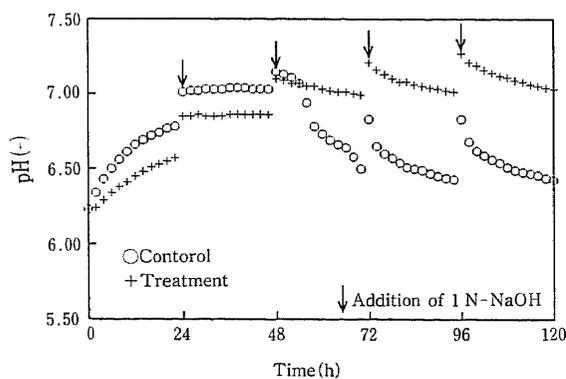


Fig. 3. Change of nutrient pH

than 7.0 with the addition of alkaline, the nutrient became cloudy, and insoluble salts were generated in the control section. On the other hand, the pH of nutrient was not rapidly changed for the quartz porphyry treatment section, and was maintained in a stable condition at about 7.0 even with the addition of 200 ml alkaline. The EC was not reduced with the addition of alkaline for the quartz porphyry treatment section. However, it was reduced for the control section because of the reduced salt solubility and the disruption in the nutrient components (Fig. 4). Additional experiments should be performed on several concentrations of the nutrient.

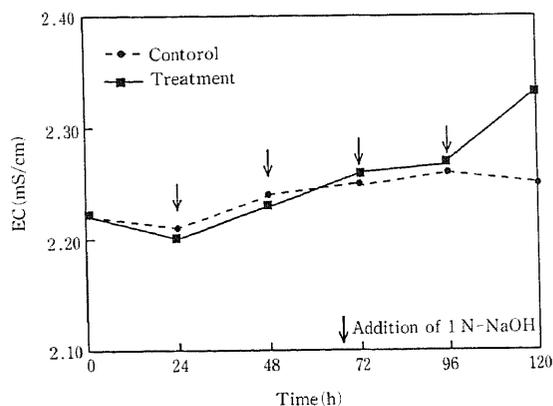


Fig. 4. Change of nutrient EC

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グリーンハウス内における水の機能化処理システム*

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要 旨

培養液の pH は植物の生育や培養液の組成変化に影響を及ぼすことから、養液栽培の安定性にとって大きな意味をもつが、培養液 pH の調節は容易ではない。そこで本研究では、培養液自体に pH 緩衝能を付与するため鉱物の有する陰荷電に着目し、pH 緩衝能やイオン交換反応が期待できる石英斑岩の特性に基づき、効率的な水処理システム (HITEC-型と称す) について検討した。その結果、アルカリの添加に対しても培養液 pH の急激な変化は見られず、ほぼ pH=7 で安定した。また EC の減少も認められなかった。

キーワード：pH 緩衝能，水処理システム，石英斑岩，機能水