Limiting sulphate load of wastewaters calls for environmental quality standards

The clean energy transition and the green transition are bringing mining and battery technology industries to Finland. As a result, the sulphate discharges into inland waters and the Baltic Sea will increase. Sulphate also has beneficial effects in water bodies, and sulphate is not currently classified as a harmful substance. However, a high local load may have negative effects on aquatic organisms, especially in lakes with naturally low sulphate concentration. In sea water, sulphate occurs naturally, and organisms have adapted to it better. However, in the brackish waters like the Baltic Sea sulphate may also be more harmful than in oceans. In the Baltic Sea large quantities of sulphate change the cycling of several substances in way that can have harmful effects.

Recommendations

- Setting environmental quality standards for sulphate in water bodies is a necessity. These standards should be added in the Government Decree on Substances Dangerous and Harmful to the Aquatic Environment. The standards will allow permitting authorities to set justified limit values for sulphate emissions. Environmental quality standards for lakes must be considerably stricter than those for coastal waters. It is also important that the permitting considers the total sulphate loads from several different emission sources into the catchment area.
- The harmful effects of sulphate can be mitigated by selecting the wastewater discharge site in an area where the wastewater will dilute rapidly, and the dilute wastewater flows downstream or into the open sea. Options for removing sulphate during manufacturing process should also be investigated.
- The distribution of sulphate emissions must be simulated already before the start of operations, by modelling at least the normal emission situation and the exceptional situation that causes the greatest possible harm. Operators should ensure that the criteria for good modelling practice are followed in the modelling.
- Sulphate concentration levels should be complemented with monitoring of the bottom sediment and organisms, when setting the statutory monitoring requirements for the environmental permits.

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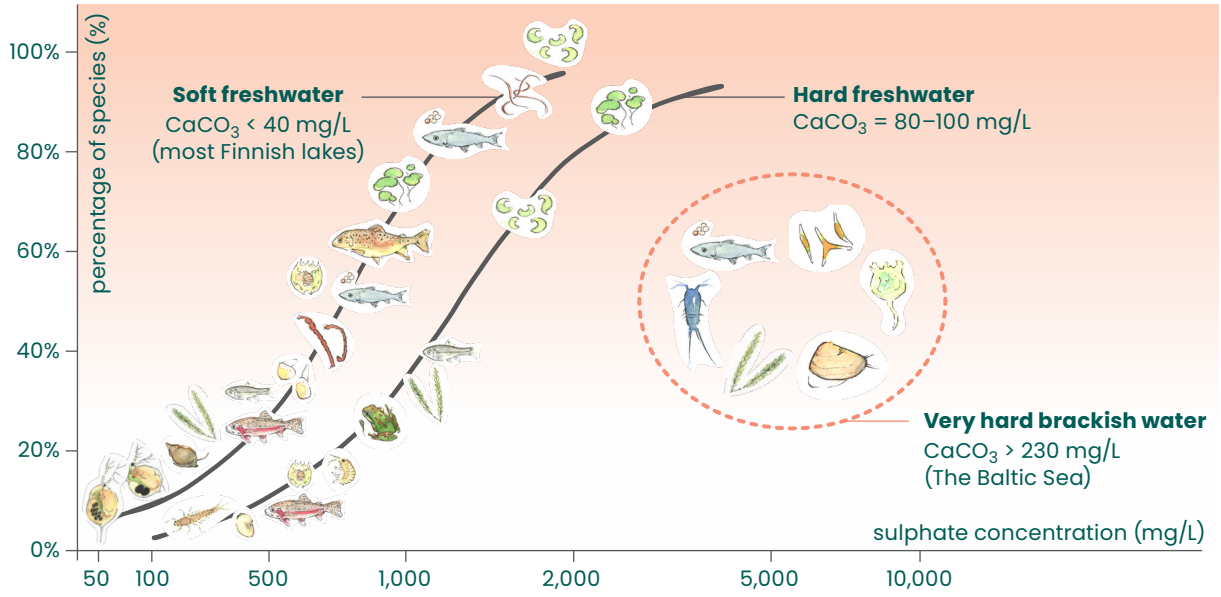
Susceptibility of aquatic organisms to sulphate



ORIGINAL IMAGE ©XIAOXUAN HU. SOURCE: SAHLIN & ÅGERSTRAND (2018)[1], KARJALAINEN ET AL.(2023).[2]

The susceptibility of species to different sulphate concentrations is tested by toxicity tests. Susceptibility is used to determine the safe sulphate concentration of waters, which can be applied as a limit value in legislation. The natural salinity of water affects the susceptibility of organisms: in soft freshwater, a smaller increase in sulphate concentration causes more harmful effects than in hard brackish water. Impacts on the species in the Baltic Sea are currently being studied.

Sulphate is harmful to aquatic organisms

The clean energy transition must be implemented so that harm to aquatic environment is minimized. Yet, the mining and battery industry will increase sulphate discharge to waters. The mining industry causes sulphate loading into inland waters, and wastewater from the battery industry generates loading into the Baltic Sea. This theme is now topical, as the Government Decree on Substances Dangerous and Harmful to the Aquatic Environment[3] will be reviewed for an update in the near future.

Sulphate is known to be harmful to aquatic organisms.[1] Despite this, no limit values for sulphate in aquatic environments have been set in Finland or hardly any other countries.

The sulphate content of the Finnish lake waters is naturally low. However, sulphate forms part of the salinity, i.e. the ionic strength of the water. The sulphate load increases the ionic strength of the water and thus interferes with the organisms' internal ionic regulation.

In the sea, in contrast, organisms remove ions to maintain the salt balance of their cells. The natural high ionic strength of the more saline waters seems to protect organisms from the harmful effects of sulphate.

The harmless concentration of sulphate has been studied with toxicity tests conducted by the University of Jyväskylä and the Finnish Environment Institute.[2] Both short-term and long-term sulphate exposures to organisms in freshwaters and the Baltic Sea were carried out. Freshwater zooplankton species appeared to be the most susceptible to sulphate, while plants and fish embryos appeared to be the most resistant. According to modelling and safety factors, the safe sulphate concentration in long-term exposure to freshwaters varied between 39 and 65 milligrams per litre. The concentration in short-term exposure varied between 257 and 339 milligrams per litre. In brackish water species, the harmless concentration appears to be approximately ten times higher. The safe concentrations for brackish water species are being specified.

When examining the harmful effects of sulphate emissions, it should also be noted that the emissions consist of different mixtures of substances whose combined effects may be harmful. Toxic effect of mixtures can be assessed by biological testing, which can show the combined effects of harmful substances.

Increased concentration speeds up transport of sulphate into the bottom sediment

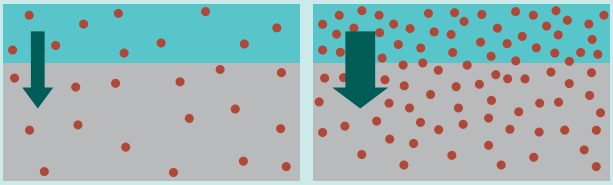


IMAGE: SYKE

The effects of sulphate on sediment and organisms must be monitored.

Sulphate plays an important role in matter cycles

If the wastewater contains a lot of sulphate, it may settle to the bottom as heavier than the rest of the water and intensify water stratification, especially in lakes. This happened as a result of the environmental accident at the Talvivaara mine.[4] The intensity of the stratification depends on the flows at the discharge site and, for example, the season. A well-mixed area from which dilute wastewater flows downstream or into the open sea must be selected as the discharge site for wastewater containing sulphate.

In the aquatic environment, substances are bind to the growth of plants and other organisms and are released back into matter cycling as organic matter decomposes. This occurs mainly through microbial respiration, for example in the bottom sediment.

Sulphate participates in the decomposition of organic matter, producing hydrogen sulphide which is toxic to organisms.[5,6] Certain sulphate reducing microbes can also produce toxic methyl mercury. On the other hand, sulphate reduces the release of a powerful greenhouse gas, methane, from the bottom sediment. When sulphate participates in the decomposition sulphides are produced, which remove harmful metals from the water by binding them into metal sulphides.

The formation of iron sulphides may increase the release of phosphorus and thus intensify eutrophication. In other words, wastewater sulphates do not accelerate the growth of algae directly, but only after the formation of iron sulphides. In the sea, this may cause local eutrophication, but in inland waters, the eutrophication may be increased in the entire lake, at worst.

The most suitable discharge site can be found by modelling

The mixing, dilution and transport of sulphate under different conditions is modelled using computer programmes and simulations. The aim is to ensure that the sulphate concentration caused by the discharge remains within the permitted limits, and that the operations are environmentally acceptable.

Modelling always necessitates assumptions and simplifications, which vary from case to case. The model must take into account, for example, the deeps and straits. The results of the models should be compared with previous observations on, for example, salinity and thermal stratification.

In wastewater collection basins, stratification can be modelled with simple models. However, lake and sea areas also require information on seasonal flow conditions, and the models are therefore more complex. The likely range of emission impacts can be demonstrated by modelling not only the most common emission and natural conditions but also the exceptional situation that causes the greatest harm.

According to the Environmental Protection Act, environmental impacts must be assessed with sufficient certainty. Too much uncertainty that the aquatic environment may deteriorate significantly prevents the granting of a permit, due to the precautionary principle. Operators should ensure that the criteria for good modelling practice are followed in the modelling.[7] This allows the operator and the permitting authority to make an adequate interpretation and assessment of the results of the modelling.

Battery industry increases the sulphate load

In Finland, at least one million tonnes of sulphate is transported into natural waters every year.[8] Sulphate data are not available for all production sectors.

The annual sulphate loading from the mining company Terrafame has varied between 11,000 and 14,500 tonnes in recent years. An individual battery materials plant can produce a sulphate load of up to 100,000 tonnes per year.

Sulphate concentration in the Baltic Sea is naturally much higher than in Finnish lakes. Sulphate is mostly imported to the Baltic Sea through the inflow of saline water from the North Sea. Medium-sized major Baltic inflows transport an estimated 80 to 150 million tonnes of sulphate in approximately one week. Some of the sulphate leaves through the Danish straits to the North Sea.

Several activities cause sulphate load to waters

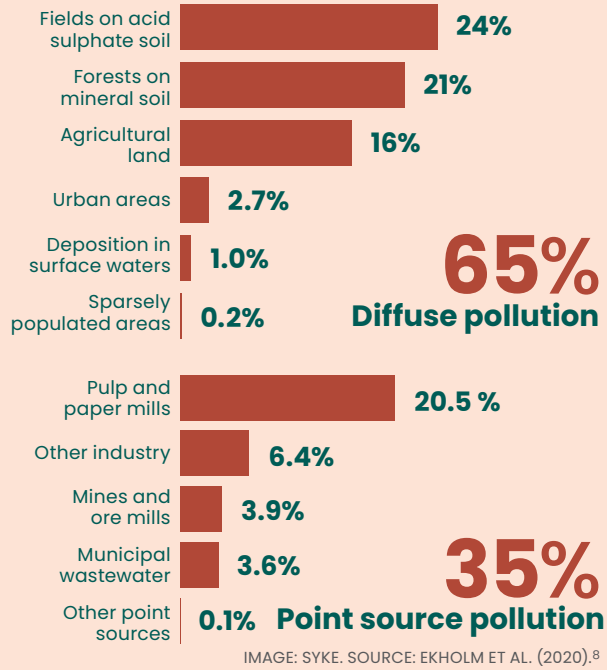


IMAGE: SYKE. SOURCE: EKHOLM ET AL. (2020).[8]

Approximately one million tonnes of sulphate is washed into waters every year. In the future, wastewater from an individual battery materials plant can cause an annual load of up to 100,000 tonnes, which means that it can account for almost 10 percent of the annual load. Graph data are from 2000s, latest values from year 2018.

The EU will draw up demands for battery manufacturing

The preparation of Best Available Techniques (BAT) definitions for battery manufacturing will start to be prepared in the EU, in 2025. The content and more detailed scope of the BAT reference document, as well as the BAT conclusions to be determined based on them, will only be confirmed during the preparation process. Possible requirements for the removal or recycling of wastewater sulphate are addressed during the process.

If necessary, Finland may impose national restrictions on the sulphate concentrations of the aquatic environment. According to recent studies, large quantities of sulphate are particularly harmful to lake organisms. The impacts on Finnish coastal areas may also be more harmful than on the seas in general, as the brackish Baltic Sea has naturally less sulphate than the oceans.

National environmental quality standards required for sulphate

In Finland, sulphate is not included in the Decree on Substances Dangerous and Harmful to the Aquatic Environment,[3] and no environmental quality standards have been set for it. Sulphate with scientifically derived environmental quality standards should be added to the decree. Freshwater and coastal waters require separate standards. The decree will be updated in the next few years. The Finnish Environment Institute has proposed adding sulphate to the decree.[9] The proposal for the quality standard of annual average concentration for inland waters is 39 milligrams per litre, and 279 milligrams per litre for the environmental quality standard of instantaneous concentration. Proposals for environmental quality standards for sulphate are also being prepared for coastal waters.

Activities that pose a risk of water contamination must have an environmental permit in accordance with the Environmental Protection Act. The permit process must ensure that discharges do not cause significant contamination of the aquatic environment. Setting environmental quality standards would make it easier to assess the risks of sulphate discharges. This would unify permit decisions across Finland. The permit process should also consider the fact that sulphate loads may accumulate into the water bodies from several different emission sources. The statutory monitoring obligations will provide more comprehensive installation specific information on sulphate discharges and their impacts.

Mining and battery technology industries are essential in the green transition. In green transition projects, it is also important to examine environmental impacts so that they include impacts on air, soil and water, as well as entire life cycle impacts of production.

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