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A global assessment of the temporal and spatial variability of national dilution factors

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1. Introduction

A continuing preoccupation in many countries is the degree of exposure of their surface waters to chemicals used daily by the human population, and which are disposed down the drain. Dilution capacity in the river is of primary importance when estimating risk caused by “down-the-drain” chemicals. However, for modeling purposes a generic dilution factor (DF) can be applied. Actual DFs, which vary temporally and spatially with factors such as river flow, population density and domestic water use, can be estimated on a global scale using a more sophisticated approach based on easily available gridded data sets. The present study develops further the approach developed by Keller *et al.*^[1] and quantifies the temporal and spatial variability of DFs within countries.

2. Materials and methods

2.1. Concept

The methodology was specifically developed to be applied across the world even within those countries where river flow data and/or wastewater effluent data is scarce. The DF is defined as the ratio between river flow Q_r ($\text{m}^3 \text{s}^{-1}$) and total domestic wastewater effluent Q_{ww} generated within a catchment. The river flow was derived from global scale runoff R (mm yr^{-1}) estimates (gridded data) whereas the wastewater effluent was obtained by combining population P (cap) estimates (gridded data) and per capita domestic water use W ($\text{m}^3 \text{cap}^{-1} \text{yr}^{-1}$) estimates (national estimates). Using gridded data, for any grid cell i the dilution factor is defined as:

$$DF_i = Q_r / Q_{\text{ww}} = (\sum R_j A_j)_{j=1,i} / (\sum W_j P_j)_{j=1,i}$$

Where A is the area of the grid cell, and j is an index for all cells contributing to the definition of the catchment upstream of cell i .

2.2. Data

There are many macro-scale models available to predict long term annual flows. Within this study, the 0.5° resolution annual and monthly composite runoff fields produced by Fekete *et al.*^[2] were used. These runoff values were estimated across the globe by combining a simple water balance model and observed river discharge data. The runoff is accumulated using a topographically-derived flow direction grid to produce river flows (Q_r) at a 0.5° resolution. Population estimates were based on the GPW (Gridded population of the world) v.3 data set for 2005^[3] at 0.5° resolution. Four main data sources for national per capita domestic water use were used: Gleick^[4], FAO^[5], WRI^[6], and OECD^[7]. However, the different data sources often quoted different values for the same countries. Where discrepancies arose, only the data for the year 2000 or later was retained, and from these the lowest estimate was selected to provide a more conservative value for the DF. These selected national estimates were then used to derive a 0.5° resolution grid of domestic water use.

3. Results and discussion

The spatial variability of the DF within a country was assessed by generating the median value and the 25th and 75th percentile for those cells where there was a river flow. *Fig 1* shows some selected DF variability across the globe, for example Finland has a median annual DF almost 1000 times higher than Tunisia (respectively 1700 and 1.9). The dilution factor often varied significantly within a country for example in the UK the 25th, 50th and 75th percentile were estimated to be respectively 6, 37 and 186. The seasonal variability in dilution was assessed by looking at the monthly values of a given statistic such as the median. These temporal variations are also significant, as is shown in *Fig 2*: in Egypt there is a factor 30 between the minimum DF in February and the maximum in August (respectively 9 and 377).

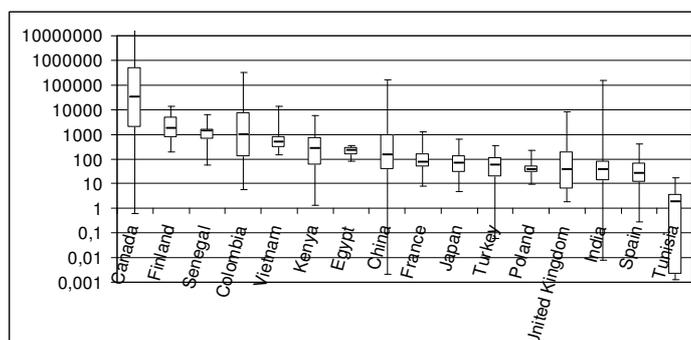


Figure 1: Whisker plot of annual dilution factors from selected countries.

As no temporal variation in population and water use were considered, the monthly variations of the DF mainly reflected the monthly flow variations.

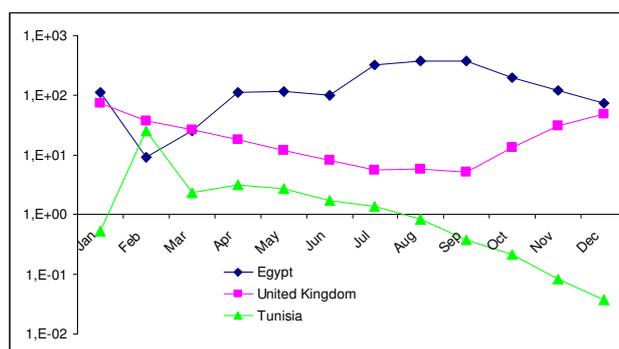


Figure 2: Monthly variability of the dilution factor for some selected countries

For some countries the temporal variation can be as important as the spatial variation. Such is the case for Canada where the median DF is about 37 in March and 47000 in July, and the annual 25th and 75th percentile are respectively 350 and 162000.

4. Conclusions

This exercise has demonstrated just how dramatically different one nation's surface water exposure to a chemical could be from another. The estimates presented here are a crude representation of the local conditions but will help identify i) geographical regions at higher risk and ii) the influence of seasonal flow variation, to refine estimates using adapted tools. The method could be further improved by accounting for local connectivity rates to sewage treatment plants.

5. References

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