CHAPTER 122

INDUSTRIAL SEWAGE IN THE WESER ESTUARY

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ABSTRACT

The in former years nearly exclusively agriculturally structured coastal areas of Lower Saxony recently undergo an increasing industrialisation. This process was introduced by the settlement of a Titandioxyd factory at the Weser estuary, which releases acid sewage. The problems, connected with the discharge of this sewage are discussed, as well as the tests performed in order to prevent a possible overstrain of the Weser water. The hitherto gained results are described and preliminarily interpreted. The recent, partly surprising biological development cannot be traced back to a measurable ecological change in the Weser estuary and therefore is inducement to think over critically the applied procedure.

In recent years the German coastal area was almost exclusively agriculturally structured. (Figure next page). Accordingly the coastal waters and affluxes were charged preponderantly with agricultural and domestic waste, and for its decomposition the self-purification-power of the used water was sufficient. Compared with this the industrial and professional sewage was altogether insignificant and only in the worst cases caused local concerns. The higher amount of waste, increasing with


N O R D S E E
Nord-
friesische
Inseln
Nord-
friesland
Sylt
Hindenburg Damm
Föhr
Dagebüll
Amrum
Langeoog
Gröde
Nobel
Hallingen
Hamburg
Nordstrandmoor
Nordstrand
Husum
Süderoog
Südlatt
Deutsche
Bucht
Tönning
Eider
Helgoland
Büsum
Trischen
Scharhörn
Neuwerk
Marne
Cuxhaven
Elbe
Ostfriesische Inseln
Wangerooge
Spiekeroog
Langeoog
Norderney
Baltrum
Minsener Oldoog
Mellum
Juist
Hemmert
Borkum
Riffgat
Norden
Jever
WILHELMSHAVEN
Jade
Weser
BREMERHAVEN
Jade Busen
Krägast
Ems
Aurich
Ostfriesland
Emden
Dollart
0 10 20 30 40km

improving sewerage, could mostly be neutralized by sewerage plants.

More imperiled were the estuaries of Elbe, Weser, Jade and Ems Rivers, which had to receive the not yet eliminated wastes of the big rivers and the harbours as well as of the port-towns. Though in these areas, too, expecially in the Elbe River, the strain of the water locally led to not unobjectionable situations, the disturbance of the biological equilibrium altogether remained in tolerable limits.

The desire of industries, producing a high amount of sewage, especially of chemic giants, for deep water, which commenced in Germany in about 1965, meanwhile resulted in the settlement of a number of bigger factories. Further settlements are in discussion or already projected. Herewith possibly a development is commenced, which in many estuaries of Europe and other continents already causes severe concerns (1).

The process of industrialization of the Lower Saxonian coastal area was introduced by the settlement of a Titandioxyd factory at the Weser estuary, on the Blexener Groden opposite of Bremerhaven, which started production in 1969. (Figures next page. Top: Sewage discharge area of the Titan factory in the Weser estuary. Bottom: View to Blexener Groden with Titan factory after commencement of production). In the permission-procedure for the discharge of preponderant acid sewage was stated, that the Titan factory intended to deposit the in the production process recoverable weak acid in the North Sea, northwestward of Helgoland Island, and to discharge the not recuperative rest-acids into the Weser River at km 65,8. In this paper it shall not be talked of the Helgoland release area, but only of the conditions in the Weser estuary. Due to the statement of the Titan management the rest-acids should contain the following pollutants:


BREMER
HAVEN
DIE WESER

$FeSO_4$	0,71	g/l	270 kg/h
H_2SO_4	0,68	g/l	1080 kg/h
$(NH_4)_2SO_4$	0,14	g/l	220 kg/h
$TiOSO_4$	0,10	g/l	160 kg/h
$MgSO_4$	0,013	g/l	16 kg/h
TiO_2	0,004	g/l	7 kg/h

Total amount of sewage: 38 200 m^3/d.

The planned release of thus big amounts of chemical sewage in an on the whole only little polluted estuary and the with view to the environment-protection world-wide raised demands for maintenance of the purity of our living space as well as the local very insufficient experiences, concerning the behaviour of liquid wastes in brackish water, made the treatment of the involved problems especially difficult.

The in the thereby commenced discussion repeatedly uttered thought, to prevent an industrialization of our coast at all in order to preserve the waters, is opposed by a number of economic-political aspects. The objective of Lower Saxony and its adjacent countries, concerning the industrial development of coastnear living spaces and economic domains, is influenced by the modern industrial society. In the coastal area Lower Saxony needs capable industries to establish safe working places, in order to retrench the gradient of prosperity, directed from north to south, and last not least to gain the growing taxable capacity, connected with any economical animation. These economic objectives however have to be confronted with very hard demands for the protection of our environment, especially of the coastal waters. Misconceptions, concerning these processes, could be irreparable for decades or even for ever.

In the German legislation and in the Lower Saxonian water law, which has to be applied for the case in question, the conditions are laid down, which have to be observed or found in case of release and transportation of waste. According to this law the minimum-requirements have to be quoted, to which the water

quality has to conform. The law further prescribes, that certain substances are not allowed to be released, which influences have to be warded off, by which the water consistence can be detrimentally influenced, and others. Further here the legal procedure is settled, which is authoritative at water usufruct. Accordingly for the water usufruct a "permission" or a "concession" can be imparted. The permission revocably authorizes to make use of a water in an appointed manner and can be timed. The concession however has a stronger legislative validity and is imparted for an appropriate time, which in special cases even may transgress 30 years. The permission allows in difficult cases and at unforeseen damages, to impose the water usufructuary subsequently and short-dated with additional conditions for the water usufruct. For this reason at industrial sewage discharge usually only a "permission" is imparted.

For the water legal procedure in question therefore above all a number of expert opinions was demanded, which should allow an estimation of the consequences to be expected at the planned sewage release and which should prove, under what conditions a permission can be imparted at all. Three complexes of questions seemed to be of special importance:

1. In what time and on which way the pollutants will be mixed with the water of the Weser estuary by tide and current?

   The studies proved, that at mean tides and upstream water conditions in the Weser water soon a dilution rate of 1 : 1500 is obtained. As expected the waste particles - oscillating saw-shaped in the tide rhythm in front of the point of release - transpose resultingly seaward. A sewage release only at certain tidal phases is of no effect (2).

2. Will the chemistry of the Weser water be in any way impaired by the release of the acid sewage respectively is even a change of pH from alkaline to acid value to be expected

and will there be an increase of sedimentation owing to the flocculation of ferro-hydroxide?

Orientated at the hydrographic results the chemical studies allowed the interpretation, that due to the expected dilution-rate a chemical change of the Weser water was not to be expected. The acid neutralization capacity respectively the rate of carbonate of the water would be sufficient for the neutralization of the appearing sulfuric acid and the iron and titan, bound to sulphates, and would be bound up only to 3,25% even under the most adverse circumstances. The expected ferro-hydroxide flocculation would be entirely insignificant compared with the normal suspended load of the Weser River (3).

3. Will there be any influences on the local biocoenosis at continued release of sewage?

The in this respect performed physiological experiments in a tank, supplied with additional acid, which was in keeping with the quality of the sewage of the Titan plant, had the preliminary result, that the lethal limit of most of the test animals is reached at a dilution rate of 1 : 3,3 to 1 : 4 and that concentrations up to 1 : 13 can be born. At the actual rate of dilution therefore a disturbance of the biological equilibrium would not have to be feared (4).

As physiological tests in tanks with simulated boundary conditions are contested in any case, and only adults were used for the tests, these results were accepted with great skepsis. Actually later experiments proved, that the limits of compatibility for herring eggs and larvae range at a much higher rate of dilution (5).

These experiments were fundamental to the lastly in 1966 confered permission for the release of sewage in the applied quality and quantity. A number of internal and external conditions were imposed to make sure, that the sewage release

doesn't slip out of control and possible damage can be avoided respectively recognized in time. Some of these conditions were: Inlet of the waste with overpressure square to the current direction in order to guarantee an instantaneous thorough mingling, fixation of the pH of the waste at the point of inlet to 1,8, restriction of the standard of solid matters to 0,5 mg/l, prohibition of additional inlet of oil and other floating substances, mechanic clarifying of additional domestic waste etc. In the Weser River in a distance of 500 m from point of inlet, horizontal as well as vertical, the pH of the polluted water is not allowed to range below 6,5. The rate of iron, solved in the water, must not exceed an increase of 0,5 mg/l and the rate of colloidal ferrous an increase of 0,5% - related to the solid matter substance.

The condition, prescribing, that in 500 m distance from the point of inlet the pH must not undercut 6,5, was violently contested. For one was due to the chemical examination to be expected, that the acid neutralization capacity of the Weser water was strong enough, that a pH reduction in such dimension is not thinkable. If on the other hand the acid neutralization capacity was not sufficient, a drop of pH in such dimension could not be tolerated, for herewith an acid bar across the Weser River would be built up, the influence of which to the biologic conditions would be immeasurable and possibly would commence a not predictable future development. But due to the fact, that the pH seemed most endangered by the release and in order not to neglect anything, this condition was finally maintained.

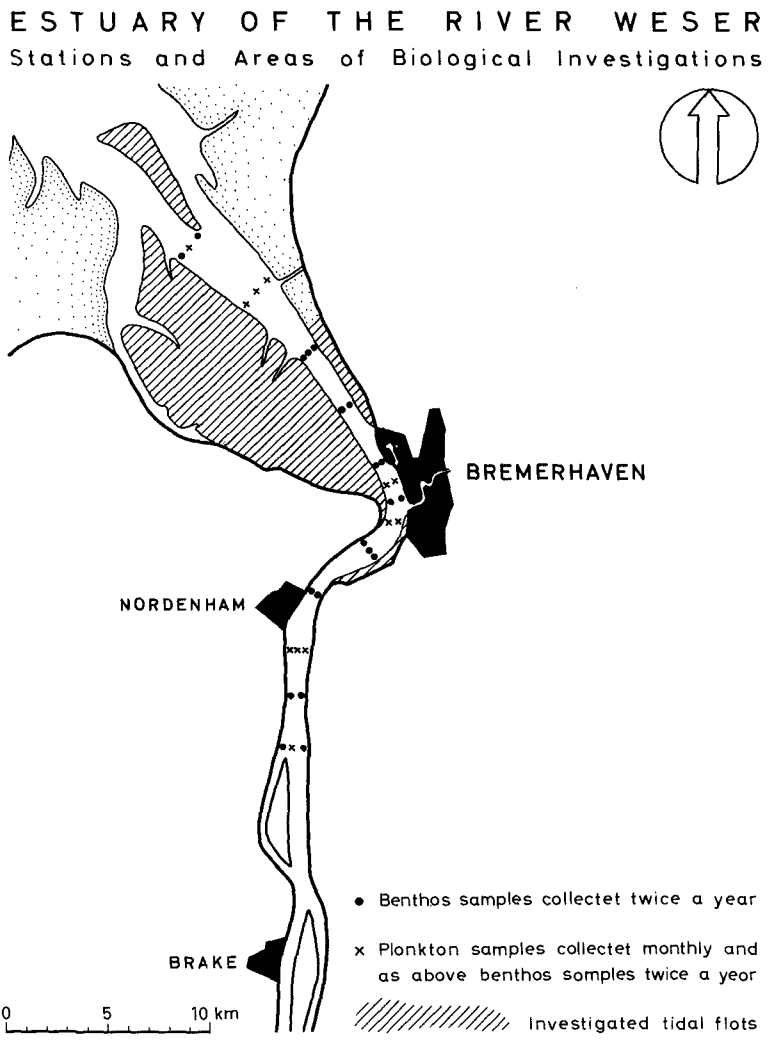
The Titan factory was obliged to equip their plant with the necessary constructions and measuring devices in order to control the conditions. Further biologic/ecologic first-investigations were demanded to estimate possible, later appearing damages in the Weser estuary, to fix the state being and to make possible comparative studies after the factory's setting to work. Herewith should be guaranteed,

that quality deteriorations of the Weser water can be intercepted in time by additional conditions.

With these biological studies to a certain extent unknown territory was entered. In Germany comparative studies in brackish water and under tidal conditions hitherto were not performed to that extent, therefore own experiences were not available. The foreign and especially the very abundant American technical literature substantially describes - as far as we were able to evaluate it in the short time - damages in their estuaries, caused by human influences. Furthermore results, gained otherwhere, hardly could be transferred to our situation without modification, due to different hydrographic boundary conditions. Further a complete seizing of the Weser biocoenosis - apart from interesting detail-results - did not exist.

For the first-investigations only one year was at our disposal, what made the whole problem still more difficult. Additional difficulties rose by the without that short-dated strong fluctuations of the pH of the Weser water from 7,1 to 7,9, caused by the release of potash-waste into the upland-Weser-river. The ecologic boundary conditions, changing with the tides - altering salt contents, shift of the boundaries of the brackish water in dependency on upland discharge etc. - had no simplifying effect, either. Furthermore, while still performing the tests, another factory - intending to release gypsum sewage - extended its production.

The studies were extended to an area of 15 km upstream to 20 km downstream from the point of release and to the tidal flats situated within this area. (Figure next page). This district comes up to approximately the mean brackish water area of the Weser estuary. The test material was gained in 10 sections during 10 excursions from December 1967 to November 1968. This guaranteed the full valuation of the seasonable fluctuations of the vegetation. Simultaneously to the collecting of the biological test portions chemical water analysis were performed


ESTUARY OF THE RIVER WESER
Stations and Areas of Biological Investigations
BREMERHAVEN
NORDENHAM
BRAKE
0 5 10 km
• Benthos samples collectet twice a year
x Plonkton samples collectet monthly and as above benthos somples twice a yeor
Investigated tidal flots

in order to safe the ecological parameter.

In detail on each excursion bottel plancton, net plancton and macrobenthos was tested. The samples in question were gained on the water surface and near the bottom. The evaluation was emphasised on the quantitative, spatial and temporal distribution. A taxanomically complete study was not planned and due to the short time, available for the investigations, not possible. The evaluation of the rich material took several years in any case. The tidal flats were only once macrobiologically mapped, as due to the short range of time multy mapping was not possible (6).

After having concluded the primary tests and having been able to develop clear conceptions regarding the biology of the test area, in the year 1971 - i.e. two years after the Titan factory's commencement of production - first comparative studies were performed.

These studies - the detailed description of which would be too prolix - had a surprising result, which is also inducement to think over again critically the whole method of the biological/ecological analysis with regard to future similar problems.

The primary test had - at least with respect to the diatom flora - the unexpected result, that - in spite of an increase of eutrophication and an intensified strain of the oxygen-household of the Weser River - the conditions qualitatively hardly had changed since the turn of the century. The then performed diatomee-tests by the way represent the beginning of the studies of protisten-plancton in the Weser River. The macrobenthos was only very insignificantly developed and lacked completely in large areas. Possibly this has to be reduced to the exclusively mechanic influences of the dredging in the Weser River. But it is also thinkable, that by the repeated deepening of the bottom ground-materials were carved, which as substratum don't suit for brackish water benthos. Altogether

in the test-area the Weser River looked as though it was so far healthy, respectively the self-purifying power was still sufficient for the decomposition of the rest-deterioration of the upland discharge as well as of additional sewage release. After all the experience of the penury of species and individuals, typical for the brackish water, was affirmed.

In 1971 comparative studies at random were performed. They had - first of all qualitatively - completely different results. Above all the feared reduction of pH in the release area nearly failed entirely. Only at turn of low water the pH of the Weser water near the point of release dropped significantly below 7, and short-dated a weak acid sewage effluent developed, which reached over the control section. At more significant current and at high water only in the immediate neighbourhood of the point of release an influence of the sewage was perceptible. The internal conditions, which were controlled simultaneously, were observed. In the test area a perceptable increase of the rate of sedimentation could not be ascertained. Compared with the natural conditions it remained neglectably small.

The at the same time achieved biological drains in the test area revealed, compared with the primary studies, qualitatively entirely different results. Conditions were ascertained, which nearly reached up to a status of depopulation. A such severe deterioration of the Weser water in so short a period was surprising. It cannot, or at least not only, be reduced to the release of waste of the Titan factory.

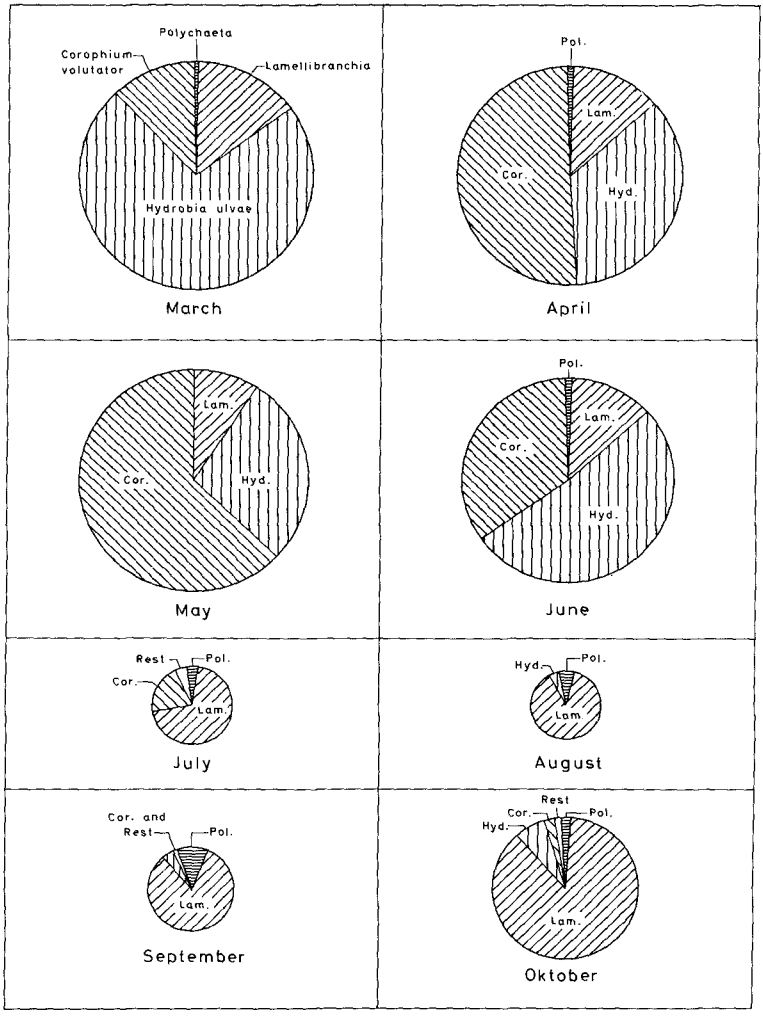
For one the short-dated and locally very limited reduction of pH in the release area seemed not to be significant enough to be able to become ecologically decisively effective. Other ecological changes, reducible to the Titan sewage, were not perceptable. On the other hand it was striking, that the biological samples lacked marine as well as limnetic detritus, which was still found in larger quantities at the primary studies.

Consequently the initial events for the biological deterioration in the Weser estuary had to be searched byond the test area. A causal effect could not be imputed to the small rate of oxygen content, having a saturation of less than 50% when performing the controll-measurements, as similar rates were found already at the primary studies. The organisms, living in brackish water, develop due to the frequently altering living conditions a strong resistance against outer influences, as is known.

Therefore for the moment only hypothesis can be developed to explain the phenomenon of depopulation. An overstrain of the Weser upland discharge in so short a time can be set aside as reason for the depopulation, as there the development is kept under control. It is possible, however, that the upland discharge is efficient indirectly, because at the comparative measurements the Weser River already for a longer time only led very little water. This could explain, too, that the limnetic detritus was no more traceable. On the other hand this is no explanation for the absence of marine detritus. So far the suppositions, basing on the hydrographic boundary conditions, are little satisfactory. It is also thinkable, that population-dynamic developments took place, which already happened elsewhere, too, without an alteration in the ecological paramenters beeing traceable. (Figure next page: Population dynamic at a test station in the tidal flat near Norderney Island as example of possible fluctuations, which were not caused by human influence.) Probably here a number of influences, which are for the time being still unknown to us, are commonly efficient. Therefore the studies shall be continued and deepened.

Nevertheless the now present experiences are inducement to think over critically the studies, performed in the Weser estuary, and to draw conclusions for subsequent similar investigations.

Above all it has to be appointed, that the time, being available



Changes in quantity and composition of the bottom fauna at a station in the eastfrisian waddensea. Sections representing number of individuals.

for contenting studies was far insufficient. Therefrom anew resulted spacial restrictions in the test area and a too coarse-meshed net of test-stations. Only by this the interpretation of the results is already extremely obstructed. Furthermore the tests and the interpretation of the results revealed exceedingly the deficiencies of our biological knowledge. In a speech a very ingenious German biologist once observed, the progress in the biological research would finally throw us back to our biological instinct. Exact scientific assertions would be an attempt of a gross illusion. This conclusion however should not be valued as oath of manifestation of the biology. It only reveals the extraordinary multiple states and ecological/biological causative relations in the lively nature. Nevertheless the instinct has to be sharpened by the augmentation of our knowledge and experiences.

Already for this reason the biological study of coast-near sea-areas and esturies should be commenced without urgent reason. We believe, that we have done our best in the Weser estuary and still are doing it. Many decisions however would have been easier and many a development would have been prognosticated better, if long-dated biological/ecological observations would have been available at the beginning of the studies, which in this case only would have been to be completed in detail.

In the meanwhile in the other German estuaries, too, similar studies have been commenced, induced by industry-settlements. Though, while studying the Weser River, we have become aware of the today's limits of these investigations, we nevertheless believe, that with increasing experiences we will become able improvingly to steer the strain of our water, which presently just is necessary in a closely colonized industrial country.

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