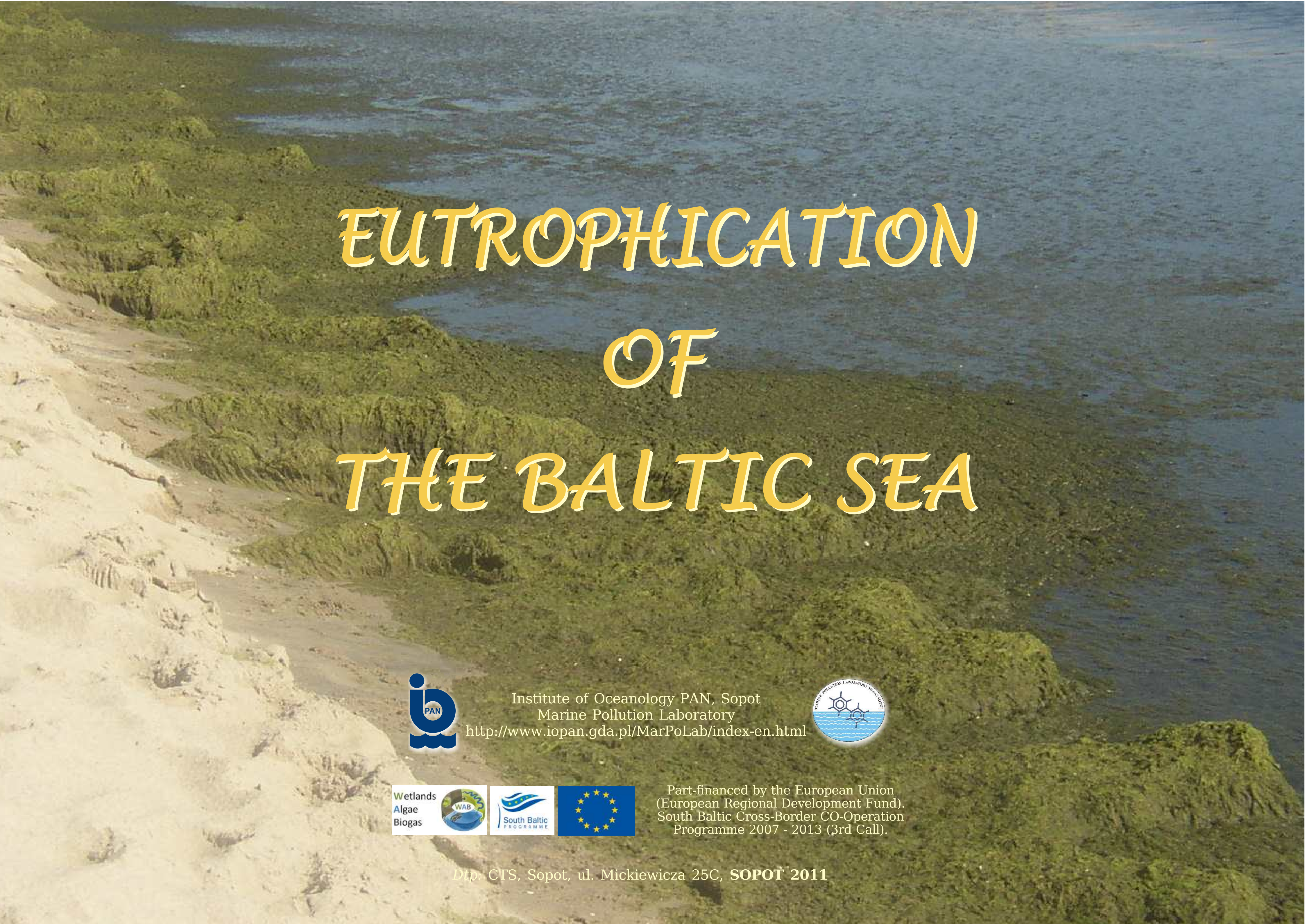

EUTROPHICATION OF THE BALTIC SEA

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Part-financed by the European Union (European Regional Development Fund). South Baltic Cross-Border CO-Operation Programme 2007 - 2013 (3rd Call).

Dtp: CTS, Sopot, ul. Mickiewicza 25C, **SOPOT 2011**

What does 'eutrophication' mean?

There is no single definition of the term 'eutrophication' (from Greek 'eutrophos' = nutritious). Some explain it as a process, some as a state of environment, and others say that it is the input of nutrients (biogens = biogenic substances). According to a recent report of the Helsinki Comission (HELCOM 2009) 'eutrophication' means well nourishing (in fact 'overnourishing') and its negative results for the environment.

Overall, one may say that eutrophication is a range of interlinked processes, which in different aquatic basins depend on different factors and proceed with different rates. That is why it is difficult to answer the question: 'what is it eutrophication?' whilst observing only one site and during a short time period. However it is much simpler to know the causes and signals of eutrophication.

Causes of eutrophication

Most often mentioned are the:

- input of biogens compounds (ions) containing such elements like nitrogen (N) and phosphorus (P) or silicon (Si);
- increase of concentration of this biogenic element, which occurs in lowest concentration (limiting factor);
- input of organic matter (Photo.1.);
- change of hydro-meteorological conditions.

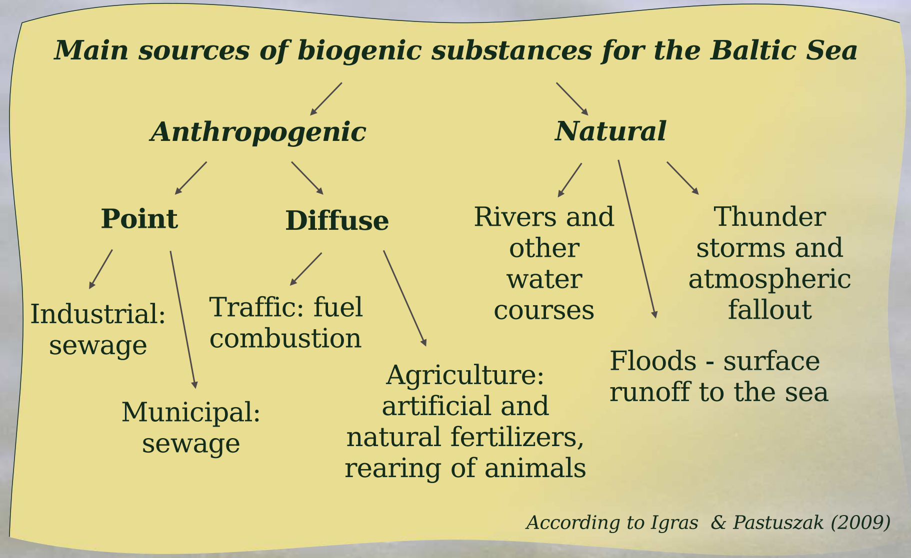


Photo.1. Suspended matter introduced by Vistula river to the Gulf of Gdansk flood of May 2010 satellite pictures (Remote Sensing Laboratory IOPAN)

Results of 'overnourishing' = signals of eutrophication

Generally, results of 'overnourishing' can be described as follows:

- Increase of primary production
- Intensive blooms of phytoplankton species, which may be toxic, e.g. blue-green algae (Photo.2);
- Proliferation of macroalgae e.g. some filamentous green-algae and brown algae, which can drift over large distances and accumulate at the shore (Photo.3);
- Increase of water turbidity in result of senescing of phytoplankton and macroalgae and sedimentation of the decaying products;
- At first development, and next extinction of the benthic species, i.e. organisms living on the bottom;
- Extinction of the fish species fished by man e.g. cod therefore a loss for fishing industry;
- Decrease of recreation and touristic values (Photo.3).

Photo.2. Blue green algae (Cyanobacteria) of the genus Anabaena, seen under microscope magnification 400 x (photo by Marine Pollution Laboratory, Institute of Oceanology PAN).

Photo.3. Algae at the beach, Sopot 24.08.2005 (Photo. Marine Pollution Laboratory IOPAN)

How to determine the stage of eutrophication?

Methods used for estimating the eutrophication level of a basin may be divided into those:

- based on following the eutrophication causes, e.g. determination of concentration and proportions of biogens in seawater;
- based on following the results of 'overnourishing', like determination of chlorophyll a concentration (Photo.4.), oxygen concentration in seawater, turbidity, number of benthic species or fish species;
- mathematical models based on different parameters.

Eutrophication of the Baltic

Eutrophication of the marine coastal zones became an important topic at different sites of the world. This is also one of the basic problems of the Baltic Sea, which is a brackish and semi-enclosed sea. It is characterized by limited water exchange with the North Sea (only through the Danish Sounds) and large inflow of freshwater, introduced mainly through rivers. As a result, in deeper areas, halocline occurs, i.e. a layer of water separating the surface less saline (lighter) water, which does not mix with the more saline (heavier) deep water. All these factors cause the Baltic Sea to be especially vulnerable to eutrophication. In some parts of the region it has occured since the nineteen fifties and in others since the nineteen seventies, especially along the western, southern and eastern coasts (Photo.4).

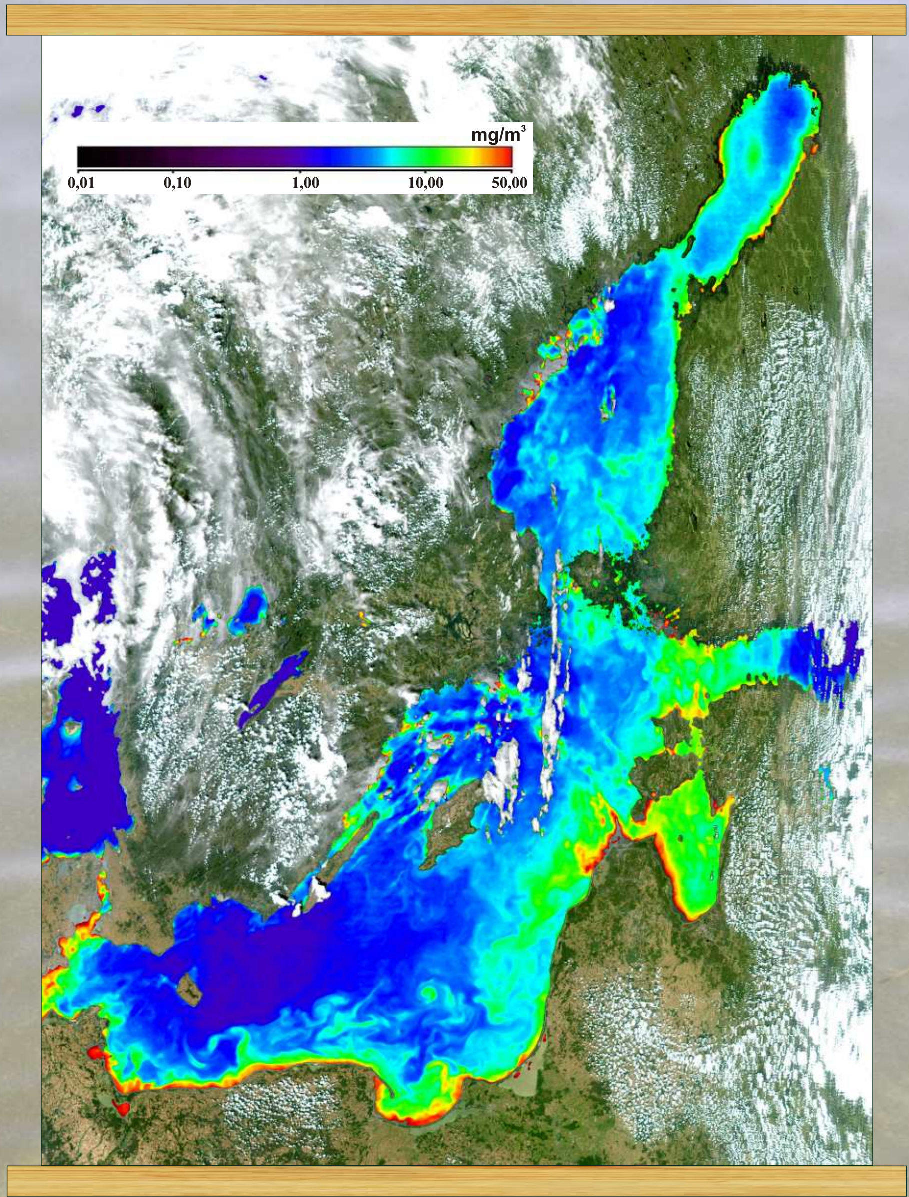


Photo.4. Baltic Sea satellite picture: concentration of chlorophyll a in the near-surface water layer (27.07.2006) on the basis MODIS AQUA data and algorithm elaborated by Remote Sensing Laboratory of IOPAN

Influence of the Polish rivers on eutrophication of the Baltic Sea

The load of biogenic substances introduced by rivers and other water courses to the Baltic Sea are directly linked to: size of the catchment area, number of inhabitants (45% of total number of Baltic catchment area population live in Poland) and size of agriculture areas (50% of agriculture areas in the Baltic catchment area are in Poland).

Around 99% of waters of Polish rivers flow to the Baltic Sea. Vistula (Wisla) river is the second largest and Odra river the seventh largest river in the catchment area of the Baltic Sea (Photo.5). Their input is 82% of the total water input from the territory of Poland.

Photo.5. Mouth of Vistula (Wisla) river (Phot. J.Czarkowski)

Directions of transfer of biogenic substances in the soil:

UP

- Collection by plants
- Evaporation to atmosphere of the gasous forms of nitrogen (NH_3, N_2, N_2O, NO, No_2)

HORIZONTAL

- Surface runoff (N, P in the dissolved form)
- Sub-surface runoff
- Drainage runoff

DOWN

- Leakage
- Soaking to underground waters

According to Igras & Pastuszak (2009)

The other rivers directly (majority of them is in the near-coastal voivodships) or by Pregola or Niemen drain 17% of water from territory of Poland. The outflow changes seasonally and annually. The Vistula drainage basin covers 54% of territory of Poland. The outflow of Vistula in between 1951-1998 was from 22 to 51 km^3/year, average 34 km^3/year.

The total outflow of biogenic load with the riverine waters to the Baltic decreased in the last twenty years, although this still locates Poland in first place among the Baltic countries.

However when we re-calculate these loads per inhabitant of the catchment area Poland is in last place (Fig.1).

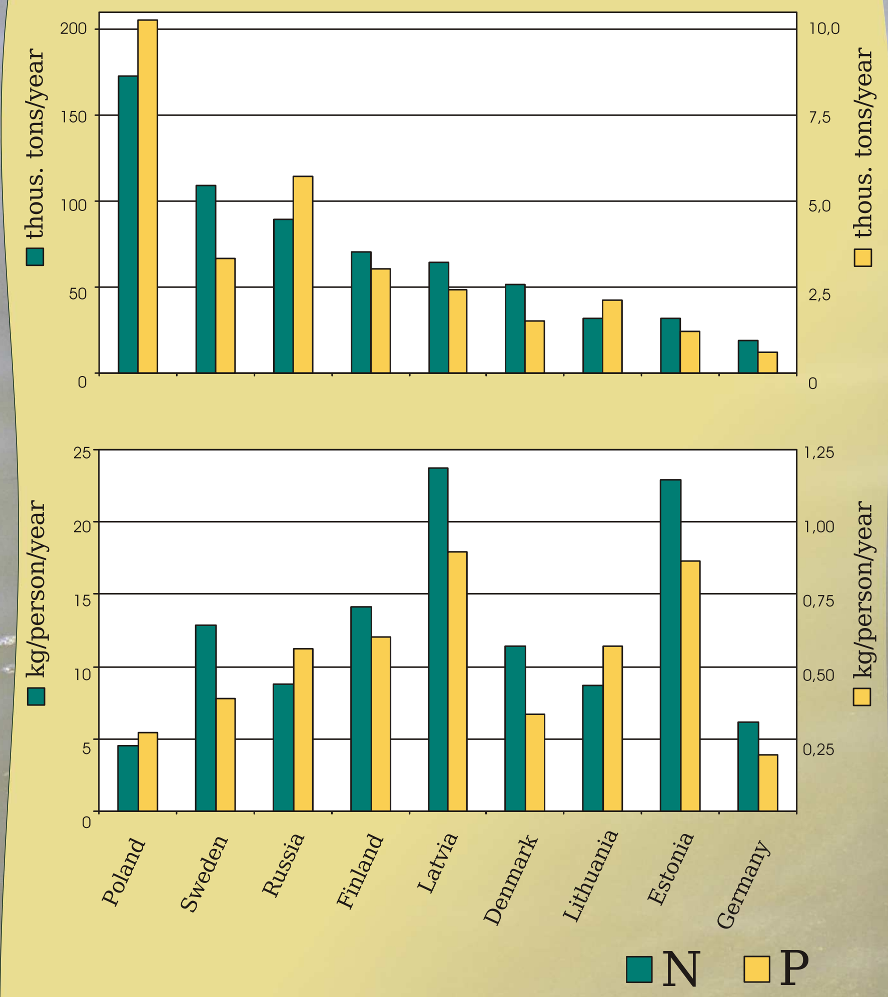


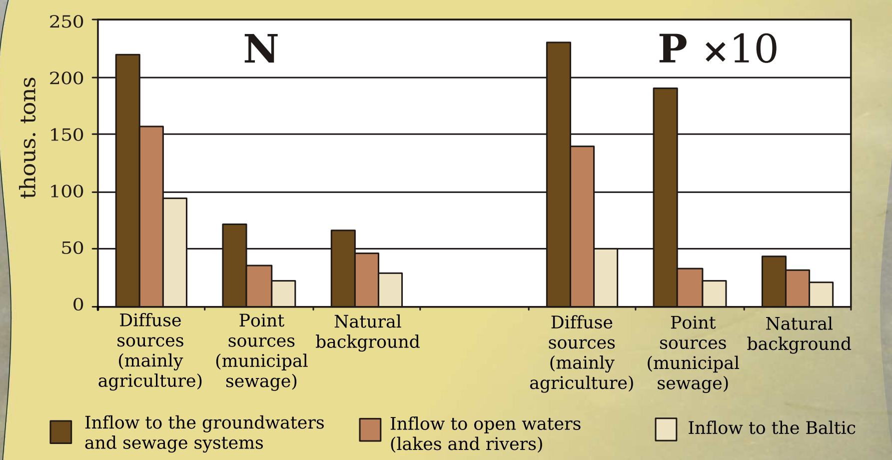
Fig.1. The mean annual loads of nitrogen (N) and phosphorus (P) introduced by the waterway to the Baltic in between 2001-2006.

According to HELCOM (2009)

Outflow of biogenic substances from the territory of Poland

Of the total outflow from agricultural areas of all the Baltic countries 50% of nitrogen (N) and 32% of phosphorous (P) comes from the territory of Poland (HELCOM 2004). The levels of *dissolved inorganic nitrogen* (DIN) forms and *dissolved inorganic phosphorus* (DIP) are 58-77% and 36-72% in *total nitrogen* (TN) and *total phosphorus* (TP), respectively.

Retention of the biogenic substances by sewage systems and on bottom and watersides of natural water courses and aquatic basisns (Fig.2).



Rys. 2. Inflow of biogenic elements (nitrogen - N, phosphorus - P) from different sources, to the Baltic from territory of Poland (2007)

According to Igras & Pastuszak (2009)

The main sources of nitrogen to Vistula river are from the groundwaters and the drainage outflow, for phosphorus sewage from the urban areas, surface runoff and insufficiently treated sewage from sewage systems.

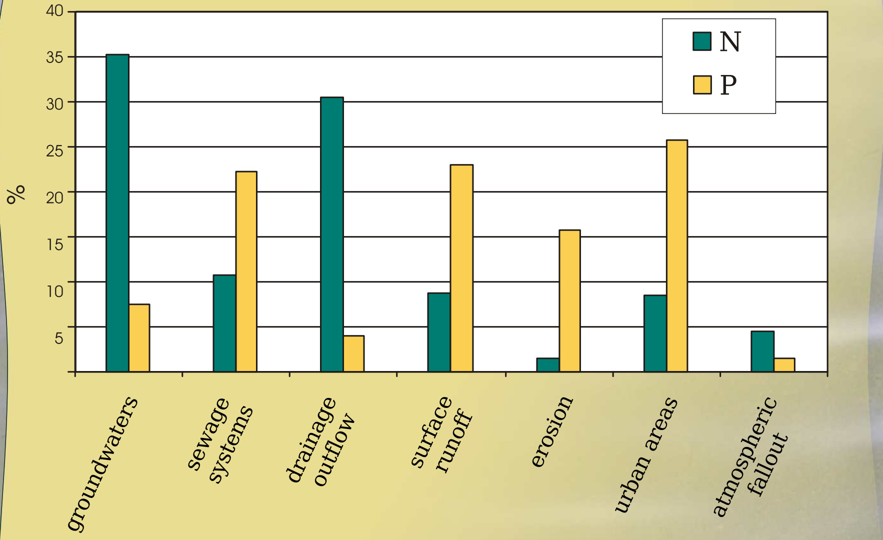


Fig.3. Percentage of the particular sources of nitrogen (N) and phosphorus to Vistula (1996 - 2000)

According to Igras & Pastuszak (2009)

The transfer by the air of biogens should be not forgotten, first of all of the nitrogen compounds (Fig.4). An important source of biogens for atmosphere is the rearing of animals. For example one cow emits up to 21 kg of nitrogen annually, only in the form of ammonia (Tab.1). Fuel combustion is also a source of nitrogen oxides to the atmosphere, e.g. the combustion of 1 kg of petrol in a passenger car forms, on average, 8.5 g of nutrient oxides (EEA, 2009).

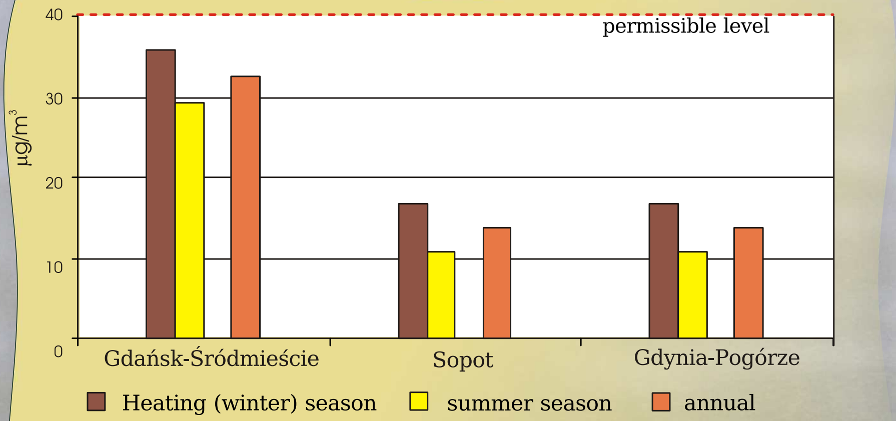


Fig.4. Mean concentration of nitrogen dioxide in the air of Tricity, in 2009.

According to ARMAAG (2010)

The pomorskie voivodship has more poor soils and belongs to the areas of an intensive agriculture. The higher usage of mineral fertilizers and of nitrogen and phosphorus is caused by high levels of animal rearing, resulting in a greater potential for harm to the marine environment, and is another example of an agriculture input to eutrophication.

Tab.1. Examples of ammonia emission indicators for different categories of animals (kg N-NH_3/item/year)

Animal category	**In the bedding system**		**In the system without bedding**
	On the deep dung system	With small amount of bedding	
calf 0-3 months	0,48	1,30	–
caws of a yield 3500 kg milk	6,40	15,72	16,90
caws of a yield 4000-6000 kg milk	7,89	19,40	20,85
pigs 70–110 kg	2,72	6,54	5,33
laying hens	–	0,239	–
turkeys	–	0,194	–
ducks	–	0,057	–

According to Igras & Pastuszak, 2009

Main legislation

- Konwencja Helsińska o ochronie środowiska morskiego obszaru Morza Bałtyckiego z 9 kwietnia 1992 roku — ratyfikowana przez Polskę w 1999 roku;
- Dyrektywa Azotanowa — Dyrektywa Rady 91/676 EWG z 12 grudnia 1991 roku w sprawie ochrony wód przed zanieczyszczeniami powodowanymi przez azotany pochodzące ze źródeł rolniczych (Dz. Urz. UE 68 PL, 15/t.2, L375/1, 31.12.1991);
- Ramowa Dyrektywa Wodna — RDW 2000/60/WE (ang. Water Framework Directive — WFD) Parlamentu Europejskiego i Rady z 23 października 2000 roku (Dz. Urz. WE L, 327/1, 22.12.2000);
- Prawo wodne z 18 lipca 2001 roku (Dz. U. Nr 115, poz. 1229, 2001 z późn. zm.);
- Ustawa o nawozach i nawożeniu z 10 lipca 2007 roku (Dz. U. Nr 147, poz. 1033, 2007).

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Sopot beach, 05.08.2010 (Photo. Marine Pollution Laboratory IOPAN)