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Filtering capacity of *Daphnia magna* on sludge particles in treated wastewater

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ARTICLE INFO

Article history:
Received 31 May 2012
Received in revised form
13 September 2012
Accepted 25 September 2012
Available online 4 October 2012

Keywords:
Biotreatment
Daphnia magna
Wastewater reuse
Particle concentration

ABSTRACT

A great challenge in water reuse is the reduction of suspended particle concentration in wastewater. In particular the reduction of the presence of small particles in suspension which cause a cloudy appearance in the water and, which also make disinfection difficult. The present study evaluates the filtering capacity of a population of Cladodera (*Daphnia magna*) in secondary effluents from a wastewater plant. The study was performed in both a mesocosm and the laboratory, in an effort to compare the grazing on sludge particles by *Daphnia* versus the settling rate of those sludge particles. The particle volume concentration of small particles (with a diameter below 30 μm) was used to evaluate the efficiency of the proposed biotreatment system for small particles. Both laboratory and mesocosm results showed that the suspended particle volume concentration decreased with time due to the *Daphnia* filtration, with the highest reduction in experiments carried out with the highest *Daphnia* concentration. In the mesocosm experiments, the *Daphnia* diameter was also found to play an important role, with an allometric relationship between the filtering rate of *Daphnia* and the *Daphnia* nondimensional diameter. In laboratory experiments, the effect of *D. magna* in the suspended concentration of small particles was in the range of 10.1–29.4%, according to the range of *Daphnia* concentration of 10–50 ind/l. For laboratory experiments, sedimentation was responsible for 62.2% of the suspended particle concentration reduction. For the mesocosm experiments, the reduction in the particle concentration attributed to the *Daphnia* filtration ranged between 2.5 and 39%, corresponding to *Daphnia* concentrations of between 5 and 100 ind/l (i.e. biovolumes of 8–60 ind/l).

1. Introduction

Wastewater reuse that preserves limited water resources is an important concern, especially in water deprived areas and also in the face of future scenarios that predict less available water due to climate change. Reclaimed wastewater is a reliable, drought-proof source for the supply of sub-potable water requirements such as irrigation, urban cleaning, toilet flushing and recreational park streams, among others.

While large particles are easily removed from wastewater via settling tanks or filtering techniques, small particles have a settling velocity too small to allow them to be trapped in sedimentation basins and they are also too small to be retained by filtering methods, thus becoming the most

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0043-1354/$ – see front matter
http://dx.doi.org/10.1016/j.watres.2012.09.047

difficult particles to remove from wastewater. Technologies based on biofiltration and precoagulation have been evaluated with the purpose to obtain an easy and low cost maintenance of the wastewater cleaning process (Hidaka et al., 2003). The methods for evaluation are based on the particle analysis, whether it is the particle content, concentration or size distribution (García-Mesa et al., 2010). Particle content in wastewaters is an important parameter for the evaluation of chemical, physical and biological treatments (Marquet et al., 2007). The presence of small particles in suspension results in an undesirable cloudy appearance of the wastewater. Furthermore, the disinfection of this low quality water becomes difficult or impossible. Wu et al. (2009) studied the relationship between the particle size distribution and suspended solids, turbidity and microorganisms and they proposed the continuous analysis of the particle size distribution to evaluate the water quality of the effluent. García-Mesa et al. (2010) characterized the water quality of different wastewater treatments by means of the analysis of the particle size distribution. Based on the reduction in the particle concentration for different particle sizes they were able to analyze the performance of three biofilm technologies. Therefore, in the removal of small suspended particles new methods with not only a low maintenance cost but also a low environmental impact are of great interest.

Cladocera are invertebrate mesozooplanktonic populations that are well known for preying on a large variety of organisms of different sizes. Burns (1968) found a maximum particle ingestible of 35 μm for a population of *Daphnia pulex* and that the *Daphnia* filtering rate decreased as the prey concentration decreased. DeMott (1982) showed that *Daphnia* ingest particles in the size range of 0.5–40 μm and in proportion to the abundance of the available food. Arruda et al. (1983) and Gliwicz (1990) demonstrated that Cladocera ingest inorganic particles when their size overlaps with the sizes of the organic particles usually ingested by these organisms. Moreover, Burns (1969) found that the filtering rate of *Daphnia* was proportional to their body length and also depended on temperature, with the optimum value being 20 °C, this result is also in agreement with Giebelhausen and Lampert (2001) and Schalau et al. (2008). Several studies (Berger et al., 2007; Straile, 2000, 2002) demonstrated the important role of *Daphnia* in the clear water phase in lakes. These studies also found a phytoplankton spring bloom followed by a growth in the *Daphnia* population that grazed on phytoplankton, which declined thereafter to its minimum value. In their study, Berger et al. (2007) also demonstrated that *Daphnia* started to grow earlier in warmer environments than in cold environments. Therefore, temperature and food seem to be the key factors in the sustainability of Cladocera. As illustrated by Shiny et al. (2005) from laboratory experiments, filter feeders (both invertebrates and vertebrates) are promising organisms in the area of water disinfection, and inactivation of *E. coli* in wastewater. Myrand and Noüe (1983), in laboratory studies, demonstrated the filtration capacity of *Daphnia magna* on phytoplankton produced in wastewater ponds. In laboratory experiments, Tredici et al. (1992) found a reduction in both nitrogen and phosphorous concentrations from wastewater due to the growth of a microalgae population, which controlled the microalgae production by a *D. magna* population inoculated into the algae suspension. Therefore, the filtration capability of Cladocera is an important feature to be explored as a potential wastewater treatment. The idea of using an ecological system for engineering purposes is in accordance with the integration of ecology and engineering formulated by Mitsch (1998). Other ecological systems, such as stabilization ponds. Huang et al. (2000) have also been used for wastewater treatment in order to reduce sewage discharge into rivers. In developing subtropical countries sewage-fed aquaculture is used to provide both a source of nutrients for fishes and to combate environmental pollution (Jana, 1998; Yan and Wang, 1998).

For this purpose, in the present study, the filtration of wastewater by an invertebrate population of Cladocera (*D. magna*) will be analyzed with the purpose to test its feasibility in the improvement of the quality of treated wastewater. Both mesocosm and laboratory experiments will be carried out with different *D. magna* concentrations. The *Daphnia* biotreatment is studied as a potential wastewater tertiary treatment in order to obtain a high wastewater quality defined by a low concentration of small particles.

2. Materials and methods

2.1. Laboratory set up and methods

Laboratory experiments were carried out in four cylindrical containers, each with a height of 45 cm and a diameter of 14.5 cm. These were filled with 7.5 l of wastewater and, with a magnetic stirrer situated at the bottom, constantly stirred at a minimum speed in order to minimize particles settling and also in order to generate a uniform mixture. Different *D. magna* concentrations ($C_{Dph} = 0$, 10, 25 and 50 ind/l) were used in each container. These values were selected in accordance to the range of *Daphnia* concentration in the mesocosm study ($C_{Dph} = 0$–100 ind/l). Water from the secondary effluent of the Empuriabrava wastewater plant was introduced into each container together with a determined *Daphnia* concentration, and they were left to evolve over a 24 h period, after which the steady state was reached. Samples from each container were taken at different times and analyzed with a particle size analyzer (Lisst 100) to determine the evolution in the suspended particle concentration. The Lisst-100 (Sequoia Inc.) has a measurable particle diameter range of 2.5–500 μm and has been found to show good performance in determining particle size distribution and concentration for both organic (Serra et al., 2001) and inorganic particles (Serra et al., 2002a, b) in water suspension. The particle concentration in a desired particle size range was calculated by integrating the concentration of particles within the range. After being analyzed, samples were gently introduced back into the container to maintain the total volume of water constant.

2.2. Mesocosm set up and methods

The mesocosm was installed in the wastewater treatment plant in Empuriabrava, NE Spain. The wastewater treatment plant in Empuriabrava has a mean flow of 1500 m^3/day in winter and 8000 m^3/day in summer. This increase in summer