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Rheology and flow characteristic of urban untreated sewage for cooling and heating source

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ABSTRACT

Urban untreated sewage is a kind of excellent cooling and heating source. The rheology and flow characteristic of sewage is the basis of the application of sewage cooling and heating source system. They are studied based on the theoretical assumption of single flow model, principle of tube-type rheometer, and field experiments. The rheological basic equations and flow characteristic of urban untreated sewage are developed. The results of research indicate that sewage has the characteristic of non-Newtonian power-law. The rheological basic equation is $\tau = 0.0031\dot{\gamma}^{0.92}$. The distance coefficient of drag in turbulence of sewage in circle pipe is $\lambda_t = 0.186(\mathrm{Re}')^{-0.208}$. The equations of velocity distribution of sewage are, respectively, $v^+ = 2.5\ln y^+ + 5.7$, $v^+ = 5.11\ln y^+ - 3.22$, and $v^+ = y^+$ in turbulence, intermediate, and laminar current zone in circle pipe. Those can be used to instruct engineering application, design, analysis, and farther research of the system.

1. Introduction

Urban untreated sewage (UUS) refers to original sewage in municipal drainage trunk canal without any physical and chemical treatment. Its temperature is appropriate both in summer and in winter, and its flow is huge. Moreover, it distributes widely in every district of city. In winter, urban sewage can be used as a heat source, and its inclusive low-grade heat is converted to high-grade heat supplied to the end users by the heat pump systems with an electrically driven compressor. In summer, UUS source heat pump systems use urban sewage as a cooling source and supply cold water to the end users by an electrically driven compressor [1–4]. The development of urban sewage cooling and heating source is one of the effective measures to save energy and reduce emission [5,6].

Calculation and analysis of rheology and flow characteristic of UUS are basis of the design, running, and regulation of UUS cooling and heating source systems. But because UUS contains a large number of garbage and waste, there are not reliable means for calculation of rheology and flow characteristic of UUS presently [7]. The formulae Chezy and Manning are used to hydraulic design of channel flow of UUS in municipal engineering broadly [8]. It is founded that the results of calculation of formulae Chezy and Manning are not suited to flow in circle pipes by measurement of engineering field [7]. And these are the main bafflement of promotion and application of UUS cooling and heating source systems. In this paper, the rheology and flow characteristic of UUS was studied by theoretical analysis and experiment in engineering field. The basic equation of rheology and calculation equations of flow resistance were developed in circle pipe for engineering application. These will provide references for the development and utilization of UUS cooling and heating source systems.

2. Experiment system

UUS heat exchangers are almost shell and tube exchangers because of the unsatisfactory water quality. Heat exchange pipes are the basic units of the shell and tube exchangers. The processes of heat transfer and flow of UUS are completed in heat exchange pipes. In addition, because of convenience of regulation and testing of experiments, the flow of UUS in heat exchange pipes is chosen as experimental object. Principles of experimental system are shown in Fig. 1.

This experimental system is built in fine grid workshop of Harbin Sewage Treatment Plant for the sameness of conditions of experiment and practical engineering. Its sewage load is 200,000 t/day. The temperature of the sewage is about 13 °C. Its density is 1011.06 kg/m^3. Its specific heat at constant pressure and coefficient of heat conductivity are 4.19 kJ/(kg K) and 0.58 W/(mK), respectively [7]. And its pH value is about 7.3. Fig. 1 is

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