Verification of Wegelin's design criteria for horizontal flow roughing filters (HRFs) with alternative filter material

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Abstract

Wegelin's design criteria founded on the "1/3 – 2/3" filter theory are still to date the most comprehensive models applied in design of roughing filters. This study aimed at verifying these criteria based on gravel as a filter medium and two other possible alternative filter media, namely broken burnt bricks and charcoal maize cobs. Gravel was used as a control medium since it is one of the most commonly used roughing filter media and also because it was used in developing these criteria. The per cent reduction in raw water suspended solids (SS) concentration was compared against the expected model prediction. SS was used as a parameter of choice since the "1/3 – 2/3" filter theory is based on SS reduction. A pilot plant study was undertaken to meet this objective. The pilot plant was monitored for a continuous 85 days from commissioning till the end of the project. Results showed that in general, filters filled with charcoal maize cobs and broken burnt bricks were off model prediction by 13% compared to gravel's 15%. The performances also varied in both low- and high-peak periods. It is concluded that the Wegelin's design criteria should be used as a guideline step followed by actual field and laboratory tests to establish the actual filter design parameters in line with the filter media in use and the quality of the raw water to be treated.

Keywords: Wegelin's design criteria, horizontal flow roughing filtration

Introduction

Hydraulic design of water treatment/filtration plants is mostly based on the various filtration theories that subscribe to the contemporary accepted scientific paradigms. Many of these are developed in laboratories and field studies at different locations with different conditions from where the actual implementation takes place. More often, the extension or implementation of such scientific theories or appropriate technologies is done in a blanket manner. In some instances, this process has led to failure in replication of the expected performance of the respective technology or scientific theory. For instance, Michele and Johannes (2004) in their study to investigate the possible reasons for excessive media losses during backwashing in a number of water treatment plants in South Africa, highlighted certain flaws in the common practices with respect to design of water filtration plants. In this study, they found compelling evidence that design procedures based on oven-dried laboratory samples underestimate the expansion of the bed after it has been in service for a number of months or years. In this regard, they further suggested the application of correction factors in the Dharmarajah and Cleasby model (the most comprehensive to date) to allow for more expansion during eventual plant operation. Given that the structural design of water treatment/filtration plants largely depend on the ensuing hydraulic design, it is thus prudent on the designers and engineers in this field to undertake some validation exercise on the theories (models) before full-scale implementation is carried out. This is important to avoid costly and wasteful utilisation of the available resources.

The application of appropriate technology in the provision of potable drinking water to the rural community needs a proper examination of the underlying principles given the crucial need for its success and sustainability. In most instances though, this exercise is undertaken through duplication of success stories from other regions or in cases where pilot-plant studies are undertaken, insufficient time is given for the development of adequate features and parameters for the adoption of such projects needs.

Use of appropriate technologies such as multistage filtration (MSF), a combination of pretreatment system (e.g. roughing filters) and slow sand filtration (SSF) in provision of potable drinking water to the rural community is being encouraged (WHO, 2004; Ochieng' et al., 2004). This is so given the success shown by such systems over the years in many countries, e.g. Rwanda (Clarke et al., 2004), Ethiopia (Mesfin, 1999), Sri Lanka (Jayalath and Padmasiri, 1996) among many others.

The horizontal flow roughing filter (HRF) is commonly applied with SSF especially in the developing countries (e.g. Jayalath and Padmasiri, 1996; Mesfin, 1999; Torabian and Fazeli, 2004). To date, the most comprehensive model applied in HRF design is based on Wegelin design criteria founded on the "1/3 – 2/3" filter theory (Wegelin, 1986; 1996).

The "1/3 – 2/3" filter theory

The "1/3 – 2/3" filter theory as described by Wegelin (1986, 1996) is a conceptual filter theory. The literature and principles behind the theory are quite elaborate and it would therefore suffice only to mention the salient points to enhance the reader's understanding of the proceedings hereafter (for in-depth documentation on this theory, refer to Wegelin, 1986; 1996 and the references therein).

By logic and experience, a particle in water can bypass a gravel grain (filter-medium grain) either on the left or on the right or settle on its surface. Hence the chance to fall on the grain (success of removal) is 1/3 and 2/3 chance of failure of removal. However, the process continues as there is a second, third and

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