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Trend methods for the assessment of effectiveness of reduction measures in the water system.

PD Dr. habil. Steffen Uhlig and Prof. Dr. Peter Kuhbier

Institut für Statistik und Ökonometrie
Freie Universität Berlin

Abridged Version

In order to prevent the detectability of temporal trends in annual loads getting worse as a result of fluctuations in the runoff quantity, an adjustment converting the input data into a "mean" (long-term) runoff level is indispensable. It may be noted here that not only trend sensitivity is adversely affected but that meteorological cycles may also cause fluctuations in the runoff quantity which in turn induces artificial trends in the load values, these being even observable where no anthropogenic trends exist. Therefore especially with short series, one has to reckon with statistical trend tests exceeding the given significance level in a manner that is inadmissible.

Subject of the research project is therefore a method for the adjustment and trend analysis of these input data. Adjustment takes place on the basis of raw data in accordance with the figure below. The adjusted loads shall then be compiled into annual loads before trend analysis is undertaken on the basis of the adjusted annual loads. Finally the trend sensitivity of the method shall be examined within the scope of a power analysis, examining for trend sensitivity is particularly significant where no trend could be ascertained.

The use of annual values rather than individual values has the disadvantage of a theoretically lower level of efficiency (power) for estimating and identifying a trend. This is balanced out by the advantage of simpler handling and a simpler statistical method. It may be noted that an automatic process is necessary in view of the large number of data sets to be evaluated, so that an individual adjustment of a complex

time-series analytical model does not appear feasible for trend analysis while examining sets of measurements recorded on a monthly or fortnightly basis, a consideration of autocorrelation proves to be absolutely essential, thereby rendering a complex individual time-series analysis indispensable.

Conceptual Approach for Adjustment and Trend Analysis

1. Provision of raw data

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2. Adjustment of loads

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3. Aggregation of the adjusted loads

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4. Trend detection and assessment

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5. Power analysis

Before undertaking the actual adjustment of the loads, the question that first needs to be addressed is how the requisite CQ function (concentration – runoff function) or the corresponding LQ function (load-runoff function) is to be fixed. A monotonic correlation between runoff and load applies for many parameters, and there is nothing that negates the assumption that the LQ relation (load-runoff relation) is linear in its first approximation, and going hand in hand with this is the assumption that the CQ function (concentration-runoff relation) in first approximation can be described through a linear function of the reciprocal value of the runoff (I/Q).

This linear relation between runoff and load constitutes the basis of the statistical methods listed in the following, these methods differing from each other with regard to the inclusion of other influence variables and in the treatment of seasonality:

- Stalnacke's Method of Non-Parametric Smoothing (Method N)
- Hebbel's Method of Estimation (Method H)
- Local Regression with Season (Method L1)
- Local Regression with Season and Lagged Runoff Effect (Method L2)
- Local Regression with Temperature and Lagged Runoff Effect (Method L3)
- Local Regression with Season, Temperature and Lagged Runoff Effect (Method L4)

The following methods take into account non-linear relations between runoff and load:

- Estimation Using Static Splines (Method S1)
- Estimation Using Dynamic Splines (Method S2)

The results according to these methods were compared with the calculation for real and normalized annual loads using the TRANSPOS program (method BC), and with the standardization of the OSPAR Load to the Long-Term Mean Runoff (method A0).

These adjustment methods were tested at seven parameters (NO_3-N, NH_4-N, P_{total}, PO_4-P, Cd, Pb and suspended matter) measured biweekly in the Rhine River (Lobith) and monthly in the Ems River (Herbrum). For the Rhine River, the use of adjusted loads instead of the OSPAR load increases trend detectability considerably for nitrate, P_{total} and suspended matter, whereas for the other substances only small differences can be observed. Using concentration mean values reduces the power substantially. For the Ems River the use of adjusted loads or concentration mean values instead of the OSPAR load increases trend detectability for all nutrients.

The investigations confirm the applicability of the adjustment concept. However, there is no single adjustment method which might be used for all substances and all rivers and locations. Therefore each substance should be considered separately.

When considering nutrients in riverine inputs, if the input is approximately linearly related to flow, adjustment method L1 is recommended to be used on a trial basis. Method L1 appears to be routinely applicable to many data sets, and insensitive to statistical assumptions. For „difficult“ parameters with extreme data values and very large variability an adjustment based on a specifically adapted model might be more appropriate.

When considering heavy metals in rivers, method L1 partially failed. This might be due to problems related to values less than the detection limit and to changes of the analytical method within the time series, so that no final conclusion can be drawn from the investigations performed so far. Further investigations using other time series from other rivers are necessary to assess the potential of adjustment of heavy metal inputs. It should also be examined whether an adjustment with regard to suspended matter would be appropriate.

Generally a trend analysis should be performed only if the time series covers at least seven years. This holds not only for a trend analysis based on adjusted inputs, but also for a trend analysis based on the unadjusted OSPAR load. Otherwise virtual trends induced by meteorological cycles may become dominant.

Annual adjusted riverine inputs should only be used for the detection of trends in these inputs. For the determination of the actual annual riverine inputs the current OSPAR procedure might be used, although considerably estimation errors might appear especially in case of strong seasonality. Revision of the OSPAR procedure taking into account the CQ function and the daily runoff is therefore recommended.