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**P**otential impact of a  
seawater flue gas  
desulfurisation (SWFGD)  
effluent on coral reef  
communities

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**Abstract**  
On basis of available literature information there is little reason to expect that the effluent from an SWFGD planned at Yanby, Saudi Arabia, will cause any damage to local coral reef formations, the nearest being about 3.5 km away. The corals may over time accumulate nickel and vanadium from the effluent, but the predicted moderate metal levels in the outfall, and the mixing of the outfall water with seawater before the reef is reached, suggest that such accumulation will be modest. Comparison of the theoretical oxygen concentration in the effluent with the normal range of the recipient seawater implies that the outfall should not have a significant negative effect on ambient oxygen conditions. There may be a reason for concern regarding the effects of the elevated temperature of the outfall, but this will be due to the use as cooling water for the power station, rather than caused by the SWFGD.

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O-98165

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## Preface

On request from ABB Environmental, Oslo, Norway, the Norwegian Institute for Water Research (NIVA) has produced a short review on the known and likely effects of the effluent from a seawater flue gas desulfurisation (SWFGD) plant on tropical, shallow water, marine organisms. The emphasis of the report is on the effects of this type of effluent on coral reef communities, and relates to a prospected SWFGD establishment at Yanby, Saudi Arabia. The report is based on information from ABB on the outfall characteristics at Yanby, general scientific literature of relevance, and on the experience gained from biological and chemical monitoring of the marine recipient outside a similar SWFGD outfall at the south coast of Tenerife, Canary Islands, Spain. Research Scientist Torgeir Bakke, NIVA, has been responsible for preparing the report in cooperation with Research Manager Ketil Hylland (information on coral reefs) and Research Manager Jan Magnusson (information on oxygen conditions), both at NIVA.

Oslo, 21 June 1999

*Torgeir Bakke*

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## Summary

The report presents a brief assessment of the potential effects of a power station seawater flue gas desulfurisation (SWFGD) effluent on coral reef organisms. The main factors that may cause any environmental impact from an SWFGD are in general pH, oxygen deficiency, elevated levels of heavy metals, and suspended particles. Elevated temperature is also an important feature of the effluent, but not caused by the SWFGD itself. In the present case the effluent characteristics given by ABB identify oxygen deficiency, nickel and vanadium levels, and temperature as the factors that may have any impact on the marine recipient.

The experience from monitoring the marine recipient outside a similar unit at Tenerife, Canary Islands, indicate that the effluent has no environmental impact, besides slight local bottom community changes probably due to the construction of the outfall pipeline arrangement or local changes in the bottom current patterns.

On basis of the effluent description and calculated ambient oxygen levels, there is little reason to expect that the effluent will have a significant negative effect on the local oxygen conditions.

The available scientific literature suggests that reef-building corals are relatively tolerant to heavy metals. The effluent level of nickel is not expected to exceed the relevant ambient standard for the area. For vanadium there is no local standard. The low metal levels in the effluent and the further dilution by recipient seawater before the effluent water reaches the nearest coral reef suggest that the metals will have no deleterious effects on the reef. A gradual accumulation of these metals in the coral skeleton is to be expected.

The effluent temperature, due to the use of the water as power station cooling water, is 6 – 20°C above ambient. This is a clear matter of concern, but until the dispersion and dilution of the temperature have been described by either measurements or modelling, the potential damage to nearby coral reefs cannot be assessed.

# **1. Background**

On request from ABB Environmental NIVA has made a brief assessment of the potential effects of a power station SWFGD effluent on coral reef organisms. The assessment is based on available scientific literature, information on ambient water and effluent characteristics related to a potential SWFGD development at Yanbu, Saudi Arabia, and previous NIVA experience regarding impact of SWFGD discharges on marine ecosystems.

## 2. Characteristics of the SWFGD effluent

In general the main factors of the SWFGD effluent, which may potentially cause environmental impact, are

- pH
- oxygen deficiency
- excess concentration of the heavy metals nickel and vanadium
- load of suspended particles
- high temperature

The last factor, high temperature, is not *per se* an effect of the SWFGD. It has been included since almost all SWFGD units utilise seawater from existing cooling water systems, and since the SWFGD water in almost all cases is discharged to the recipient as part of the cooling water effluent. However, the contribution of the SWFGD to the elevated temperature is small, normally less than 1°C. In the Yanby project the SWFGD water will contribute to a rise of about 0.5°C in the temperature of the total outfall. This represents 2.5 - 8 % of the total overtemperature of the cooling water, being 6 - 20 °C depending on the ambient temperature.

Table 1 shows the various cooling water streams of the Yanby project and their physical-chemical characteristics. The table also contain discharge and ambient standards to which the effluent shall comply. This shows that the pH already in the outfall channel meets the ambient standard of 8.

The factors which may be of concern regarding the environment, are oxygen decreases, enrichment of nickel and vanadium, and increased temperature.

**Table 1.** Expected levels of water quality parameters in the partial and total outfall from the power station and SWFGD at Yanby, and relevant effluent and ambient water quality standards.

-: no standards given.

Parameter	SWTP outlet	Outfall channel	Effluent standard	Ambient standard
Volume (m <sup>3</sup> /h)	40 000	235 000	-	-
Temperature (°C)	38.8	38.1	-	-
pH	6	8	6	8
COD (mg O <sub>2</sub> /l)	1	0.2	75	Shall not cause a contra- vention of the DO standard
DO (% saturation)	70	80	5 mg O <sub>2</sub> /l	100
Vanadium (µg/l)	24	4	-	-
Nickel (µg/l)	11	1.8	200	2



### 3, Experience from other SWFGD effluents

To our knowledge there exists no SWFGD unit in operation from which there are reliable monitoring data on the possible impact on coral reefs. We will, however, regard the results from the monitoring around the SWFGD units of the UNELCO power station at Granadilla, Tenerife, Canary Islands as being partially relevant for the situation at Yanby. Both power stations are oil fuelled, and the recipients are warm water regions. The salinity and temperature regimes in the two recipients are given in table 2, reflecting the tropical and highly saline characteristics of the Yanby region and the subtropical of Tenerife. One may expect that the ecosystem at Yanby at periods lives closer to its upper temperature tolerance limit than at Tenerife, and hence is more sensitive to a temperature increase due to the cooling water. Also the oxygen concentration at 100 % saturation will be less at the high temperature and salinity at Yanby, which puts an extra hypoxic stress on tropical organisms. This difference in hydrography may therefore have an influence on the ecosystem sensitivity to the cooling water overtemperature and oxygen content, but there should be no systematic difference in the potential effects of the other effluent factors.

**Table 2.** Approximal annual range in surface temperature and salinity at Yanby, Saudi Arabia and Granadilla, Tenerife, Canary Islands.

	Yanby	Granadilla
Temperature (°C)	18 - 32	19.5 – 24.5
Salinity	39.0 – 42.5	36.7 – 37.0

So far the Tenerife results have shown no pollution effects in the recipient. There are indications of slight modifications in the soft bottom community structure very close to the discharge point (i.e. within less than about 200 m) due to a change in grain size distribution of the sediment. This is most probably a consequence of either the construction of the outlet arrangement or changes in bottom water movement due to the physical presence of the outlet and the discharge jet current (SEMALL 1998). Also the construction itself has created a new hard bottom substrate, and the early algal growth on this may have increased the population of sea urchins, which again seems to have enhanced a grazing effect on the nearby natural bottoms.

## 4. Impact of oxygen deficiency on coral reefs

Due to the low solubility of gases in warm saline tropical waters, tropical marine organisms face lower oxygen concentrations compared to marine organisms at higher latitudes even at 100% saturation. The range in oxygen concentrations at Yanby has been reported to be 3.5 – 5 mgO<sub>2</sub>/l. An antropogenic reduction in oxygen saturation may therefore have stronger implication on such systems than in colder water. A reduction in oxygen content of warm surface waters has been a concern regarding potential coral reef damage (e.g. Hylland 1994).

Two factors contribute to a reduction in the oxygen concentration in the final effluent from the SWFGD compared to the ambient waters:

- the reduced saturation in the SWTP outlet due to oxidation of SO<sub>2</sub> to SO<sub>4</sub><sup>2-</sup> (which is partially compensated for in the aeration basin),
- any remaining, unoxidised SO<sub>2</sub> expressed as COD (chemical oxygen demand).

Table 1 shows that the final outfall will be 80 % saturated with oxygen, corresponding to a theoretical concentration of 4.2 - 4.3 mgO<sub>2</sub>/l at the temperature and salinity of the outfall. If the COD is realised through further oxidation this should lower the concentration slightly to 4.0 – 4.1 mgO<sub>2</sub>/l. However, according to information from ABB evidence shows that the realisation of the remaining COD is relatively slow, and will probably not be manifested until long after the water has been discharged.

The ambient standard requirement for oxygen to comply with is 100 % saturation, which would be theoretically impossible to reach by dilution unless the dilution water is supersaturated. On the other hand the theoretical minimum oxygen content of the outfall of 4 mgO<sub>2</sub>/l is within the natural range in the area (3.5 – 5 mgO<sub>2</sub>/l). This in itself would imply that the effluent should not have a significant negative effect on the oxygen conditions in the recipient.

The potential effect of low oxygen solubility at high temperature and salinity should not be exaggerated. In a shallow water system with strong water movements the organisms are only taking out a fraction of the available oxygen in the seawater. As long as the saturation is reasonably high (even if the oxygen concentration at 100 % saturation is low) the respiratory extraction of oxygen should cause no stress to the organisms. Our experience shows that when measuring respiration experimentally, one can normally allow for the saturation to vary between 100 and 70 % without any apparent effect on the oxygen uptake in marine organisms.

## 5. Impact of metals on coral reefs

Several studies deal with impact of heavy metals on reef-building coral organisms, but most of these treat accumulation in tissues and coral matrix rather than biological effects. There is evidence of decreased growth rates and excessive mucus production in coral organisms as result of metal exposure (Howard and Brown 1984). The presence of symbiotic algae (zooxanthellae) in corals seems to stimulate metal accumulation (Harland et al. 1990), and loss of such symbionts have been reported after exposure to elevated levels of iron (Harland and Brown 1989). No reports on biological effects of nickel and vanadium have been found, although there are several reports on accumulation of these metals in corals.

The general impression is that coral organisms are relatively tolerant to metals, and since they tend to incorporate metals in the coral skeleton over time, they have been used by many authors as indicators of metal pollution (e.g. Hanna and Muir 1990, Scott and Davies 1997 and many others). This use would also imply a certain tolerance to toxic effects of metals.

The ambient standard for nickel (table 1) of 2 µg/l is not expected to be exceeded in the final outfall (1.8 µg/l). This level further corresponds to the classification "moderately polluted" by the Norwegian State Pollution Control Authority (class 2 on a scale from 1: *clean* to 5: *very heavily polluted*). Taking into consideration that further dilution of the outfall will occur in the recipient, there is little reason to expect any deleterious effects of the nickel input to the nearest coral reef area, approximately 3.5 km from the discharge canal. One may, however, expect that the long term supply of nickel (and vanadium) to the recipient will be reflected in some accumulation of these metals in the coral skeleton over time, but without any apparent harm to the coral organisms.

There is no ambient standard for vanadium for the region in question. In a recent environmental impact assessment in the Gulf of Venezuela (Bakke et al. 1992) an ambient standard of 100 µg/l was used, based on Mance et al (1988). The outfall concentration of 4 µg/l is far below this level, hence there is little reason to expect any damage due to vanadium.

## **6. Impact of excess temperature on coral reefs**

As discussed earlier any impact from the excess temperature of the discharge will occur whether the SWFGD unit is in operation or not, since this is caused by the use of the seawater as cooling water for the power station itself.

There is increasing evidence that depigmentation due to loss of zooxanthellae (bleaching) in corals is caused by elevated temperature. Bleaching events over rather wide scales have been recorded as results of periodic ocean warming (e.g. El Niño, Glynn and de Weerd, 1991), and has caused a general concern for the effects of global warming on coral reefs. Although some recovery during colder periods has been reported, such bleaching is in many cases followed by coral death. Tropical coral reefs are frequently close to the upper limit of their temperature tolerance, and an excess temperature of 1°C above long term averages seem to be sufficient to elicit bleaching (Goreau and Hayes, 1994).

The outfall channel temperature of 38.1°C, which is 6 - 20°C above the ambient range (18.3 – 32.2°C at the water intake), is therefore a clear matter of concern. Until the temperature dilution and distribution pattern in the recipient is described (by measurements or modelling), one cannot assess the danger of damage to local coral reefs.

## **7. Conclusions**

On basis of available information there is little reason to expect that the outfall from the SWFGD planned at Yanby in itself will cause any damage to the coral reef formations in the recipient area. The corals may over time accumulate nickel and vanadium from the effluent, but the predicted moderate metal levels in the effluent, and the further mixing of the outfall water with natural seawater until the nearest reef formations about 3.5 km away is reached, suggest that such accumulation will be modest. Comparison of the theoretical oxygen concentration in the outfall with the normal range of the recipient seawater implies that the outfall should not have a significant negative effect on the ambient oxygen conditions. There may be a reason for concern regarding the effects of the elevated temperature of the outfall, but this will be due to the use as cooling water for the power station, rather than caused by the SWFGD.

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