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Hydrology and Earth System Sciences Discussions

Interactive comment on "Importance of stream temperature to climate change impact on water quality" *by* A. Ducharne

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General Comments

This paper covers a predictive assessment of the impact of climate change on the run-off/discharge as well as the water temperature at selected pairs of air/water monitoring stations, and the relationship of these inputs on water quality output obtained via the model RIVERSTRAHLER, exemplified within the River Seine Basin, France, and due to polluting point source discharges as they existed in 1991, and as predicted for 2050. Based on these remarks I propose to rename the title of the paper as follows: "*Predicted impact of climate change induced discharges and stream temperature on water quality under differently polluting emissions*".

The paper is well structured and in principle well discussed. Its novelty is the type of "integrated approach" as presented above, based on modelling procedures already in use or as shown in this paper. A. Ducharne is aware of the fact that the method derived for the prediction of water temperature fits within the context of the River Seine Basin (particularly starting with Paris and downstream), but differing results may emerge if the underlying statistically derived approach is applied in differently structured river basins. I subscribe to the view that basin shapes, the slopes of the river network and thus the speed of flow, as well as the sequences of river orders along the main rivers may influence respective outcomes.

The existing polluting discharges downstream of Paris and upstream of Conflans are since 2007 lower compared with the ones underlying the modelling work (in A. Ducharne et al., 2007) for 1991 in the frame of the PIREN-Seine Programme, see e.g. the web-pages of SIAAP (Syndicat Interdépartemental pour l'Assainissement de l'Agglomération Parisienne), http://www.siaap.fr/. Valid for the date of 2007/12/07 – with values averaged over all days of the year 2007 for all plants of SIAAP – "full carbon removal" (in the sense that the quickly biodegradable carbon is removed) is installed, and efficiencies for nitrification and the removal of total phosphorus amount to $\sim$ 75%. For the treatment plant Paris-Achères (Seine Aval) downstream of Paris – treating $\sim$ 75% of the wastewater of all plants of SIAAP – the respective values are 72% for P-removal and 63% for nitrification. One has to be aware of, however, that these values are still substantially larger than the ones anticipated for the year 2050 in the underlying simulation work (A. Ducharne et al., 2007).

The in-stream parameters used (inter alia for describing "water quality") are flow and water temperature, plus chlorophyll-a, dissolved oxygen, phosphate and ammonium; silica is unfortunately missing, if available to be added in Fig. 2. The monitoring results presented are based on a calibration (see Fig. 2). The results predicted for 2050 are presented in the Figs. 8 and 9 (silica is contained, phosphate is missing). Fig. 7 presents the predicted change in discharge and water temperature, based on underly-

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ing climate change scenarios for the year 2050. An independent verification run of the modelling approach is not presented. I am aware of the fact that the missing link to this is the period of time needed (at least one year, if not more) until new circumstances – as mentioned before – have allowed the assessment of data that can be used for a verification run. In regard to this aspect I am eagerly waiting until Mme. Ducharne will inform us anew what has been achieved in the years after the work for this paper was undertaken.

The main conclusion reached on the impact of climate change on water quality downstream of Paris is that substantially reduced polluting discharges will lead to usual concentrations of dissolved oxygen, the peaks of chlorophyll-a (riverine eutrophication) will be smaller compared with the discharge situation of 1991, and dissolved silica will still remain in solution, allowing the growth of diatoms in the Seine Estuary, and thus also improving the ecological status of the coastal waters of the River Seine Basin. The increased temperature due to climate change will only have a comparably small impact on water quality (with reference to the parameters chosen in the modelling approach). I imagine that these predictions are quite likely, but I can not actually prove them by an independent approach.

Interlude: What can we perceive as "water quality" and what is its relationship with waste water treatment?

Nature demands on us its assessment, and the nature we are here dealing with is a complex structure. In contrast to this quantification is in need of simplification. This in turn means that a "qualitative residual" emerges when we are using the term "water quality". This residual is formed on the one hand by our trials to assess the "actual water quality" with all our possible senses, from which we "deduct" in a certain way all those parameters that are strictly quantifiable. Ammonium is e.g. a parameter for which practically no residual exists.

In the following I thus hint at approaches in interpreting "water quality" over time in

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(Central) Europe due to polluting emissions and to man's additional interactions with water bodies in rivers. I do so in order to properly contrast this term as used in this paper – see the parameters already mentioned – in line with some developments of over time, including the present status in EU legislation.

Long-lasting artificial channel experiments (at varying degrees of loading with polluting substances) were run at EAWAG/Switzerland. An overview paper by K. Wuhrmann puts these channel experiments into a broad conceptual perspective ("Some problems and perspectives in applied limnology", Mitt. Internat. Verein. Limnol., **20**, 324-402, 1974, http://library.eawag.ch/EAWAG-Publications/pdf/EAWAG_00480.pdf). This paper is to my knowledge a good summary describing how difficult it was to interpret the term "water quality" in Central Europe at the middle of the 1970s – and this is even valid today. Additional experimental work by K. Wuhrmann and his coworker E. Eichenberger on periphyton primary production and on growth and photosynthesis during the formation of a benthic algal community is also easily downloadable, see http://library.eawag.ch/EAWAGPublications/pdf/EAWAG_00517.pdf and http://library.eawag.ch/EAWAG-Publications/pdf/EAWAG_00518.pdf.

The introduction of full carbon removal and full nitrification in biological waste water treatment plants in Switzerland, Germany and Austria was to a substantial extent founded on these channel experiments, albeit a full applied implementation of treatment works took longer than anticipated in 1974. The additional area-wide removal of phosphorus and the banning of poly-P in detergents emerged in the 1980s, with a full implementation in the 1990s. The application of nitrogen removal in single sludge activated sludge plants was driven by the fact that operating treatment plants in this way the amount of energy needed is smaller than for full nitrification (also valid for hybrid plants). As soon as this experience became publicly aware in the 1980s the requirements for nitrogen removal were introduced, with the aim of protecting the receiving seas. The impact of nitrogen removal on water quality is not part of this paper.

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K. Wuhrmann also showed in his overview that in more shallow reaches of the river continuum all “self-purification processes” (like e.g. the removal of dissolved and particulate carbon and algal growth) are concentrated at the sediment-water interface, whereas with the increase in relative depth in large rivers the related biological transformations start to get dominant in single cells and flocs transported in suspension. As large rivers do not dominate in Switzerland, the work by Wuhrmann and his colleagues centred more on shallow streams. Wuhrmann concluded in his overview also that predation can be a very dominant loss factor, and that growth rates of primary biomass producers may be heavily biased by herbivores.

The EU Water Framework Directive (2000/60/EC) is strongly based on status assessment of biological quality elements (phytoplankton; macrophytes and phytobenthos; benthic invertebrate fauna; fish fauna), and is in addition also considering hydromorphological quality elements and physico-chemical quality elements. Among these quality elements fish fauna is the one most likely to be impacted by changes in temperature.

Conclusions to the General Comments

Concluding I state that the “water quality parameters” used in the model are certain indicators that support the assessment of the “water quality elements” as required today by the EU Water Framework Directive. In actual implementation of this Directive many more parameters have to be assessed and interpreted; these, however, are at present not easily amenable to a quantitative modelling approach.

With this contrast I do in no way intend to be in contradiction with the efforts underlying this paper. I am fully aware how difficult it is in this field to bind together all what in the end makes up the needed balance between <men and ecology> in the field of water environment. I strongly hope that the salmonid species (salmon; sea trout) that are observed since recent times in River Seine 150 km upstream of its estuary will find migration routes and proper habitats in the whole River Seine Basin, and that finally they will be able to reproduce naturally where they did in the past, despite the predicted increase in water temperature due to climate change.

Specific Comments

2430:16 – 18

Sorry, I am having a certain problem with the sentence “Thus, the spatial-temporal variations of water quality are only controlled by the boundary conditions of the river network”. This sentence is “true” in the sense that the term “water quality” is only determined by the contents of the RIVERSTRAHLER model (including the living species it describes), but for sure in contradiction with a concept of “water quality” in line with the existing resp. the aimed-at ecological status as defined in the EU Water Framework Directive. I thus am suggesting to Mme. Ducharne to explain more precisely what she means.

2433:22 and further on “organic matter”

Reference is made to this term (which is, as presented in the paper, a parameter of the RIVERSTRAHLER in-stream water quality model composed of several fractions, and by the same token also one of the “faces” of polluting discharges from SIAAP); unfortunately Fig. 2 contains no actual information on this parameter (in-stream).

In respect to “organic matter”, see also 2433:28; 2442:10 (“organic matter” is cited; no data on polluting discharges at present contained in Table 2); 2443:28 (here I agree); 2444:02 (“organic matter” is again cited, no actual data contained in Fig. 8); 2444:07 same situation; 2445:08 same situation, no data contained in Fig. 9; 2445:13 same situation; 2447:02 evidence in the paper based on data missing / in actual practice existing – or existed in the past – depending on the actual discharges in 1991.

Additional remarks on “organic matter” and its interplay with “water quality”:

The overview paper by K. Wuhrmann already cited discusses the issue of “organic matter” in its Chapter 5 in an indirect way. He showed that “organic matter” per se as an input to a river – and as also contained in the RIVERSTRAHLER model – can

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be utilized at strongly differing speeds (e.g. dry-fall of leaves or branches in clean streams decompose in much more slowly than downstream of the outfall of an untreated wastewater discharge), and that a differentiation is needed. I further hint at the fact that industrial / trade waste discharges could also contain slowly decomposable and refractory organic substances.

In order to make any reader aware of the fact that the usual parameters “BOD” or “COD” (or “matières carbonées” as used within SIAAP) discharged as sedimented effluents in a usually composed urban waste water, with partial carbon removal and with full carbon removal force quite differently (and in a non-linear) way the resulting riverine conditions I refer to a paper given by K. Wuhrmann in Austria, see specifically the Figure on page B-15 in http://library.eawag.ch/EAWAG-Publications/pdf/EAWAG_00346a.pdf.

From this we can clearly conclude that at least “full carbon removal” with respect to polluting discharges has to exist in order to allow for a saprobic status in receiving waters that can be accepted. The dilution in the channel experiments was made with “clean river water”. K. Wuhrmann became later aware of the fact that the term “clean” in this context is relative and not fitting in the context of natural sciences. He ran also channel experiments with groundwater as dilution water, where he showed that already a minute concentration increase of $>$ 0.2 to 0.3 mg DOC/l of untreated urban waste water in groundwater will produce visible growth of organic microphytes, in contradiction with a good quality status (with respect to this see K. Wuhrmann, Fig. 7 in “Aktuelle Ziele des Gewässerschutzes: Alter Wein aus neuen Schläuchen?”, http://library.eawag.ch/EAWAG-Publications/pdf/EAWAG_00793.pdf).

The paper by A. Franz et al., http://www.iwaponline.com/wst/03312/wst033120047.htm, covers the design and operation of the Mödling waste water treatment plant (simultaneous nitrification, de-nitrification and P-removal with a long sludge age) and its impact on the receiving Toad Creek (dilution ratio at out-of rain season $\sim$ 20 units of waste water to 1 unit in the Creek). Saprobicity is at the β-mesosaprobic level. This is thus fully in line with Wuhrmann's predictions.

Proposed solution to “organic matter”:

I am asking Mme. Ducharne to properly check what she intends to explain with the term “organic matter” in case she uses it, and to also supplement data in Figures / Tables if needed. The preceding remarks can hopefully be a certain guidance.

2442 and Table 2:

The polluting point source discharges on which the calculations are based are mentioned in overview (see also Table 2); a full readability of the paper as a stand-alone publication is only assured if more details to the polluting discharges are highlighted, similar to the paper by A. Ducharne et al., 2007.

2444:18, 2444:20 and 2444:28

I propose to speak about “loss rate” or “loss factors”, and not about “mortality”. I do so with reference to the overview paper by Wuhrmann.

2445:12

Reference is made to nutrient limitation, but no evidence is shown in Figs. 8 and 9. Based on the work by Wuhrmann the question remains open whether e.g. phosphate is actually limiting. My asking to Mme. Ducharne is to actually prove the statement.

2446:23 to 28

If Mme. Ducharne agrees I propose the following text for this part of the paper: “*The simulated results highlight how water quality as modelled is driven by three factors, namely river discharge, water temperature and inputs to the river network. The existence of species that relate to water quality as modelled, and their complex interaction with their environment lead to this result. The underlying evolution is strongly determined by human activities, either directly or indirectly (e.g. climate change).*”

Editorial proposals

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Proposed rephrasing / new wording in italics; deletions no longer shown.

2427:24 and 26: .... use present tense (.... *shows* that ....; ..... *is* the first-order ....)

2429:07 ...... *million*

2429:15 ...... *quantitative* water resources

2429:22 .... *aspects of* ecological ....

2432:27 .... limiting *during this period*, this error .....

2433:20 .... input*s* between .....

2437:27 .... water temperature (*WT*) ......

2437:28 .... air temperature (*AT*) ....

2438:24 .... 0 to 24 *observations* per year ....

2441:02 .... the *necessary* assumption ......

2441:22 .... dependence *on* temperature ....

2442:01 .... under *the* present climate .....

2442:25 ...... *leads* instead of led ....

2444:22 .... , which take dissolved silica *up* as a nutrient. .....

In Chapter 7 please use the present tense instead of the past tense, i.e.

2445:20 ...... *presents* instead of presented;

2445:22 ...... *is* instead of was;

2446:07/08 ... *are* instead of have been;

2446:21 ...... *illustrates* instead of illustrated;

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2446:23 ...... *highlight* instead of highlighted;

2446:30 ...... *is* instead of was; the same also in 2447:03 and 2447:04

2447:05 ...... discharge change*s* *are* higher .....

2447:06 ...... change increased with the magnitude ......

Fig 1, title .... *monitoring* stations instead of measurement stations;

Fig 7, title .... Paris, but are *also* representative *for* Conflans, ...

Some words to the referee

Civil engineer by training (diploma, TU Vienna, 1967; master's degree in environmental health engineering, Univ. of Texas at Austin, 1970; doctoral thesis, 1973, TU Vienna; habilitation, 1985, TU Vienna). I was working with Dr.-Ing. W. v.d.Emde in the field of sanitary engineering until 1987 (the stress of my work was with pulp mill effluents and a guidance to public administration in Austria how to proceed with waste water treatment). In 1987 Dr.techn. H. Kroiss took over at IWAG. The type of work was always applied, and modelling approaches were then non-existent. In the late 1970s and early 1980s work started also on non-point source pollution and its impact on water quality. By the end of the 1980s I proposed (for a year-long group study by students) the setting-up of the 1^{st} balance of reactive nitrogen for Austria. Since 1994 I am employed in public administration, and in the period 1995 till 2001 I worked in the interim Secretariat of the International Commission for the Protection of River Danube.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 4, 2425, 2007.

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