Erik Somer,
Skråvej 12,
DK-2880 Bagsværd, Denmark.
Tel: (+45) 44982850,
e-mail:somer@oncable.dk

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Re: Evaluation of NERI´s research on Eutrophication and Oxygen Depletion.

Abstract:

My claim is: NERI´s statement that oxygen depletion in internal , coastal waters is mainly due to Danish nitrate discharges is wrong. My statement is that oxygen depletion in most Danish internal coastal waters is due mainly to discharges of nitrate from central European rivers which cause extreme algal blooms (particularly *phaeocystis sp.)* along the west coast of Jutland. The decaying algal mass of these blooms and remaining nitrate is by the Jutland Coastal Current (JCC) transported into Kattegat in a submerged intermediate water body under the outflowing Kattegat surface water causing oxygen depletion on its way southward.

The reason for NERI´s claim is in my opinion poor scientific understanding of the hydrography of Danish waters and in particular of the waters around the Skagerrak front where the JCC meets the outflowing Kattegat surface water. Operational hydrographic measurements in all Danish waters are NERI´s duty but NERI does not fulfill this obligation in a satisfactory way. Thus, NERI lacks scientific information about the transport of nutrients and easily degradable organic matter into Danish coastal waters and therefore is not able to give a scientific plausible reason for the eutrophication and oxygen depletion which has happened in Danish coastal waters over the last decades.

My background:

I have been director of the Danish Isotope Center (DIC), a non profit research institute within the Danish Academy of Technical Sciences from 1954 to 1974, when I was asked to join the National Agency of Environmental Protection (NAEP) as chief engineer in charge of environmental problems in Danish ground -, fresh and marine waters. I retired at the end of 1992. The DIC has in the period 1960 –80 carried out extensive hydrographic measurements in Danish and international coastal waters by means of radioactive tracers and traditional hydrographic equipment in order to predict the spread of waste water from planned waste water outlets into the sea. The DIC also assisted professor Gunnar Kullenberg, who for a shorter period was professor of physical oceanography at the University of Copenhagen in studying vertical mixing processes near the Skagerrak front and in Northern Kattegat waters by means of radioactice tracers. All the mentioned activities have given me a good understanding of flow and mixing processes in Danish water bodies above and below the pycnocline. Both at the DIC and at NEAP I have had the chance to aquire a scientific knowledge of the chemical and biological problems involved in eutrophication.

Already in my job at NEAP I had the view that the influence of Danish nutrient discharges into the sea was exaggerated by NERI. This was not in conformity with the overwhelming political ideas of the time and led to decreased influence in NEAP and eventually to my relatively early retirement. After my retirement I have not taken part in further discussions about the cause of eutrophication in internal Danish waters until I was provoked by an article by three members of the staff of NERI in the Danish periodical “Ingeniøren” in november 2002 /1/ giving a picture which in my opinion was totally wrong about the input and fate of nitrogen nutrients and organic oxygen consuming matter into Danish waters. My response was an article in “Ingeniøren” in January 2003 /2/ which led to a further dialog between NERI /3/ and me /4/ in “Ingeniøren”.

The criticism by me and others concerning NERI´s view on the reason for oxygen depletion in internal coastal waters led to a request by the Danish Minister for the Environment to carry out an independent evaluation of the scientific quality of NERI´s activities with respect to eutrophication and oxygen depletion. As soon as I heard of this in the beginning of March I prepared a statement in Danish /5/ for the use of the panel. This was done in a hurry as I had to go abroad in the middle of March. It was mailed to the Minister of Environment around 15 March, because the time schedule for the activities of the panel was unknown to me. Neither did I know that the panel would consist of distinguished English speaking scientists. Otherwise I would have prepared it in English which is the case with the present statement which supplements the earlier one since I now have had the chance to dig deeper into the activities of NERI.

NERI´s shortcomings.

NERI has since its establishment (and members of the present staff even before that) given advice on the causes of eutrophication and oxygen depletion in Danish internal waters to the public authorities and to the public via the media. This advice has let to extremely costly measures which in my opinion will have a doubtful effect. The causes of eutrophication can not be established in a scientific way unless one has a thorough knowledge about the transfer of matter and energy across the boundaries of the water body in question. Does NERI have this knowledge? The best prove that this is not the case can be found in a statement by NERI itself:

The activities of NERI in the marine field are supervised by a Steering Group for Marine Waters and the Atmosphere. The chairman of this group is Mr. Bo Riemann, the director of Research of NERI. Also the secretary of the group is provided by NERI. The other members are biologists of the counties, of NEAP and of the National Agency for Forests and Nature. This group had a meeting on 8 May 2002. The report of this meeting can be found on NERI´ s homepage.

One of the main items of the meeting was the operation of the marine monitoring system. A mathematical model for the Danish waters (the Farvandsmodel) has been under development by the Danish Hydraulics Institute – Water and Environment. In this connection it was noted :

“ at der på bundlinjen står at beregning af randdata ophører, da farvandsmodellen reelt ikke har tilvejebragt randdata med den fornødne kvalitet”.

My translation: ” on the bottom line it is established that the calculation of boundary data discontinues as the Farvandsmodel has not been able to produce boundary data with sufficient quality”.

In my opinion this statement seems to have been formulated by the secretary who probably has no thorough knowledge about how models are established. A mathematical model does not “produce” boundary data, but relies on an input of boundary data with sufficient quality in order to be of any use. Therefore, I understand this statement that such boundary data do not exist. This is confirmed later in the record:

“5.5. Samlet var der I styringsgruppen enighed om, at vi ikke længere har styr over de eksterne tilførsler til de danske farvande….”

My translation**: ”In conclusion the steering group was in complete agreement that there was no control anymore concerning the external contributions to the Danish waters.”**

This seems to be a very clear statement, which I fully endorse. Actually, this control has been lacking for more than 30 years.

In 1968 the head of the Hydrographic Department of the Danish Institute of Oceanography and Fisheries, State Hydrographer Frede Hermann wrote /6/: (My translation)

“ There are few areas in the world where there have been carried out more hydrographic measurements than in Kattegat and the Belt Sea. 9 Light ships and a number of coastal stations carry out daily measurements of temperature and salinity. With respect to the lightships this takes place not only at the surface but with 5 meter intervals from surface to bottom. The surface current velocity and direction is determined every 4 hours day and night from the light ships. The same kind of measurements take place on Swedish and German lightships and the they are supplemented by cruises of research vessels of different nationalities.” So, these measurements cover all the Danish waters from the German Bight to the Baltic.

Al this information going back to the 1890s can be found in year books issued by the Danish Commission for Marine Investigations. They also contain oxygen depth profiles and current velocity and direction profiles and overall evaluation of the total current and mixing situation in all waters.. This is what I consider good operational oceanography and open, available records of hydrographic measurements. What happened after world war two can only be described as a catastrophe.

First of all the light ships were replaced by unmanned buoys. Thus, the most intensive measurements taking place were discontinued. Then with the establishment of NERI the Danish Institute of Oceanography and Fisheries was changed to the Danish Institute of Fisheries, thus abandoning the hydrographic division of this institute, because this now was to be NERI´s responsibility. However, NERI has never had and still does not have a single hydrographer or scientifically trained physical oceanographer.

In response to my article /1/ director of Research of NERI Bo Riemann writes in/3/: (my translation): “Regrettably we don´t have many years data about the doings of sea currents”. This proves that NERI is not aware about the tremendous amount of data available in 100 years of Danish hydrography or about the newer international research in this field, mainly by German and Swedish oceanographers.

There has been an earlier international evaluation of the scientific state of physical oceanography in Denmark both at University level and at NERI. The conclusion was: “The panel recommends that the restoration of a strong Physical Oceanography should be addressed as a matter of emergency”. Since then the University of Copenhagen has got a professor in Physical Oceanography, but absolutely nothing positively has happened at NERI.

NERI has since its establishment undertaken a number of measurement cruises in Danish waters. The planning of the cruise season seems to be totally without any long term scientific strategy. Let us go into details:

For most of the years NERI´s earliest cruise has taken place in January-February. Generally this cruise not only covers the internal waters but also Skagerrak and the Danish North Sea waters down to the German Bight. This coverage is perfectly in order, if it not just with very few exceptions was the only annual cruise going beyond Kattegat. There was in the beginning an appropriate reason for a cruise at this time of the year. Primary production is at this time still at a minimum and inorganic nutrients can thus be considered to be conservative tracers. NERI established that that there is reciprocal linear relationship between nitrate and salinity in the JCC. I have extrapolated this relationship to zero salinity and could show that it corresponds to the nitrate level in river Elbe late in the year.

These cruises also show that there is an inflow of JCC water into Kattegat below the primary halocline even at this time of the year except in years with strong westerly wind where the JCC enters Kattegat as a surface current and only dips under the outflowing lighter Kattegat water further south in Kattegat. This is exactly what I write in /1/ but NERI denies this fact and claims that the inflowing water from Skagerrak is due to upwelling of Skagerrak deep water, even if the relatively low salinity of the inflowing water corresponds to JCC water (about 32-33%o) and not to Skagerrak deep water (35.1%o). See figure 13, Cruise report no.207 and figure 13, Cruise report no.214. (*Both cruise reports can be downloaded from NERI´s homepage* http://www.dmu.dk

So, for a couple of years this cruise has provided useful information. However, if there is a shortage of cruise resources it would have been advisable years ago to shift the cruise to a later date as there are very good figures for the river outflow available directly from Germany. In March -April the river outflow is at a maximum and so is the primary production first of diatoms and then of flagellates. This would show the level of eutrophication of the Danish West Coast which has not been regarded by NERI at all and give a most useful input for an evaluation of the input of nutrients and oxygen consuming organic matter into Kattegat. In stead NERI in its reports uses figures for this input which are much lower than found internationally and not based on any scientific evidence.

This is shown clearly in the latest NERI report on "Nutrients and Eutrophication in Danish Marine Waters" which I will discuss later in the present paper. In stead we will now look at the other annual cruises undertaken by NERI. With few exceptions these cruises take place in August, September, October and often in November. These cruises have the expressed main aim to show the extent of areas with oxygen depletion. They take place at a time when the primary production level generally is low and when the important (in my opinion) inflow of JCC water is equally low. So all the main inputs and processes which lead to oxygen depletion have passed. The main purpose of these cruises seems to be oriented towards the media who love to write about the "catastrophic" situation in internal Danish waters and thus induce further political national activities for the reduction of Danish nutrient inputs. It is difficult to see that these cruises contribute to our scientific understanding of the causes of oxygen depletion.

This is by and large all the operational oceanography carried out by NERI! In my opinion a disaster!!

NERI´s and my evaluation of the importance of the JCC.

On 1 April 2003 NERI has published a comprehensive report in English "Nutrients and Eutrophication in Danish Marine Waters – A challenge for Science and Management". *(This report has probably been handed out to the panel or the panel should request it. It can also be downloaded from NERI´s homepage http://www.dmu.dk).* Let us see how NERI meets this challenge.

On page 27 one finds figure 2.6. One sees that the salinity of the outflowing Kattegat water and northgoing JCC water have the same value of 32 %o at the northern tip of Jutland . This figure is derived from cruise no.207 mentioned above. At the time of this measurement there blew a strong westerly wind (7.0m/s) according to page 2 of the cruise report. According to my earlier Danish statement to the panel the Skagerrak front moves eastward at wind speeds above 6 m/s. Usually the front meets the Danish west coast of Jutland around Hirtshals.

On page 35 one finds table 2.4 and figure 2.11. These figures are taken from the article in "Ingeniøren" /1/ which caused my first intervention. There are small changes in the figures given, but generally the situation described is the same. It is seen from figure 2.11 that according to NERI only 39 kt/y (red arrow) of biological active nitrogen enter Kattegat from the JCC. This is in my opinion a gross understatement. Considering that NERI admits "not to have control about the doings of the currents" it is hard to understand how NERI arrives at this low figure.

The Swedish institute SMHI declares in several of its annual reports that the Swedish West Coast was strongly influenced by water coming with the central European rivers /*Sveriges meteorologiska och hydrologiska Institut SMHI, annual report 1994 and 1995/.* This water can only enter Kattegat across the northern tip of Jutland and due to the correolis effect it will move first of all southward along the Danish coast before it spreads across Kattegat. If the figure for nitrogen really was as low as stated by NERI one would not expect any significant effect on the Swedish side.

But let us first look at the transport of DIN and biodegradable organic matter northward with the JCC. There are many different figures given for the DIN transport. Some are given by working groups in which representatives of NERI took part. They are generally low. Thus, OSPAR in its Quality Status report 2000 (*can be downloaded from OSPAR´s homepage)* gives the figure 136 kt/y (page 83). However, independent reports give much higher figures. Thus, Rydberg et al. /J.Sea Res. 35(1-3):23-38(1996/ arrive at 350 kt/y DIN and 600 kt/y TN. The North Sea Task Force (1993) says 400 kt/ antropogenic nitrogen from the Southern. North Sea into Skagerrak.

Considering a probable Redfield ratio C:N of 7 the different DIN figures if totally consumed by primary production would lead to annual TOC figures between 900 kt/y and 2100 kt/ using the lowest respectively highest estimates given here. This TOC would be easily biodegradable. At least half of the primary production takes place in spring and would then arrive at the Skagerrak front in early summer. At this time of the year there is a nearly constant southward current submerged directly below the northward flowing Kattegat water. This can only be JCC water. This water mass is still in the photic zone. So, whatever it contains DIN or TOC or a combination of both it would give rise to eutrophication effects in Kattegat.

There are a number of reports prepared by N. Højerslev and some of his students as well as a report by Højerslev, Gunni Ærtebjerg and Kathrin Richardson.. As Højerslev also makes a statement to the panel I expect that reference to these reports will be found in his statement. An overall conclusion from these reports is that only about 10 % of JCC water enter Kattegat on an annual basis. Personally, I doubt the quality of these reports. Højerslev has personally admitted to me, that for the summer period an influx of the order of 50 % is not unrealistic.

As the maximum river flow occurs in March and the primary production peaks in April –May along the west coast of Jutland, these water masses will arrive at the Skagerrak front in early summer, when the JCC influence is highest. Again, considering the figures for DIN and TOC given above, the influx during summer of TOC either directly transported into Kattegat or produced by remaining DIN within Kattegat would be between at least 200 kt and 500 kt.

The intermediate layer of inflowing JCC water in Kattegat has a thickness of about 10 meter (the average depth of Kattegat is 23 meter and the outflowing Kattegat water has an average thickness of about 13 meter) and covers an area of about 20.000 sq.km corresponding to a volume of 200 cub.km

. If we consider the TOC evenly distributed within this water mass it would correspond to a concentration of between 1 and 2.5 mg/l TOC, which certainly is enough to cause oxygen depletion in large areas of Kattegat either directly or when the particulate part precipitates in the deeper parts, as 1 mg TOC consumes 2.7 mg oxygen.

The important transport of organic suspended matter via the JCC into Kattegat is also indicated by investigations using CS-137 of Chernobyl origin as tracer. There was a considerable fall out of Cs-137 over central Europe, while the North Sea did not get anything of importance. Sediment in Kattegat had high levels of Cs-137 normalized with respect to TOC. This can only have arrived via the JCC. This is demonstrated in **figure 2** in my earlier Danish statement to the panel.

Other calculations lead to high amounts of TOC transported with the JCC. Silke Rick, now at the University of Louisiana, Lafayette, USA, who has done some excellent work on the influence of river Elbe on the phytoplankton spring bloom in the German Bight has also studied chlorophyll and primary production in the area. I am sure that member of the panel, professor Nancy Rabalais, who also works at the University of Louisiana is familiar with her studies. Silke Rick has from a grid of altogether about 70 stations found daily production values between 0.7 and 15.8 gCm-2d-1 during spring. For the primary production capacity of the German Bight she finds a range of 300 to 400 g Cm-2.y-1. If we consider that the highest production is found in areas with the highest nutrient content (see figure IV in addendum 1 of my Danish statement) it is plausible that the highest production rate is found within the JCC. As production outside the bloom period of about two months is low, we may consider a production of 300 gCm-2.2months-1 within the JCC. The area covering the bloom is about 50 x 200 km = 10,000 sq.km. This means that the production of organic C moving towards the Skagerrak front is 300 x 10,000 ton = 3000 kt.

If we assume a daily production rate of 10 gCm-2.d-1 within the JCC (2/3 of Silke Ricks max. value) it would mean that we over the bloom period of 2 months have a production of 10 x 60 x 10,000 ton = 6000 kt. Off course, these calculations are only extremely rough estimates, but they demonstrate how absurd it is to use a figure of only 39 ton bioavailable N for the input via the JCC as NERI does.

But are there no indications that NERI actually is aware of a significant transport from the JCC into Kattegat. In a report to the European Environmental Agency on Remote Sensing as contribution to evaluate eutrophication in marine and coastal waters , where a staff member of NERI was task leader.(*The report can be requested from NERI)* It mentions (page 26) that the Skagerrak front is not seen in the summer mean image pictures (my remark: remote sensing only shows surface chlorophyll) and concludes that this probably is due to the fact that the chlorophyll during summer is mainly concentrated in the subsurface halocline at the stratified side of the front. Well, this side is precisely the submerged JCC entering Kattegat in the way as I have described it. By the way, the remote sensing pictures show the enormous transport of chlorophyll northward with the JCC.

I have mentioned the cruise reports of February 2002 and 2003 earlier. Figure 14 in both reports shows the nitrate distribution in a transect through the north-eastern Kattegat and then further south and east. We have the Skagerrak border on the left side of the picture. In both years one sees high nitrate concentrations in the waters coming from Skagerrak. Compared with the earlier mentioned salinity figures it is clear that even at this time of the year we have a transport of nitrate rich JCC water into Kattegat. In 2002 with strong westerly wind the cloud of nitrate is close to the surface, in 2003 it is in an intermediate layer again connected with JCC salinity. The report mentions that nitrate does not penetrate deep into Kattegat. The untrained reader may understand this so, that JCC normally does not penetrate deep into Kattegat. One most however consider the time of the year and the travel time of JCC water into Kattegat. Then one realizes that the nitrate front in Kattegat has started its travel from the German Bight just when nitrate starts to raise in fall and that waters south of the nitrate front in Kattegat still could be JCC water originating from the period where there was very little DIN in the JCC.

Why is oxygen depletion more frequent now than before?

The river discharge of nutrients into the German Bight has increased by a factor 4 for nitrogen and a factor 1.5 for phosphorous over the period 1963 to 1984 according to Radach &Berg, Helgoland 1986.According to these authors the production of diatoms in the southern part of the JCC has remained the same during these 30 years (about 8 microgram C/l) while the production of flagellates has increased by a factor of at least 10 (from less than 4 microgramC/liter to 40 microgram C/l). There we have the cause of all the problems we are discussing here.

The faster increase of N than of P (and Si) has resulted in a situation where all inorganic P (and Si) is consumed at a time when there still is DIN available. This results in a particular niche for flagellates, particularly *phaeocystis sp.* They exude an enzyme, alkaline phosphatase, which is able to convert organic bound P to inorganic P. I have studied the blooms of *phaeocystis* for a period of more than 10 years (1980 to 1992) together with time series of DIN and DIP at a station in the central part of the JCC. Almost every year there were tremendous blooms of *phaeocystis* causing huge foam formation at the beaches being of great nuisance for the recreational activities at the beaches. These blooms always started when DIP was depleted and they ended when also DIN was depleted. Only one year where the river transport of DIN was very low DIN and DIP were depleted simultaneously. This year there was no bloom of *phaeocystis.* Such blooms have probably always existed, but they occurred only in rare years with an extremely high DIN outflow. Now these blooms occur almost every year. Only in years with an extremely low outflow of DIN we avoid them.

Where do we find oxygen depletion in Danish waters.

Figure 4 in my Danish statement shows the depth distribution of Danish waters.We can see that Kattegat on the Danish side is very shallow, so the intermediate layer of JCC water can only form a thin bottom layer here except in the channel between Jutland and the northernmost Island of Laesoe. In this trench we meet the first signs of oxygen depletion - far from local sources. Further south we have a channel which passes through the Great Belt and then when entering the waters south of the Danish isles there is an arm going westward into the southern Little Belt. In summer and fall TOC rich water coming all the way from Skagerrak can pass through this channel and cause oxygen depletion on its way. Figure 5 in my Danish statement shows the situation in the Little Belt in 1930 and in 1995. It is evident that oxygen depletion comes from the channel of open water and not from the coast both in the southern Little Belt and in the outer Vejle fjord in the north. Actually, similar situations can be shown in most of the waters where oxygen depletion has occurred.

As an example of a fjord where the eutrophication is claimed to be derived from local nutrient sources NERI´s English report of 1 April mentions the fjord of Mariager in the central-northern part of Jutland. It should be noted that this fjord is the only Danish sill fjord of the same type as most of the Norwegian fjords and as Pudget Sound near Seattle. Here we have a bottom layer of stagnant water which is renewed when higher salinity water (which here has a high TOC content) is able to pass over the sill. In my opinion even here it is doubtful if the oxygen depletion found here almost every year is due to local sources.

In my opinion there only very few of the Danish fjord systems and no open coastal waters which are seriously influenced from local Danish nutrient sources.

This means that the very costly measures that have been taken in order to reduce the nutrient discharge from Denmark most likely will prove to have very little effect.

However, it is still justified to take such measures, because it is most important to reduce nutrient inputs to the sea from Central Europe. Measures taken by Denmark will be a prerequisite for our political activity to encourage other European countries to reduce their nutrient discharges. Any attempt to claim that the troubles we have with oxygen depletion of coastal water are due to our own discharges will counteract attempts to induce other countries to take steps in order to improve the situation in our waters.

Thus, I see NERI´s standpoint that coastal oxygen depletion is our own fault not only scientifically wrong but also politically dangerous.

References:

/1/ NERI´s article to be found as addendum (in Danish Bilag) 2, page 20 of my Danish statement to the panel

/2/ My response to /1/, addendum 1, page 14 in my Danish statement

/3/ NERI´s response to /2/. addendum 3, page 23 in my Danish statement.

/4/ My response to /3/, addendum 4 , page 25 in my statement.

/5/ My Danish statement, earlier mailed to the panel.

/6/ Frede Hermann: in Danmarks Natur, vol.3, 1968, pg.37.