Technical note

Class frequency distribution for a surface raw water quality index in the Vaal Basin

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ABSTRACT

A harmonised in-stream water quality guideline was constructed to develop a water quality index for the Upper and Middle Vaal Water Management Areas, in the Vaal basin of South Africa. The study area consisted of 12 water quality monitoring points; V1, S1, B1, S4, K9, T1, R2, L1, V7, V9, V12, and V17. These points are part of a Water Board's extensive catchment monitoring network but were re-labelled for this paper. The harmonised guideline was made up of 5 classes for NH_4^+, Cl^-, EC, DO, pH, F^-, NO_3^-, PO_4^{3-} and SO_4^{2-} against in-stream water quality objectives for ideal catchment background limits. Ideal catchment background values for Vaal Dam sub-catchment represented Class 1 (best quality water), while those for Vaal Barrage, Blesbok/Suikerbosrand Rivers and Klip River represented Classes 2, 3 and 4, respectively. Values above those of Klip River ideal catchment background represented Class 5. For each monitoring point, secondary raw data for the 9 parameters were cubic-interpolated to 2 526 days from 1 January 2003 to 30 November 2009 (7 years). The IF-THEN-ELSE function then sub-classified the data from 1 to 5 while the daily index was calculated as a median of that day's sub-classes. Histograms were constructed in order to distribute the indices among the 5 classes of the harmonised guideline. Points V1 and S1 were ranked as best quality water (Class 1), with percentage class frequencies of 91% and 60%, respectively. L1 ranked Class 3 (34%) while V7 (54%), V9 (53%), V12 (66%) and V17 (46%) ranked poorly as Class 4. B1 (76%), S4 (53%), K9 (41%), T1 (53%) and R2 (61%) ranked as worst quality (Class 5). The harmonised in-stream water quality guideline resulted in class frequency distributions. The surface raw water quality index system managed to compare quality variation among the 12 points which were located in different sub-catchments of the study area. These results provided a basis to trade pollution among upstream-downstream users, over a timeframe of 7 years. Models could consequently be developed to reflect, for example, quality-sensitive differential tariffs, among other index uses. The indices could also be incorporated into potable water treatment cost models in order for the costs to reflect raw water quality variability.

Keywords: class frequency distribution; cubic interpolation; harmonised in-stream water quality guideline; ideal catchment background; Vaal basin; water quality index

INTRODUCTION

Understanding complex systems involves constructing models, comparing their predictions with observations and improving them by using feedback mechanisms from continuous assessments (Even et al., 2007). For water quality management purposes, assessments are done based on the prevailing guidelines. This approach assumes that proper identification of contamination sources for individual parameters that are assessed can be done to provide a basis for environmental and legal compliance. However, the approach does not readily offer a holistic view of the spatial and temporal trends in water quality expressed in a single value, especially for catchments that are perturbed by various pollutant types. More importantly, options for restoring heavily degraded catchments are limited, hence assessment tools that are supported by robust water quality data should be continuously developed (Bohensky, 2008).

Limitations, though, exist where compliance with water quality objectives proves to be prohibitively expensive or technically impossible (Mey and van Niekerk, 2009). Further, even in catchments where data are aligned with specific sampling objectives, data for a required parameter, for example, might be unavailable, rendering the dataset inadequate for use with a specific water quality index (WQI). Yet indices are expected to provide simplified interpretation of results since in their various forms they summarise, in one value or concept, a series of parameters (Abrahão et al., 2007; Couillard and Lefebvre, 1985; DWAF, 1996). This is desirable, especially in cases where decisions require interpretation of the severity or extent of pollution impacts.

An index can be limited if it requires data of longer duration than is available (most models are done with retrospective data). In addition, a model can predefine its input parameters or even the number of input parameters, both of which might not be available. Further, if a model requires a subjective constant that relates to a particular water body at a specific time of sampling, but which was not captured then, it renders the historical dataset inadequate for use with that model (Abrahão et al., 2007; Pesce and Wunderlin, 2000). Thus many indices have been developed since the first index was suggested by Horton (1965), to try to satisfy various conditions within ecological system boundaries, which constantly shift in time and space. As at 1985 more than 100 scientists had already developed indices for specific water-related settings (Couillard and Lefebvre, 1985). Some of the indices were based on statistical or planning approaches while others represented trophic states of

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