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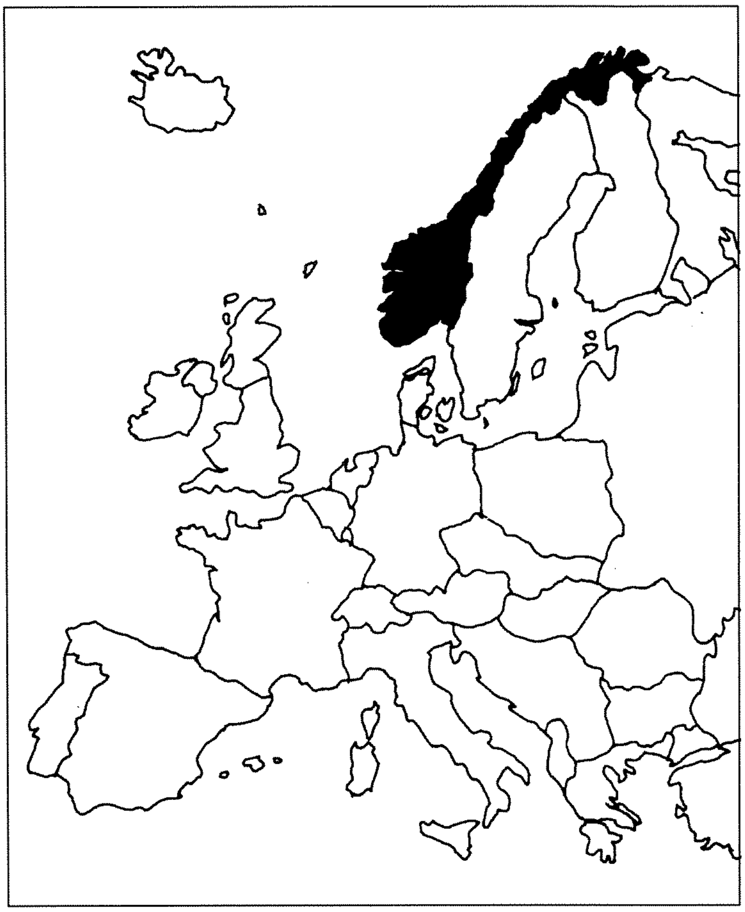
Levels and environmental effects of TBT in marine organisms and sediments from the Norwegian coast.

A summary report



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NIVA Norwegian Institute for Water Research

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REPORT

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Abstract. Concentrations of TBT in sediments, blue mussels (*Mytilus edulis*) and dogwhelks (*Nucella lapillus*) from the Norwegian coast is summarised. The occurrence of imposex in dogwhelks along the coast is given. Most of the sediments contained concentrations below 100 ng/g d.w.. Sediment from 16 sites contained more than 1000 ng/g d.w. TBT whereas sediment from 17 sites contained between 100 and 1000 ng/g d.w of TBT. Maximum concentration of TBT was found in sediments from a navy harbour near the city of Bergen (103800 ng/g d.w.). Traces of TBT were, however, also found in sediments from remote, sparsely populated, areas along the coast. The concentrations of TBT in mussels from the Norwegian coast varied from less than 10 µg/kg wet weight to about 3000 µg/kg wet weight. The highest concentrations were found in and around harbours. Some degree of imposex occurred in all populations of dogwhelks except four stations in northern Norway (Finnmark). At about half of the total number of sites, a part of the female dogwhelk population was sterile. The concentration of TBT in the dogwhelks from the unaffected populations in Finnmark was below the detection limit (17 ng/g d.w.). The concentration of TBT in dogwhelks from affected populations was in the range 50-2676 ng/g d.w. It was observed a positive relation between concentration of TBT in dogwhelks and the degree of imposex. The results demonstrate that organotin compounds are present in most anthrophogenic influenced areas along the Norwegian coast. The major use of TBT in Norway is in antifouling agents on boats larger than 25 m. Total amount of TBT sold in Norway in 1994 was 36.7 t (23.4 t in antifouling paints for large boats). It is expected that a general reduction in the occurrence of organotin compounds along the Norwegian coast can only be achieved by enforcing restrictions on the use of such compounds on large vessels.

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1. TBT	1. TBT
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Levels and environmental effects of TBT in marine organisms and sediments from the Norwegian coast. A summary report

Preface

The present report has been financed by the Norwegian State Pollution Control Authority (SFT). The report summarises available data on organotin (mainly TBT) along the Norwegian coast. The main purpose of the report is to summarise relevant national data as part of the International Maritime Organization`s (IMO) effort to get a global overview of possible effects of antifouling agents in the marine environment. This will be part of the backgound information for an evaluation of the need to enforce further restrictions on the use of TBT in antifouling agents on ships. The report is also for use within the framework of OSPARCOM [Oslo and Paris Commissions and SIME (Working group on Concentrations,Ttrends and Effects of Substances in the Marine Environment]. Parts of the present report were submitted to SIME in 1996.

Most of the data presented are from reports within the State Pollution Monitoring Program of Norway, sponsored by SFT. The data on the concentration of organotin in dogwhelks are from work done by Norunn Følsvik at NIVA as part of her cand. scient. thesis. at the University of Oslo (Supervisors: Tyge Greibrokk, Einar M. Brevik, John Arthur Berge)

Oslo, April 10th, 1997

John Arthur Berge

Contents

Summary

Tributyltin (TBT) is one of the most toxic substances known. In the marine environment the main focus has been on the antifouling agent TBT although other organotin compounds may also be present. Unintentional effects of TBT have been discovered in populations of certain snail species (neogastropods), and have greatly reduced their densities. Effects of TBT has been observed primarely as the induction of male sex characters in females, known as "imposex". Imposex have been found in about one hundred species of gastropods worldwide. Imposex occurs because exposure to TBT results in the accumulation of a male hormone (testosterone) in female gastropods. Species particularly sensitive to TBT may show signs of effects at water concentrations of TBT as low as 1 ng/l. Many countries have therefore introduced restrictions on the use of TBT. In Norway, its use on boats less than 25 m in length has been prohibited since 1989 and in aquaculture a total ban of the use of TBT on fish cages was introduced in 1989/90.

In Norway the amount of TBT in antifouling paints, sold for use on ships larger than 25 m, has been in the range 11.7(1985)-28.5 (1991) ton/yr during the last 11 years. Approximately 90 % of the TBT used on the hull of ships and 10 % of the TBT used as wood preservatives are expected to end up in the environment. Total discharges of TBT from these two sources to the aquatic environment in Norway during the period 1985-1995 has been estimated to be in the range 18.7 ton/yr in 1989 to 57.3 ton/yr in 1985 (approximately 1-1.5 ton/yr of this was derived from wood preservatives). However, other sources may also contribute.

In order to evaluate the current status of organotin pollution along the Norwegian coast, sediments (100 stations) and blue mussels (*Mytilus edulis*) (63 stations) has been analysed for TBT (GC/MSD). The occurrence of imposex in dogwhelks (*Nucella lapillus*) were investigated in 41 populations sampled in 1993-1995 along the coast from Finnmark to the Skagerrak in the south. The degree of imposex was classified by the Relative Penis Size Index (RPSI) and the Vas Deferens Sequence Index (VDSI). The concentration of TBT was analysed in dogwhelks from 16 of the 41 populations characterised with respect to imposex. The quantification was done by gaschromatography equipped with an atomic emission detector (GC-AED).

The sediment concentrations of TBT in harbours in Northern Norway were highly variable. Most of the sediments contained concentrations below 100 ng/g d.w.. Sediment from 16 sites contained more than 1000 ng/g d.w. TBT, whereas sediment from 17 sites contained between 100 and 1000 ng/g d.w of TBT. The maximum concentration of TBT was found in sediments from a navy harbour near the city of Bergen (103800 ng/g d.w. TBT). The analysis show that many harbour sediments are contaminated with TBT. Analysis of sediment from more remote, sparsely populated, areas along the coast were few, but traces of TBT were also found in sediments form such sites.

The concentration of TBT in mussels from the Norwegian coast varied from less than 10 μg/kg wet weight to about 3000 μg/kg wet weight. The highest concentrations were found in and around harbours. Even in open waters, however, concentrations of up to 150 μg/kg wet weight were found in mussels, which corresponds to concentrations in water exceeding the threshold for injury to sensitive organisms.

Some degree of imposex occurred in all investigated populations of dogwhelks except four stations in Northern Norway (Finnmark). At about half of the sites, a proportion of the female population was sterile (VDSI>4). The concentration of TBT in the gastropods from the unaffected populations in Northern Norway was below the detection limit (17 ng/g d.w.). The concentration of TBT in

dogwhelks from affected populations was in the range 50-2676 ng/g d.w. There seems to be a positive relation between concentration of TBT in dogwhelks and the degree of imposex .

The results demonstrate that organotin compounds are present in the environment in most anthropogenic influenced areas along the Norwegian coast. Biological effects on dogwhelks are widespread in most Norwegian coastal areas apart from some remote northern regions. Populations of *Nucella* from six stations investigated both in 1991 and in 1993 showed signs of reduction in VDSI and RPSI and thus indicate some imposex recovery.

It is expected that a general reduction in the occurrence of organotin compounds in the environment along the Norwegian coast best can be achieved by enforcing restrictions on the use of such compounds also on larger vessels.

1. Introduction

The use of organotin compounds as antifouling agents, fungicides, insecticides and bactericides has increased dramatically over the last 30 years (Huggett *et al.,* 1992 with references) and are considered among the most toxic compounds introduced to the marine environment by man (Goldberg, 1986). In the marine environment the main focus has been on the extremely effective antifouling agent tributyltin (TBT) although other organotin compounds may be present in water and sediment (Rosales *et al.,* 1992). Unintended environmental effects from TBT in antifouling paints was first found in the Arcachon Bay in France in the late 1970s on the Pacific oyster (*Crassostrea gigas*) (Alzieu *et al.,* 1986 with references, see also Ruiz et al. 1996). Effects of organotin compounds have since then been reported for a variety of other marine species (fish, gastropods, crustaceans, echinoderms, micro algae) at concentrations that may be found in anthropogenically influenced areas (Beaumont & Newman, 1986 a and b; Walsh *et al.,* 1986; Hall, 1988; Bryan *et al.,* 1986, 1989; Johansen & Møhlenberg, 1987; Bushong et al., 1990; Fent & Meier, 1994). In the last decade much attention has been paid to induction of male sex characters in female snails, known as "imposex", observed mainly in neogastropods (Bryan *et al.,* 1986; Gibbs & Bryan, 1986; Gibbs *et al.,* 1987; Horiguchi *et al.,* 1994). The first description of imposex was given by Blaber (1970).

Most investigations points to TBT as the agent responsible for imposex, however, there are some indications that other compounds/situations also may induce this condition in gastropods (Nias et al., 1993; Evans *et al.,* 1995). TBT-induced imposex is suggested to be caused by an inhibition of the cytochrome P-450 dependant aromatase system leading to an increase in the androgen (testosteron) level in the gastropods (Bettin *et al.* 1996).

Imposex in gastropods is believed to be a wide spread phenomenon (Ellis & Pattisina, 1990) and has in the open North Sea been related to shipping traffic intensities (Ten Hallers-Tjabbes *et al.,* 1994). In some cases local populations of dogwhelks (*Nucella lapillus*) were reduced or disappeared (Bryan *et al.,* 1986). Common non-neogastropods like *Littorina littorea* may, however, also be affected by TBT (Minchin *et al.* 1996). *Littorina* recruit by means of pelagic larvae, and consequently local populations do not so easily become extinct as *Nucella,* which lay their eggs directly on the substrate.

Unintended effects of TBT in the marine environment has led to restrictions on its use as antifouling agent on small boats in a number of countries. Monitoring in areas where such restrictions has been enforced indicate a reduction in environmental concentrations (IMO, 1994; Shiraishi & Soma, 1992; Evans *et al.,* 1995) and also some recovery in populations suffering from imposex (Evans *et al.,* 1991; Bryan *et al.,* 1993; Evans *et al.,* 1995), indicating that environmental problems caused by organotin has been reduced in areas which previously were heavily affected by small boats. In Norway restrictions on the use of TBT in antifouling agents for boats smaller than 25 m was enforced in 1989. The use of TBT on small aluminium boats were however allowed until 1993. A considerable amount of TBT was previously used in the aquaculture industry (table 1). A total ban on the use of TBT in the aquaculture industry (on fish cages) was enforced in 1989.

Investigations concerning the concentration of TBT in the marine environment of Norway started as late as in 1993-1994. Consequently, little is known about temporal trends of organotin contamination in Norway. Only limited data are also available on spatial distribution of organotin contamination in sediments (mostly lacking from areas outside harbours) and water. Investigations on possible effects on organisms apart form dogwhelks has yet not been performed in Norway. The Norwegian State Pollution Control Autority have, however; from 1997, in their monitoring of the Norwegian coast, included analysis of TBT in dogwhelks and and blue mussels in their monitoring. Investigations on imposex in dogwhelks and intersex in *Littorina littorea* have also been ncluded.

The present report summarises available data related to TBT in sediment, blue mussels *(Mytilus edulis*) and dogwhelks (*Nucella papillus*) collected along the Norwegian coast.

2. Methods

2.1 Sampling

Sediments were generally sampled with a gravity corer (Niemistö, 1974) except for seven samples were an Ekman grab were used (Fagerhaug, 1997). The top 0-2 cm were analysed.

Composite samples containing 20-50 mussels (*Mytilus edulis*) from shallow water (0-2 m) were analysed from each station.

Composite samples of dogwhelks (*Nucella lapillus*) collected in the intertidal zone were analysed. The samples analysed from each station containing 30-60 female and male dogwhelks respectively.

Dogwhelks were analysed for imposex using the method of Gibbs *et al.* (1987). Both the Relative Penis Size Index (RPSI) and the Vas Deferens Sequence Index (VDSI) were calculated/recorded.

RPSI was calculated as follows:

RPSI=[(mean female penis length)^3 x (mean male penis length)$^{-3}$] x 100%

Vas Deferens Sequence (VDS) recognises the development of a vas deferens in a female in 7 stages. Stage 0= Normal female, Stage 6= Genital papilla overgrown, aborted egg capsules can be seen. Individual snails with a VDS of 5 or 6 are prevented from releasing eggcapsules from their genital papilla and are sterile. VDSI represents the mean VDS for all the anlysed females from a station.

VDSI gives an indication of the reproductive ability of a population. Populations with a VDSI >4 indicate that a certain part of the female population are sterile.

A map of Norway is shown in figure 1.

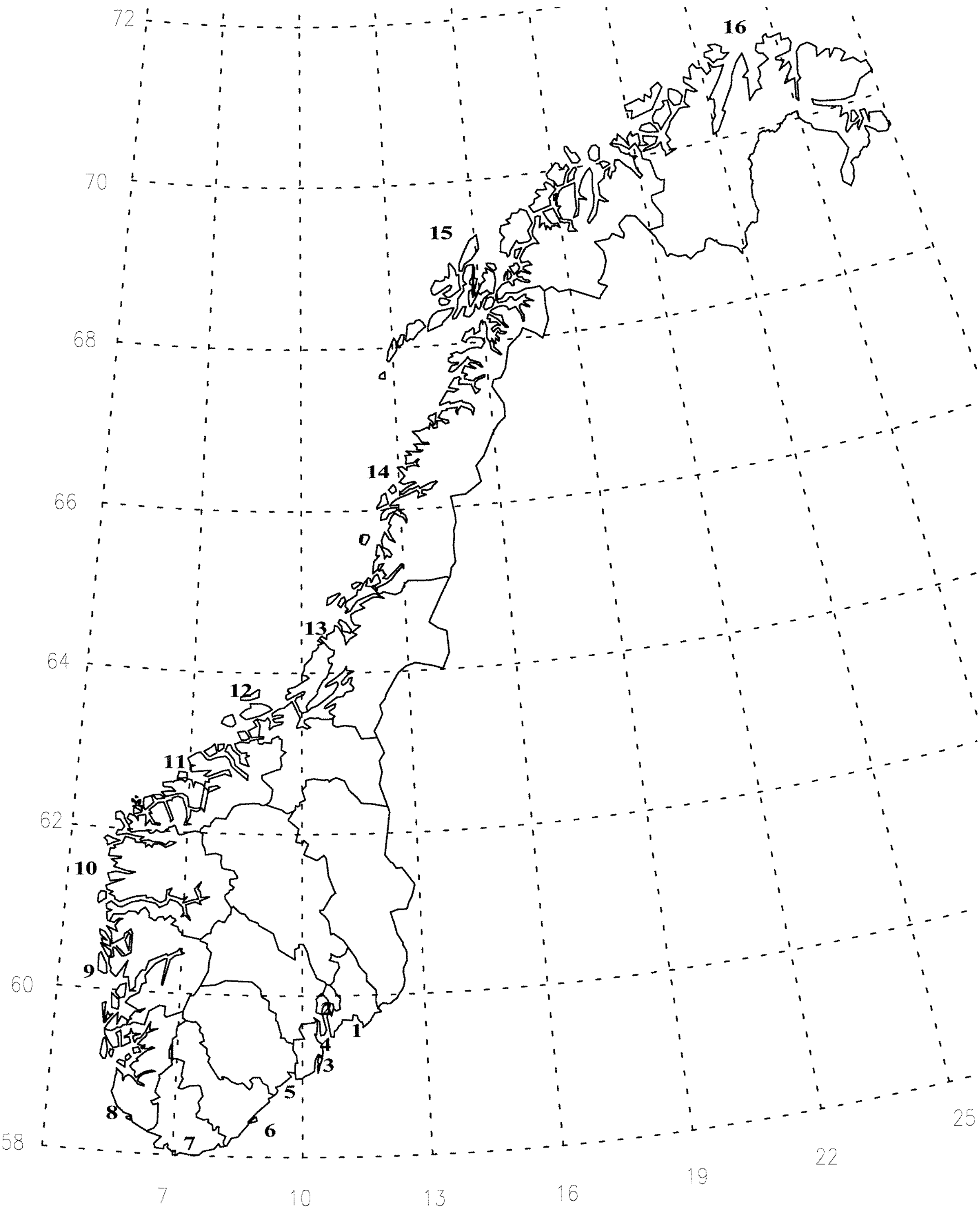

Figure 1. Map of Norway showing latidute (58-72°N, left side) and longitude (7-25°E, bottom). The different counties along the coast are indicated.
1:Østfold, 2:Akershus/Oslo, 3:Vestfold, 4:Buskerud, 5:Telemark, 6:Aust-Agder, 7:Vest-Agder, 8:Rogaland, 9:Hordaland, 10:Sogn og fjordane, 11:Møre og Romsdal, 12:Sør-Trøndelag, 13 Nord-Trøndelag, 14:Nordland, 15 Troms, 16:Finnmark.

2.2 Determination of organotins:

2.2.1 Blue mussels and sediments

Levels of organotin compounds in blue mussel (*Mytilus edulis*) and sediments were determined using acid dissolution of the samples, derivatisation with a Grignard-reagent (methylmagnesiumbromide) and analysis by GC-MSD. 1-2 g of the samples was dissolved in HCl, ascorbic acid and tropolone in methanol was added before extraction with n-hexane. The extract was dried with $CaCl_2$ to remove any traces of water. After removal of air by flushing N_2 into the sample-glasses, the extracts were derivatised by addition of methylmagnesiumbromide. Excess derivatizing reagent was removed by adding HCl and the final extract was concentrated before analysis by GC-MS.

Seven of the sediment samples from the county of Møre and Romsdal were analysed with a modification of the above method (Fagerhaug 1997).

2.2.2 Dogwhelks

A different method, involving dervatization with sodiumtetraethylborate was adopted for all the analysis of dogwhelks (*Nucella lapillus*). Implementation of the method was part of a cand. scient. thesis (Norunn Følsvik). The method was developed because the Grignard-derivatization used for analysing sediments and mussels is both time-consuming and very sensitive to the effective removal of water and air from the samples. Direct ethylation with sodiumtetraethylborate has also other advantages compared to the Grignard-derivatization as it can be performed directly on wet samples and is far less time-consuming.
The samples (1-2 g) were dissolved in a 10 % solution of a tissue solubelizer (tetraethylamoniumhydroxid) in methanol before direct ethylation with $NaBEt_4$. The organotins are present as "free" chlorides and hydroxides. The efficiency of the derivatisation is very pH-dependent and it is therefore urgent to adjust the pH before the derivatisation. Samples were shaken thoroughly and left for 10 minutes to complete the derivatisation. The tetraalkylated species were then extracted with n-hexane. The whole process was repeated once. Before analysis the samples were concentrated with nitrogen to approximately 100 µL.

Quantification:The organotin compounds were identified and quantified by GC-AED. A Hewlett Packard-5890 gas chromatograph with a HP-5921A microwave induced plasma atomic emission detector was used. Injections were made by a HP-7673 automatic injector.
Samples were injected onto a 30 m HP-5 column which mainly separates the compounds after increasing boiling point. Thus the lighter organotins reach the detector first and there the sample is atomised and exited and the intensity of characteristic lines is measured by a photodiodearray spectrophotometer.

Calibration was carried out by running a five point calibration curve for every series analysed. An internal standard was also used to compensate for losses during sample preparation. The different organotin species were identified by analysis of pure standard solutions.

The quality of the analysis was assured by analysing a standard for every 10 samples. In addition, the sample preparation was controlled by analysis of a standard reference material (NIES No. 11) and blank-samples. A home made biological "reference" material was also analysed to verify the long term reproducibility of the method. An analytical precision better than 10 % (RSD < 10%) was achieved when analysing parallel samples.

Comparison of the methods used for analysing *M. edulis* (section 2.2.1) and *N. lapillus* (section 2.2.2) , indicate that the TBT concentrations in *M. edulis* probably are considerably underestimated (2-3 times) when using acid dissolution of the samples and derivatization with a Grignard-reagent

2.2.3 Conversion factor

In this document the concentrations are usually given on a TBT basis. Other investigations may report results on a tin (Sn) basis. The following conversion can be used:

Concentration on TBT basis =2.44 x concentration on Sn basis.

3. TBT sources in Norway

Organotin compounds are generally of anthropogenic origin apart from methyltins, which may be produced by biological methylation. The total amount of TBT used in Norway after 1988 is reported to be dominated by the use of TBT in antifouling agents on boats larger than 25 m (table 1, see also Fjelldal, 1994) and as wood preservative (table 1, see also Fjelldal, 1994). World wide a large part of the consumption of TBT lies in the use as preservative for wood (Fent, 1996). A relatively large amount of TBT was previously used in the aquaculture industry (table 1). A total ban of such use was introduced in 1989/90.

The total annual amount of TBT in products sold in Norway during the last ten years has been in the range 28.7-73.2 ton (table 1). The total consumption of TBT in Sweden in 1989 is reported to be 400-500 t. Of this, close to 150 t was used in antifouling agents (Anonymous, 1989). The Norwegian consumption of TBT (table 1) seems to be relatively low compared to what has been reported for Sweden.

The amount of TBT used on small boats is assumed to be low since the ban was introduced in 1989 (table 1). The annual amount of TBT in antifouling paints sold for use on ships larger than 25 m has been more stable and are reported to be in the range 11.7-28.5 tons (table 1).

Approximately 10 % of the TBT used as wood perservatives and 90 % of the TBT used as antifouling agent on ships are expected to end up in the environment (Fjelldal, 1994) (see table 1 and table 2). Estimated total discharges of TBT to the aquatic environment from these two sources during the period 1985-1995 has been in the range 17.8-57.3 ton/yr (table 2).

It is claimed that the only/most important Norwegian source for the introduction of TBT to water is through antifouling agents (Fjelldal, 1994). Recent investigations have, however, shown that municipal wastewater and sludge may be an additional source for TBT and other organotins (Fent, 1996). Much of the TBT in the raw waste water is retained in the sludge. The amount retained (40-98%) depend on the performance of the treatment plant (Fent, 1996). The remaining TBT is discharged to aquatic systems. The concentration of TBT in waste water and sludge are so high that ecotoxicological consequences should be regarded. No information is available on the concentrations of TBT in wastewater from Norwegian sewage treatment plants.

It is assumed that the main source for the present introduction of TBT to the aquatic environment in Norway is through the use of antifouling paints on ships larger than 25 m. Sand blasting of the underwater hull of ships in order to remove old paint also be an important secondary source for TBT in harbours with dry docks. Other supplementary sources and routes for introduction of TBT to Norwegian coastal waters can not be excluded.

Table 1. Amount of TBT (ton) in products sold in Norway. Source: Norwegian State Pollution Control Authority. n.d.=no data, u.z.=usage assumed to be zero

Year	Antifouling paints small boats	Antifouling paints large boats	Antifouling paints all boats	Wood preservatives	Antifouling paints on cages used for aquaculture	Total use in antifouling and as preservative
1985	13.1	11.7	24.8	15	33.4	73.2
1988	9.7	16.2	25.9	15	n.d.	40.9
1989	1.2	17.9	19.1	15	n.d.	34.1
1990	0.5	23.0	23.5	15	u.z.	38.5
1991	1.5	28.5	30	12	u.z.	42
1992	2.7	26.6	29.3	12	u.z.	41.3
1993	0.5	18.2	18.7	10	u.z.	28.7
1994	0.5	23.4	23.9	12.8	u.z.	36.7
1995	u.z.	27.8	27.8	12	u.z.	39.8

Table 2. Estimated discharges of TBT from wood preservatives and antifouling paints. The estimated discharges from antifoulingpaints includes approximately 5 % triphenyltin. Source: Norwegian State Pollution Control Authority.

	Estimated discharges of TBT (ton)	
Year	Wood preservatives	Antifouling paints
1985	1.5	55.8
1988	1.5	23.1
1989	1.5	17.2
1990	1.5	21.2
1991	1.2	27.0
1992	1.2	26.4
1993	1	16.8
1994	1.3	21.5
1995	1.2	25.0

4. TBT in the environment

Few if any studies on organotin compounds in the aquatic environment have been performed in Norway before 1990. Since then investigations have mainly focused on concentrations of TBT in coastal sediments, mussels and effects of TBT in dogwhelks (*Nucella lapillus)*. Recently an investigation on organotin compounds (TBT, DBT and MBT) in dogwhelks has been started. Only a few analyses of TBT in fish from Norwegian coastal areas have been performed.

4.1 TBT in sediments

Most of the sediments contained concentrations below 100 ng/g d.w. (appendix A, figure 2). Sediment from 16 sites contained more than 1000 ng/g d.w. TBT whereas sediment from 17 sites contained between 100 and 1000 ng/g d.w of TBT. The concentrations in the harbours were highly variable. Maximum and minimum concentration were 103800 ng/g d.w. (navy harbour) and <1ng/g d.w. (Stavern inner harbour), respectively (Appendix A). TBT is a manmade substance and is not reported to occur naturally in the environment.
Concentrations above the detection limit (1-5 µg/kg d.w., Appendix A) thus indicate that TBT is discharged to the environment. The results show that some harbour sediments are heavily contaminated with TBT whereas the concentration of TBT in other harbours sediments are below the detection limit.

Resuspention of contaminated sediments may be a secondary source for the uptake of TBT in marine organisms.

Generally, there seems to be no obvious single factor responsible for the varying concentrations of TBT in the different harbour sediments. Distance to shipyards and quays, shipping traffic intensities, water renewal, bottom current regime and sedimentation are together responsible for the highly variable concentrations. Patchiness resulting from such factors probably is high, but has not been investigated in these introductory studies
Highly variable TBT concentrations in sediments has also been found in other areas (cf. table 3)

Analyses of sediment from more remote locations along the Norwegian coast are few and analysis of sediments from and near harbours are dominating in our data (Appendix A).

Table 3. Concenetrations of TBT (µg Sn/kg d.w. sediment) found in sediment in Canadian coastal harbours (selected values from Maguire et al. 1986).

Area	Concentration (µg Sn/ kg d.w.)	Concentration (µg TBT/ kg d.w.)
British Columbia		
Nanaimo Harbour	<3 1)	<7.7
Tsehun Harbour	180	439
Deep cove	<3 1)	<7.7
Patricia Bay	<3 1)	<7.7
Esquimalt Harbour	140-1400	342-3416
Vancouver Harbour	<3 1)-10780	<7.7-26303
Nova Scotia		
Pictou Harbour	<10 2)	<24.4
Sydney Harbour	10	24.4
Halifax Harbour	<10 2)	<24.4
Newfoundland		
Conception Bay	30	73
Argentia Harbour	<10 2)	<24.4
St. John´s Harbour	<3 1	<7.7

1 Below limit of detection (approx. 3 µg Sn/kg d.w.)

2) TBT detected but concentration below quantification limit (approx 10 µg Sn/kg d.w.) but larger than detection limit.

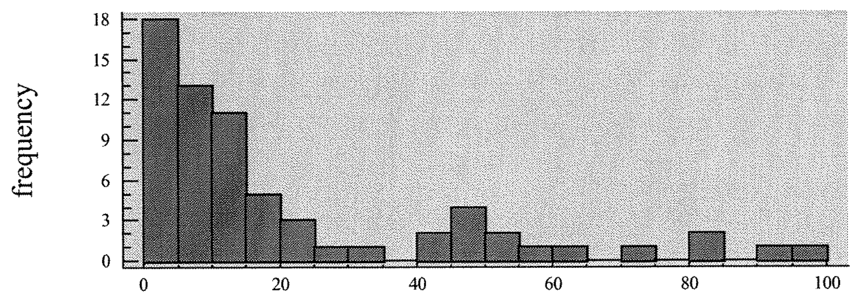

Figure 2. Frequency distribution of the concentration of TBT in sediments collected from harbours along the Norwegian coast. Only sediments with concentrations below 100 ng/g d.w. are shown. (67 % of the data). All data are found in appendix A.

4.2 TBT in blue mussels

Contamination with TBT in Norwegian harbours has been investigated in 1993-1994 using the common mussel (*Mytilus edulis*) as indicator of TBT-level. Mussels have been sampled from 63 harbours along the Norwegian coast from the county of Østfold in Skagerrak to Finnmark on the border to the Barents Sea (figure 1, Appendix B)

Median concentration of TBT in the mussels were 700 µg/g d.w. Maximum and minimum concentration was 16649 and 35 µg/g d.w., respectively (Appendix B). Mussels fromapproximately 50 % of the sites contained concentrations below 1000 µg/g d.w. (figure 3). Examples of very high levels were found in several of the harbour localities (Table 1), where shipyards, drydocks and boating activities probably are the most dominant sources. The results also indicate TBT contamination even in mussels from some more remote reference areas (Table 1). Investigations from other areas indicate that TBT are associated to marinas or areas of high boat traffic (Short & Sharp, 1989; Short *et al.*, 1989).

The concentrations of TBT in mussels from the Norwegian coast generally falls within the range found in other coastal areas around the world (table 4). It is noteworthy, however, that high concentrations still were found in most areas 3-4 years after the restrictions on use of TBT on small boats and aquaculture was enforced in Norway. TBT in antifauling agents used on large ships and from resuspention of TBT contaminated sediments are the most likely sources for this.

Time series on TBT concentrations in mussels are not available from the Norwegian coast. Results from other areas indicate that restrictions on the use of TBT on small boats have resulted in decreased concentrations in mussels (table 4). Investigations on transplanted mussels indicate that depression of TBT is a biphasic two-component process involving a rapid component (half life: 2.2-5.3 days) followed by a slower loss (half life: 28-69 days) (Page *et al.* 1995).

An assumed bioconcentration factor (BCF) of 10000 (Knutzen *et al.,* 1995 with references) gives TBT concentrations in ambient harbour waters mostly in the order of 10-50 ng TBT/l, in extreme cases up to about 300 ng/l. Similar calculations for localities far from land based sources gave values from <1 to 5-15 ng/l, which must be regarded as serious when compared to water quality criteria of 1-2 ng/l in Canada and UK (c.f Zabel *et al.*1988, Waite *et al.* 1991). It should be emphasized, however, that literature data on BCF varies considerably, - from < 5000 to >50000 (Knutzen et al., 1995 with references) - and that it is observations which indicate that BCF increase with reduced exposure. Consequently, the general use of a BCF as low as 10000 probably imply a safety factor when TBT exposure is relatively low.

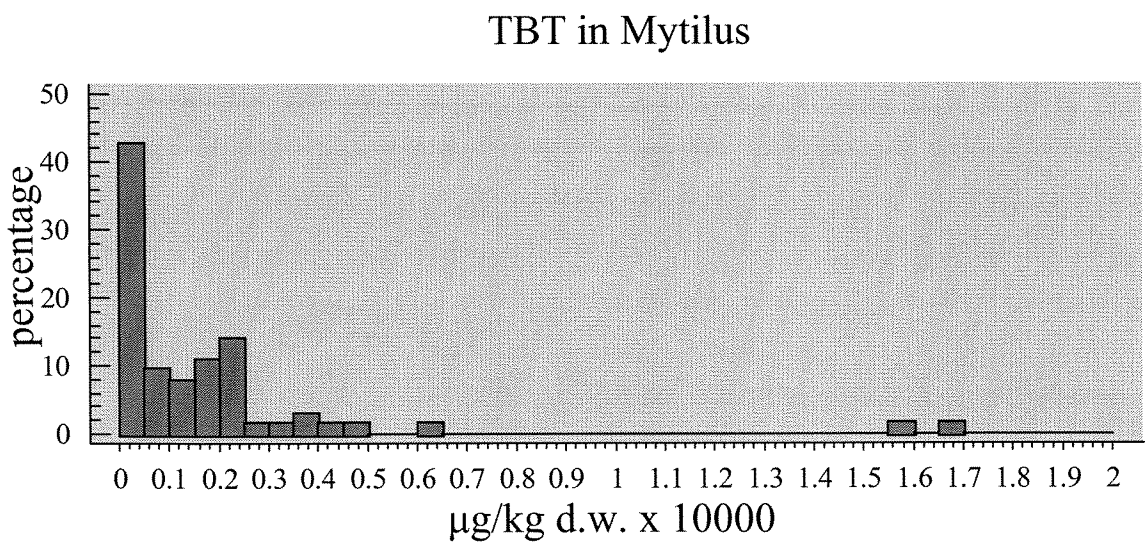

Figure 3. Frequency distribution of the concentration of TBT in mussels collected from harbours along the Norwegian coast.

Table 4. Data for TBT in mussels (mainly *Mytilus edulis*) from various countries.

Area, year	TBT (µg /kg w.w.)	TBT (µg /kg d.w.)	Ref./comment
SWEDEN			
West coast, stations 1984		~700-9200[1)]	Bjørklund, 1987
Stockholm archipelago, 1986		~3000-4000[1)]	Bjørklund, 1987
Stockholm archipelago (outer part), 1986,		<230[1)]	Bjørklund, 1987
West coast, stations, 1987-88		~350-6300[1)]	Bjørklund, 1988,
Baltic sea stations., 1987		~350-1700[1)]	Bjørklund, 1988,
Gothenberg area, 1992	60-256	~360-1500[2)]	Granmo and Eklund, 1993
West coast stations. 1993	20-91	~120-540[2)]	Granmo and Eklund, 1993
DENMARK			
Lyø south of Fyn, 1986	~160[2)]	~1000[1)]	Zuolian og Jensen, 1989. Assumed "unpollute locality"
BRITISH ISLES			
Several estuaries, (1986)	330-2570	~2000-16000[2)]	Waite et al., 1991
Same estuaries as above. (1989)	70-810	~420-4900[2)]	Waite et al., 1991
Several estuaries 1986	170-2570	~1000-15500[2)]	MAFF, 1993
Same estuaries as above (1991)	20-250	~120-1500[2)]	MAFF, 1993
NETHERLANDS			
Eastern Scheldt, Grevelingen, 1988	~20-400[2)]	130-2300	Ritsema et al., 1991
Waddeen Sea, 1988 (mussel farm)	<0.2[2)]	<1	Ritsema et al., 1991
PORTUGAL			
Sado estuary, 1986	<7-50[2)]	<45-280	Quevauviller et al., 1989
CANADA			
Several stations, 1986-89	<12-10500	~70-63000	Thompson og Stewart, 1994
Georgia-stredet-Frazer River, 1992-93 (after TBT ban.)	~20-130[2)]	~130-780[1)]	Stewart og Thompson, 1994;
USA			TBT-begr. i USA 1988
West coas stations., 1986-87	20-1000	~120-6000[2)]	Short og Sharp, 1989
Auke Bay, Alaska, 1987-80	<5-350[2)]	<25-2000[1)]	Short et al., 1989
San Diego Bay	68-1067	~400-6300[2)]	Stallard et al., 1989
San Diego Bay, 1986-1988,	100-2100	¨600-12500[2)]	Valkirs et al., 1991
San Diego Bay 1989-1990 (same stations as above)	30-1700	~180-10000[2)]	Valkirs et al., 1991
East- and West coast stations 1987-88	~17-540[2)]	105-3256	Uhler et al., 1989
45 East coast stations., 1989-90	~2-660[2)]	10-4030	Uhler et al., 1993
31 West coast stations "	~2-230[2)]	10-1380	Uhler et al., 1993

1) Recalculated fom Sn-based values to TBT (f=2.43).
2) Recalculated from wet weight values assuming: concentration (d.w.)/concentration (w.w.)=6/1.

4.3 TBT and imposex in dogwhelks

Imposex in the dogwhelk (*N. lapillus)* have been documented in Southern and Western Norway in 1991 (Harding *et al.,* 1992) and again in 1994 (Evans et al., 1996). A more comprehensive investigation of imposex in *N. lapillus* were carried out in 1993-1995 on 41 stations along most of the Norwegian coast. Preliminary results from this investigation (figure 4, table 5) indicate widespread effects of TBT along the Norwegian coast. Only a few stations (approximately 10%) showed no signs of imposex. These stations were located in rather remote sparsely populated areas mostly in, northern Norway (Finnmark).

The results imply that populations from a majority of the stations contained sterile females (figure 4, VDSI>4, Gibbs & Bryan, 1986; 1987).

On Iceland imposex in *N. lapillus* has been found at 38 out of 45 localities studied and was most frequent near harbours (Svavarsson & Skarphédinsdóttir 1995). On Iceland imposex were found out to a distance of approximately 20 km from the nearest harbour. A preliminary evaluation indicate similar effects in Norway as found on Iceland. The absence of imposex at some remote locations in Iceland and Norway are noteworthy, as some indication of imposex usually are found at virtually all locations studied in more densly populated areas.

Dogwhelks from some of the stations investigated for imposex have also been analysed for TBT (table 5). The concentration levels of TBT in females and males were in the same range (figure 5). The results also show that the degree of imposex is related to the concentration of TBT in dogwhelks. (figure 6, figure 7).
Dogwhelks in populations with VDSI larger than 4 all contained more than 100 ng/g d.w. TBT. In contrast no clear sign of imposex was seen in gastropodes in population containing less than approximately 50-100 ng/g d.w. (figure 6, figure 7).

The main source for new TBT to the aquatic environments is probably through the continued use of TBT on large ships (see chapter 3). A link between shipping traffic intensity and imposex is also indicated since *N. lapillus* from sites near large harbours (shipping large amounts of goods) seems to be more heavily affected than those in areas with less traffic (figure 9).

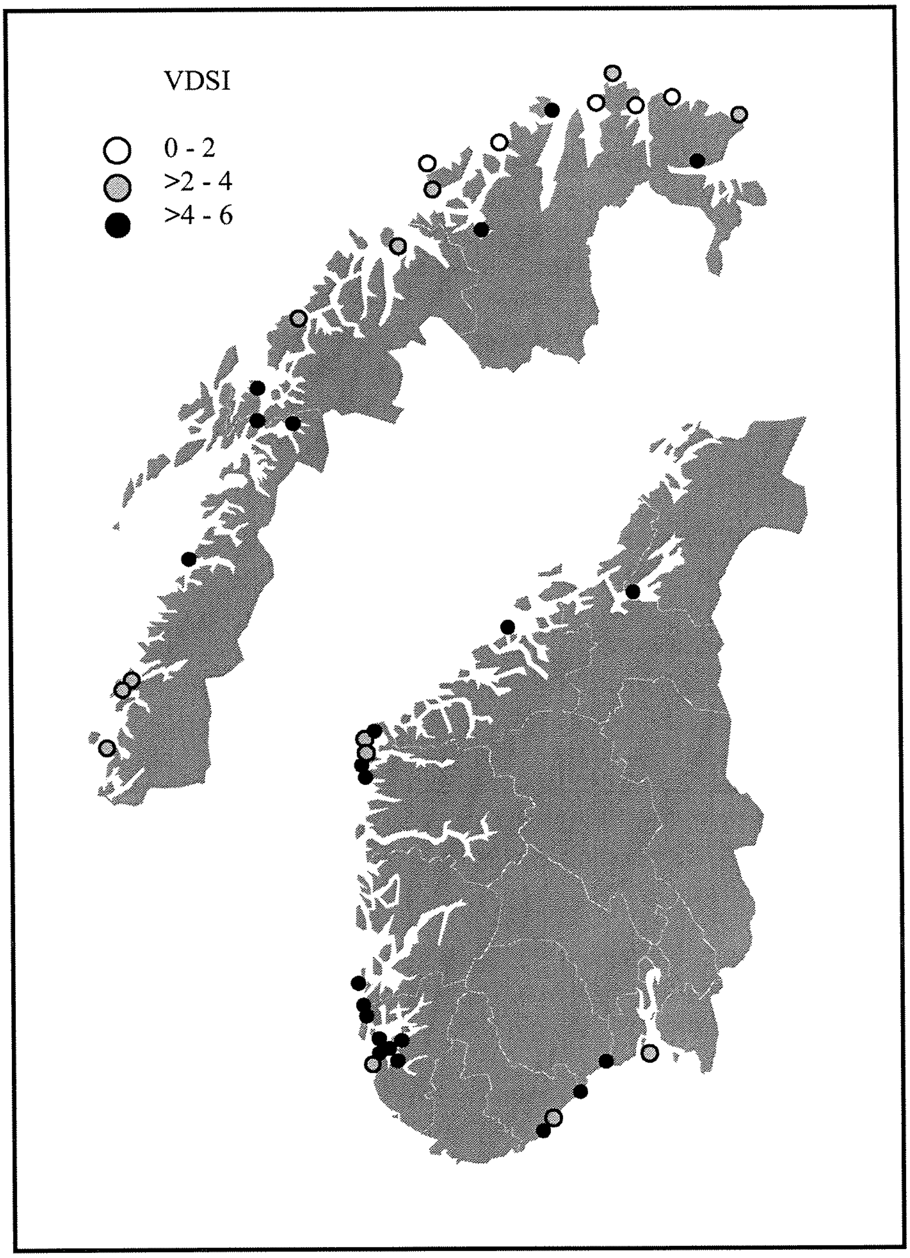

Figure 4. Vas deferens sequence index (VDSI) in dogwhelks (*Nucella lapillus*) along the Norwegian coast, 1993-1995.

Table 5. Mean relative penis size index (RPSI) and vas deferens sequence index (VDSI) found in *Nucella lapillus* sampled along the Norwegian coast 1993-95. Preliminary data generated at NIVA. RPSI is a measure of the mean size of the female penis in relation to that of the male. VDSI recognises the development of a vas deferens in the female in 7 stages. Stage 0= Normal female, Stage 6= Genital papilla overgrown, aborted egg capsules can be seen. For further explanation see Gibbs *et al.,* 1987. Station numbers (no.) are referred on map (figure 4). TBT analysis were performed as part of an Cand scient. thesis (Norunn Følsvik).

no.	Station	Date of collection	Pos. N (NN° NN.NN′)	Pos.E (NN° NN.NN′)	Count	VDSI	VDSI St.dev.	RPSI (%)	TBT in females (ng/g d.w.)	TBT in males (ng/g d.w.)
	AKERSHUS/OSLO									
1	Færder	13/09-93	59 01.55	10 31.70	20	3.95	0.22	10.34	138	109
	TELEMARK									
2	Langesund (Fuglø)	13/09-93	58 58.95	09 48.50	20	4.1	0.31	28.94	150	145
	AUST-AGDER									
3	Risør	13/09-93	58 43.80	09 17.50	20	4.2	0.41	8.38	193	138
4a	Tromøy, Alvekilen/Timmerstøberget	18/06-95	58 27.92	08 53.75	52	3.46	0.92	3.06		
4b	Tromøysund, northeast	04/10-94	58 30.77	08 56.79	20	4.3	0.66	8.14	138	143
	ROGALAND									
5a	Stavanger	08/09-93	59 01.55	05 40.10	20	4.35	0.49	55.5	293	215
5b	G1-Fjoløy, Stavanger	20/09-95	59 05.40	05 33.95	20	4.25	0.44	24.9		
5c	G2-Alstein, Stavanger	18/09-95	59 05.40	05 31.68	20	4.6	0.5	45.38		
5d	G3-Grønningen, Stavanger	19/09-95	58 59.05	05 30.06	20	4.15	0.37	16.62		
5e	G4-Tungeneset, Stavanger	20/09-95	59 02.25	05 35.00	20	4.05	0.22	33.81		
5f	G5-Vistnes, Stavanger	19/09-95	58 59.05	05 33.88	20	3.8	0.52	6.61		
6	Kopervik	08/09-93	59 16.95	05 19.40	20	4.4	0.5	44.31	433	325
7	Haugesund	08/09-93	59 25.00	05 14.00	20	4.65	0.49	37.11		
	HORDALAND									
8	Espevær (Marholmen)	08/09-93	59 34.75	05 08.90	20	4.15	0.67	6.02		
	SOGN OG FJORDANE									
9a	Florø, north	28/08-93	61 36.41	05 03.33	20	4.72	0.55	91.37	470	567
9b	Florø, south	04/09-93	61 35.57	05 03.62	20	4.95	0.39	107.01	2673	1178
10	Bremanger	04/09-93	61 45.95	04 56.00	20	3.75	0.44	4.68		
11a	Måløy, north	04/09-93	61 58.43	05 08.50	20	4.9	0.31	71.22		
11b	Måløy, south	04/09-94	61 55.75	05 07.40	20	4	0	47.41		
	MØRE ROMSDAL									
12	Kristiansund	02/09-93	63 06.40	07 45.15	20	4.25	0.44	30.89		
	SØR TRONDELAG									
13	Trondheim	01/09-95	63 27.02	10 23.32	20	4.25	0.44	22.11	194	166

Table 6.(cont.)

no.	Station	Date of collection	Pos. N (NN° NN.NN′)	Pos.E (NN° NN.NN′)	count	VDSI	VDSI St.dev	RPSI (%)	TBT in females (ng/g d.w.)	TBT in males (ng/g d.w.)
	NORDLAND									
14	Brønnøysund	29/08-93	65 28.35	12 11.93	20	3.55	1.15	2.23		
15a	Sandnessjø,. indre	28/08-93	66 01.55	12 38.20	23	4	0	26.57	220	344
15b	Sandnessjø,. ytre	28/08-94	66 02.95	12 40.60	20	2.65	1.09	0.27	111	158
16	Bodø	27/08-93	67 17.25	14 21.80	30	4.5	0.51	37.04	152	183
17	Narvik	27/08-93	68 25.45	17 20.00	20	4.15	0.37	18.53		
18	Ramsund	16/08-94	68 29.90	16 29.80	20	4.4	0.5	52.72		
	TROMS									
19	Harstad	16/08-94	68 49.30	16 33.92	20	4.75	0.64	45.36		
20	Finnsnes	17/08-94	69 13.55	17 58.50	34	4.15	0.44	13.23	117	128
21	Skjervøy	19/08-94	70 02.15	21 00.30	27	3.89	0.32	8.71		
	FINNMARK									
22	Alta	20/08-94	69 59.20	23 18.80	20	4.1	0.72	14.5	156	167
23	Elenheim, st44	04/09-95	70 31.10	22 15.40	20	2.35	1.53	0.41		
24	Sørøya, Åfjorden	05/09-95	70 37.89	22 22.99	20	0	0	0	<18	<18
25	Saughamnneset, ytre	03/09-93	70 45.80	24 19.80	20	0	0	0		
26	Honningsvåg	21/08-94	70 59.12	25 57.77	20	4.3	0.47	53.69		
27	Kifjordneset	02/09-95	70 52.86	27 22.20	20	0	0	0	<18	<18
28	Mehamn	22/08-94	71 02.55	27 50.35	27	3.96	0.34	20.29	210	206
29	Tanafjorden	01/09-95	70 41.58	28 33.27	21	0	0.22	0.05	21	<18
30	Båtsfjord	23/08-94	70 38,67	29 45.00	27	1.67	1.11	0.36		
31	Vardø	24/08-94	70 22.65	31 06.50	23	3.52	0.99	0.75	48	46
32	Vadsø	24/08-95	70 04.48	29 42.90	20	4.3	0.57	6.11		

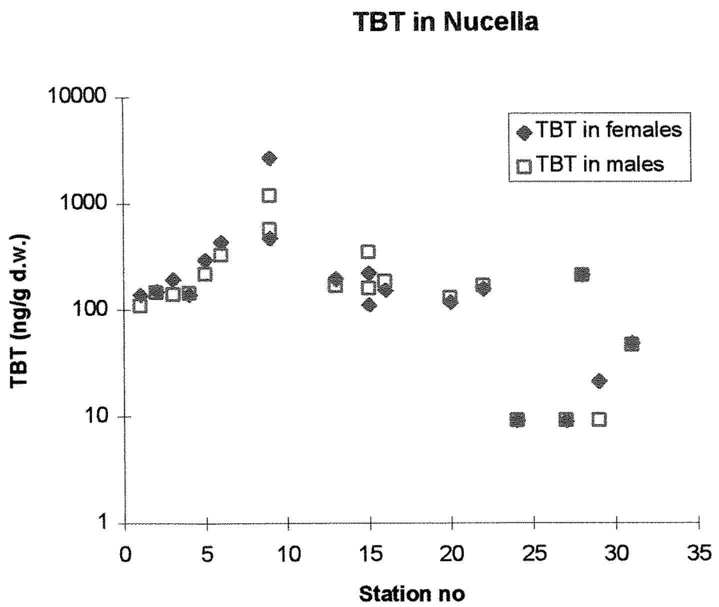

Figure 5. Concentation of TBT in male and female dogwhelks (*Nucella lapillus*). Concentration of TBT below the detection limit (<18 ng/g d,w,) is shown as 9 ng/g d.w. i the graph.

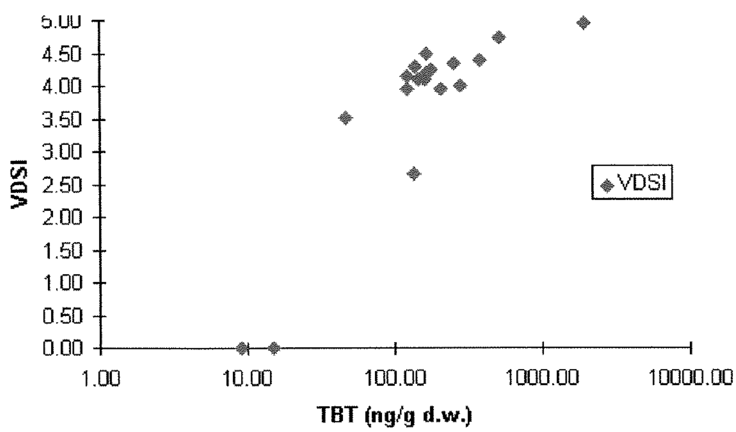

Figure 6. Vas deferens sequence index (VDSI) in dogwhelks (*Nucella lapillus*) as a function of the mean concentration in males and females. Concentration of TBT below the detection limit (<18 ng/g d,w,) is presented as 9 ng/g d,w in the graph.

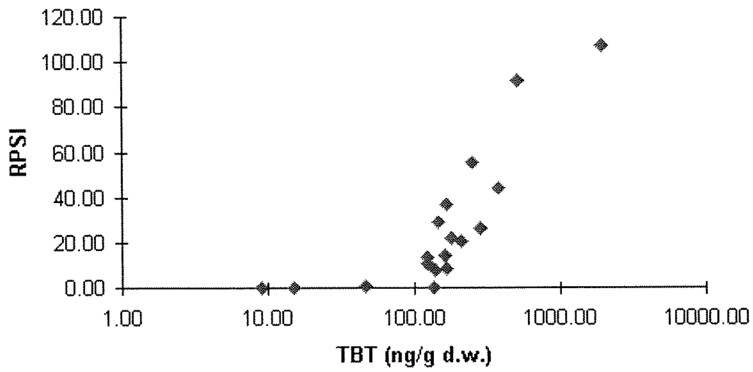

Figure 7. Relative penis size index (RPSI) in dogwhelks (*Nucella lapillus*) as a function of the mean concentration in males and females. Concentration of TBT below the detection limit (<18 ng/g d.w.) is presented as 9 ng/g d.w. in the graph.

Some recent studies show some signs of recovery in populations suffering from imposex (Evans *et al.*, 1991; Bryan *et al.*, 1993; Evans *et al.*, 1995, Evans *et al.* 1996), indicating that environmental problems caused by organotin has been reduced in areas which previously were heavily affected by small boats. The first investigation recording imposex in Norway was conducted in 1991 (Harding *et al*, 1992). All revisited Norwegian populations now show some recovery (table 7). At the station near Koppervik (only station visited 3 times) a consistant decrease in RPSI was indicated (figure 8).

Table 7. Relative penis size index (RPSI) and vas deferens sequence index (VDSI) found in *Nucella lapillus* sampled on the same stations along the Norwegian coast in 1991 (Harding *et al.* 1992), 1993 (Evans et al. 1996) and 1993-95 (data generated at NIVA, see table 5).

A:Adults , SA=subadults (15-21 mm), J=juvenlies (<15 mm)

Station	Date of collection	Pos. N (NN° NN.NN')	Pos.E (NN° NN.NN')	VDSI	RPSI (%)	
Færder (st. 15)	Sept-Oct. 1991	59 01.40	10 31.65	A:4.5 J:4.0 SA: 4.0	A:23 J:32,34 SA: 28,38	Harding et al. 1992
Færder	13/09-93	59 01.55	10 31.70	3.95	10.34	NIVA
Langesund (Fuglø) (st. 14)	Sept-Oct. 1991	58 58.95	09 48.50	A:4.60	A:36.08	Harding et al. 1992
Langesund (Fuglø)	13/09-93	58 58.95	09 48.50	4.1	28.94	NIVA
Tromøy, most easterly tip (st. 13)	Sept-Oct. 1991	58 30.64	08 57.40	A:4.48	A:33.1	Harding et al. 1992
Tromøy, Alvekilen/Timmerstøberget	18/06-95	58 27.92	08 53.75	3.46	3.06	NIVA
Koppervik (st.11)	Sept-Oct. 1991	59 17.00	05 19.35	A:5.25	A:63.21	Harding et al. 1992
Kopervik	08/09-93	59 16.95	05 19.40	4.4	44.31	NIVA
Koppervik	1994	59 16.95[1)]	05 19.40[1)]		32	Evans et al. 1996
Haugesund (East of Storøy(St 4)	Sept-Oct. 1991	59 25.00	?	A:5.36 J: 4.47 SA:4.39	A:54.89 J:60.19 SA:63.06	Harding et al. 1992
Haugesund	08/09-93	59 24.99	05 14.02	4.65	37.11	NIVA
Espevær (St 1)	Sept-Oct. 1991	59.34.93	05 08.36	A:4.28 SA:4.18	A:24.42 SA:29.25	Harding et al. 1992
Espevær (Marholmen)	08/09-93	58 34.75	05 08.90	4.15	6.02	NIVA

[1)]Map in Evans et al. (1996) indicate that the station sampled is the same as used by NIVA in 1993.

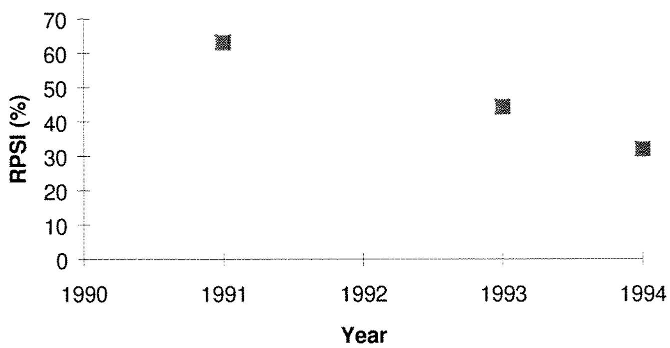

Figure 8. RPSI in dogwhelks from Koppervik (Data from Harding *et al.* 1992, Evans *et al.* 1996 and NIVA.

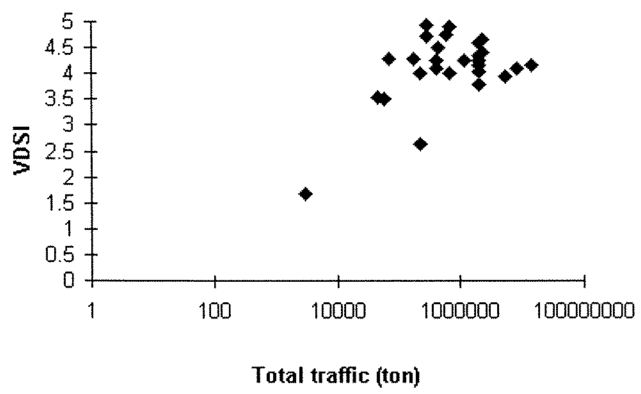

Figure 9.VDSI as a function of total annual amount of goods traffic (1993) through the nearest large harbour (.

5. Conclusions

The main source for the introduction of TBT to the marine environment today is through the use of antifouling paints on ships larger than 25 m. Resuspention of contaminated sediments may also be a secondary source for TBT contamination and result in biological effects. However, other supplementary sources (wood preservatives, possible illegal use and sewage treatment plants) and routes for introduction of TBT to Norwegian coastal waters should also be considered. Approximately 90 % of the TBT used on the hull of ships and 10 % of the TBT used as wood preservatives are expected to end up in the environment.

Mussel and sediment data from Norwegian coastal areas clearly demonstrate that organotin compounds are present in most areas, with especially high concentrations found near harbours. Imposex in dogwhelks caused by TBT has also been recorded in almost all such areas. At about half of the total number of sites, part of the female gastropod population was sterile (VDSI>4). The concentration of TBT in the dogwhelks from unaffected populations in Northern Norway (Finmark) was below the detection limit (17 ng/g d.w:). The concentration of TBT in dogwhelks from affected populations was in the range 50-2676 ng/g d.w. The results also show that the degree of imposex is related to the concentration of TBT indogwhelks. (figure 6,
figure 7).

The concentration levels found in sediment from harbours and in mussels and biological effects in dogwhelks clearly gives cause for further concern about other effects from TBT pollution and possible more widespread damage to small and less conspicuous species.

Restrictions on the use of TBT as an antifouling agent on small boats have been enforced in several countries (France, England, USA, Sweden, Norway and Japan among others). These restrictions have caused indications of improvements (reduced concentration in sediment, biota and reduction in frequency of imposex). Investigations on imposex in dogwhelks in Norway indicate indirectly, that the occurrence of TBT may have been somewhat reduced along parts of the Norwegian coast.

Little is known about temporal trends of organotin contamination in Norway. Only limited data are also available on spatial distribution of organotin contamination in sediments (mostly lacking from areas outside harbours) and water. Investigations on possible effects on organisms apart form dogwhelks has yet not been performed in Norway. The Norwegian State Pollution Control Autority have from 1997, included analysis of TBT in dogwhelks and in blue mussels in their monitoring. Investigations on imposex in dogwhelks and intersex in *Littorina littorea* are also included.

Our results is in accordance with other studies which clearly show that TBT still is a widespread problem and posing a threat to sensitive species, at least in coastal areas where shipping traffic intensities are above a certain level and in the vicinity of harbours. Consequently it must be assumed that significant reduction in the all over occurrence and unintended effects of organotin compounds only can be achieved by enforcing regulations on the use of such compounds also on large vessels (>25 m).

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Appendix A.

Concentrations of TBT in surface sediment (0-2 cm) in and near harbours along the Norwegian coast.

SK= Coastal map, HS = harbour map.

A1. Sediments collected in the northernmost part of Norway (Kirkenes-Ramsund) in August 1994 (data from Konieczny, 1996).

A2. Sediments collected within and near harbours along the Norwegian coast from Narvik to Kragerø (data from Konieczny and Juliussen 1995a, Konieczny 1994, Fagerhaug 1997).

A3. Sediments collected within and near harbours along the Norwegian coast from Stavern to Hvitsten in March 1994 (data from Konieczny and Juliussen, 1995b)

A1.

Station code	Sample no.	Station name	Station description	GPS Pos. N (NN° NN.NN′)	GPS Pos. E (NN° NN.NN′)	Depth (m)	Map referance	TBT (ng/g d.w.)
KIR	02A	Kirkenes harbour	Outer harbour	69 43.380	30 06.490	12	SK116	6
VAS	02A	Vadsø harbour	Inner harbour Ø	70 04.450	29 44.420	6	SK114	17
VAS	01A	Vadsø harbour	Inner harbour V	70 04.370	29 43.170	8.5	SK114	12
VAR	02A	Vardø harbour	Inner harbour	70 22.610	31 06.490	18	SK114	110
VAR	01A	Vardø harbour	Outer harbour	70 23.080	31 06.553	47	SK114	12
BÅT	02A	Båtsfjord harbour	Inner harbour	70 37.325	29 42.377	20	SK294	45
BÅT	01A	Båtsfjord harbour	Outer harbour	70 38.184	29 43.952	23	SK294	61
BER	02A	Berlevåg harbour	Inner harbour	70 51.553	29 05.776	7	SK294	85
HON	03A	Honningsvåg harbour	Outer harbour	70 58.950	25 57.670	66	SK103	6
HON	01A	Honningsvåg harbour	Storbukta	70 59.600	25 58.200	30	SK103	18
HAM	02A	Hammerfest harbour	Inner harbour	70 40.020	23 41.170	30	SK98	12
ALT	02A	Alta harbour	Bossekop	69 57.970	23 14.200	21	SK96	12
ALT	01A	Alta harbour	Elvebakken	69 58.750	23 19.300	25	SK96	9
SKJ	02A	Skjervøy harbour	Inner harbour	70 01.902	20 59.072	30	SK94	15
SKJ	01A	Skjervøy harbour	Outer harbour	70 02.113	21 01.346	80	SK94	12
TRØ	04A	Tromsø harbour	Inner harbour/ship yard	69 39.085	18 57.865	4	SK87	190
TRØ	03A	Tromsø harbour	Tromsøysund N	69 40.480	18 59.850	50	SK87	10
TRØ	02A	Tromsø harbour	Near fuel station	69 39.603	18 58.480	8	SK87	51
TRØ	01A	Tromsø harbour	Tromsøysund S	69 38.430	18 57.050	8	SK87	21
FIN	02A	Finnsnes harbour	Outer harbour	69 13.810	17 57.670	36	SK83	49
FIN	01A	Finnsnes harbour	Finnfjorden	69 13.470	18 03.320	65	SK83	34
HAR	04A	Harstad harbour	Outer harbour	68 47.976	16 33.594	74	SK487	190
HAR	03A	Harstad harbour	v/ Kaarbø M.V.	68 47.785	16 32.749	18	SK487	2400
HAR	02A	Harstad harbour	Mathiassen M.V.	68 47.389	16 32.875	12	SK487	1060
HAR	01A	Harstad harbour	Gangsåsbotn	68 47.192	16 33.063	34	SK487	1550
RAM	02A	Ramsund harbour	Main quay North	68 29.499	16 30.084	45	SK230	11
RAM	01A	Ramsund harbour	Main quay South	68 29.356	16 30.385	54	SK230	26

A2 [appendix A(continued)].

Sation code	Sample no.	Station name	Station description	GPS Pos. N (NN° NN.NN´)	GPS Pos. E (NN° NN.NN´)	Depth (m)	Map referance	TBT (ng/g d.w.)
NAR	01A	Narvik harbour	NV inlet to harbour	68 25.655	17 22.693	29	HS461	<5
BOD	02A	Bodø harbour	Midle harbour	67 17.126	14 22.299	25	HS476	5
BOD	03A	Bodø harbour	Inner harbour	67 17.561	14 23.330	20	HS476	5
SAS	01A	Sandnessjøen harbour	Høvding as.	66 01.250	12 38.700	30	SK57	8
SAS	02A	Sandnessjøen harbour	Outer harbour	66 01.461	12 38.243	18	SK57	92
SAS	03A	Sandnessjøen harbour	Inner harbour	66 01.365	12 37.554	10	SK57	2570
BRØ	02A	Brønnøysund harbour	Inner harbour	65 28.469	12 12.428	35	HS488	10
NAM	04A	Namsos harbour	Inner harbour	64 27.944	11 29.234	23	SK47	<5
TRO	02A	Trondheim harbour	Ila basin	63 25.957	10 22.590	10	HS458	15
TRO	04A	Trondheim harbour	Nyhavna Dora	63 26.477	10 25.740	8	HS458	60
KRI	01A	Kristiansund harbour	Vågen	63 07.068	07 44.180	27	HS454	75
KRI	03B	Kristiansund harbour	Dalasundet	63 07.280	07 46.200	53	HS454	17
MOL	02B	Molde harbour	Outer harbour	62 43.868	07 12.829	55	SK33	<5
13	-	Tomrefjorden, indre	Ship yard, mechanical workshop	62 35.15[3)]	06 55.60[3)]	20-35	SK53	16000
29	-	Lyngsvika, v/Kværner kleven	Ship yard, mechanical workshop	62 19.50[3)]	05 50.70[3)]	15-45	SK30	5600
28	-	Dalasundet øst	Ship yard, industrial dumpsite	63 07.19[3)]	07 46.30[3)]	10-50	SK454	2500
5	-	Dalasundet vest	Ship yard, industrial dumpsite, sewage treatmentplant	63 06.98[3)]	07 45.60[3)]	10-30	SK454	1700
18	-	Fiskerstranda-Kvalsundet	Ship yard	62 26.54[3)]	06 16.85[3)]	15-35	SK456	1500
10	-	Nerbøvågen	Ship yard	62 48.90[3)]	06 54.10[3)]	5-15	SK33	700
20	-	Lyngnevika, near Ulsteineast	Ship yard	62 20.50[3)]	05 50.25[3)]	12-24	SK30	700
MÅL	01A	Måløy harbour	Ulvesund N	61 58.189	05 08.867	46	HS490	8
St.3	-	Haakonsvern	Navy harbour	60 20.55[1)]	05 14.3[1)]	7	SK21	103800[2)]
St.8	-	Haakonsvern	Navy harbour	60 20.55[1)]	05 14.3[1)]	11	SK21	1040
St.9	-	Haakonsvern	Navy harbour	60 20.55[1)]	05 14.3[1)]	14	SK21	2650
St.12	-	Haakonsvern	Navy harbour	60 20.55[1)]	05 14.3[1)]	4.6	SK21	1150
St.13	-	Haakonsvern	Navy harbour	60 20.55[1)]	05 14.3[1)]	7	SK21	490
St.16	-	Haakonsvern	Navy harbour	60 20.55[1)]	05 14.3[1)]	9	SK21	100
FLO	03A	Florø harbour	Inner harbour N	61 36.320	05 03.390	52	HS479	12
HAU	02A	Haugesund harbour	HMV	59 24.350	05 16.150	30	HS469	1266
SAN	01A	Sandnes harbour	Inner harbour	58 51.660	05 45.203	26	HS485	23
STA	02B	Stavanger harbour	Ulnesgr. SW	58 59.069	05 42.777	57	HS455	55
STA	03A	Stavanger harbour	Bangarvågen	58 59.584	05 43.383	12	HS455	83
EGE	03A	Egersund harbour	Inner harbour	58 27.125	05 59.900	6	HS467	42
FAR	02A	Farsund harbour	Outer harbour	58 05.480	06 48.530	16	HS477	10
MAN	02B	Mandal harbour	Middle harbour	58 00.590	07 26.365	18	HS457	103
LIL	03A	Lillesand harbour	Inner harbour	58 14.800	08 22.809	19	SK8	8
GRI	03B	Grimstad harbour	Outer harbour	58 20.161	08 36.450	40	SK8	12
ARE	03B	Arendal harbour	East harbour	58 27.596	08 46.825	32	HS453	22
KRA	02A	Kragerø harbour	Tangen ship yard	58 52.105	09 26.000	62	SK6	285

[1)] Approximate locations, sediment from several stations in the same area analysed (see Konieczny, 1994 for more details)
[2)] Approximate value (instrument response exceeded calibration curve)
[3)] Approximate position (5-6 stations in the same area, see Fagerhaug 1997)

A3 [appendix A(continued)].

Sation code	Sample no.	Station name	Station description	GPS Pos. N (NN° NN.NN')	GPS Pos. E (NN° NN.NN')	Depth (m)	Map referance	TBT (ng/g d.w.)
STV	01A	Stavern harbour	Main quay	58 59.795	10 02.753	12 m	SK2	19
STV	03A	Stavern harbour	Inner harbour	59 00.473	10 02.602	6 m	SK2	<1
VIK	01A	Viksfjorden	Outer fjord	59 01.214	10 05.900	32 m	SK2	3
SAF	01A	Sandefjordsfjorden	Near discharge	59 04.959	10 14.775	56 m	HS480	46
SAF	02A	Sandefjordsfjorden	Volvo/Tranga	59 06.144	10 14.051	35 m	HS480	227
SAF	03A	Sandefjordsfjorden	Hystastranda	59 06.333	10 13.945	28 m	HS480	152
SAF	04A	Sandefjordsfjorden	Pronova/Jotun	59 06.492	10 13.762	26 m	HS480	269
SAF	05A	Sandefjordsfjorden	Kilen	59 07.580	10 14.260	5 m	HS480	284
SAF	06A	Sandefjordsfjorden	Sentralhavna	59 07.460	10 13.830	8 m	HS480	7
SAF	07A	Sandefjordsfjorden	Mechanical workshop	59 06.850	10 13.850	12 m	HS480	1374
SAF	08A	Sandefjordsfjorden	Slipway SW	59 07.130	10 13.800	16 m	HS480	979
SAF	09A	Sandefjordsfjorden	Tranga N	59 06.760	10 13.720	22 m	HS480	253
SAF	10A	Sandefjordsfjorden	Outer fjord	59 05.360	10 14.560	53 m	HS480	50
SAF	11A	Sandefjordsfjorden	Dumping site	59 04.390	10 14.950	70 m	HS480	166
SAF	12A	Sandefjordsfjorden	Reference station	59 04.060	10 14.950	85 m	HS480	19
MEF	01A	Mefjorden	Outer fjord	59 03.677	10 17.300	26 m	SK2	1
VRE	01A	Vrengensundet	Chemical factory.	59 10.150	10 23.670	30 m	SK2	15
BOL	01A	Bolærne	North	59 13.475	10 28.875	31 m	SK2	4
TØN	01A	Tønsbergfjorden	Træla area	59 14.900	10 26.700	11 m	HS468	48
VAL	02A	Valløy-area	Valløy- area	59 16.286	10 31.176	73 m	HS468	<1
ÅSG	01A	Åsgårdstrand	Outer harbour	59 21.100	10 28.622	13 m	HS481	<1
HOL	02A	Holmestrand-area	Hydro	59 29.380	10 19.190	45 m	SK3	1
HOL	03A	Holmestrand-area	Inner harbour	59 29.410	10 19.180	15 m	SK3	131
HOR	01A	Horten harbour	Channel outlet	59 24.927	10 30.200	12 m	HS486	1
HOR	03A	Horten harbour	Inlet N	59 26.662	10 29.204	10 m	HS486	<5
HOR	04A	Horten harbour	Central harbour	59 25.998	10 28.547	19 m	HS486	<5
HOR	05A	Horten harbour	Inner harbour	59 25.696	10 28.615	11 m	HS486	540
HOR	06A	Horten harbour	Mellomøya	59 27.030	10 27.673	76 m	HS486	7
HOR	07A	Horten harbour	Løvøya	59 26.870	10 25.475	50 m	HS486	5
HOR	08A	Horten harbour	North West	59 26.877	10 23.650	88 m	HS486	<5
MOS	01A	Moss harbour	Channel South	59 24.970	10 38.910	24 m	HS482	1977
MOS	02A	Moss harbour	Inner harbour	59 26.250	10 39.230	34 m	HS482	<5
MOS	03A	Mossesundet	Kambo NSO	59 28.970	10 40.830	83 m	HS482	10
MOS	04A	Mossesundet	Son harbour	59 31.450	10 41.000	24 m	SK4	<5
HVI	01A	Hvitsten	Katten	59 35.800	10 38.510	20 m	SK4	6

Appendix B.

TBT in the blue mussel (*Mytilus edulis*) from Norwegian harbours (*) and other localities from the Norwegian coast 1993-1994. The provisional background concentrations are regarded to be near 3 µg/kg d.w.. Y: Outer, I: Inner, M: Central, N: North; S: South. (From Knutzen *et al.,* 1995). Please note that the TBT concentrations presented in this table probably are considerably underestimated (2-3 times). For further information see chapter 2.

County/locality/date		Location		Blue mussel	
		Pos. N (NN° NN.NN')	Pos.E (NN° NN.NN')	µg/kg w.w.	µg/kg d.w.
ØSTFOLD					
Sponvikskansen	18/10-94	59 05.27	11 12.90	138	1290
Singløykalven	18/10-94	59 05.63	11 08.50	145	1593
N. Asmaløy	18/10-94	59 04.70	10 57.70	131	-
*Papper	18/10-94	59 06.82	10 51,42	206	1731
AKERSHUS/OSLO					
Near Rambergøya	30/10-94	59 52.70	10 42.85	99	~600
Solbergstrand	29/10-94	59 37.35?	10 38.95?	6	~35
VESTFOLD					
Færder	29/10-94	59 01.55	10 31.70	17	~100
BUSKERUD					
Mølen	29/10-94	59 29.25	10 30.15	42	~250
TELEMARK					
Arøy/Langesundsbukta	13/09-94	58 59.90	09.47.80	59	386
*Kragerø	13/09-94	58 51.81	09 25.20	47	255
Bjørkøy/Breviksfj.	28/10-94	59 01.35	09 45.40	174	~1050
AUST-AGDER					
*Risør	13/09-93	58 43.30	09 15.20	57	259
*Arendal I	12/09-94	58 27.45	08 46.40	39	188
*Arendal II	03/10-94	58 27.46	08 46.50	411	2258
*Grimstad	12/09-93	58 20.28	08 36.18	84	393
*Lillesand	12/09-93	58 14.70	08 23,45	75	296
VEST-AGDER					
*Mandal	11/09-93	58 00,58	07 27,45	20	87
*Farsund	10/09-93	58 05,80	06 48,90	84	462
ROGALAND					
*Egersund	09/09-93	58 26,82	05 59,12	103	440
*Sandnes	08/09-93	58 53,12	05 44,48	138	762
*Stavanger Y	08/09-93	58 59,50	05 42,90	229	1279
*Stavanger M	08/09-93	58 59,40	05 43,78	387	2331
*Stavanger I	08/09-93	58 58,35	05 43,80	418	2211
*Kopervik	08/09-93	59 16,95	05 19,40	311	1620
*Haugesund Y	08/09-93	59 24,80	05 14,10	29	125
*Haugesund I	08/09-93	59 24,55	05 16,40	361	2162
HORDALAND					
Espevær		59 35.10	05 08,65	25	133
*Bergen I (Nordnes)	23/10-94	60 24,03	05 18,15	719	4730
*Bergen II (Laksevåg)	23/10-94	60 22,87	05 19,75	921	6099
*Bergen III (Damsgård)	29/11-94	60 23,03	05 19,05	2564	16649
*Bergen IV (Solheimviken)	29/11-94	60 23,62	05 17,05	2641	15720

Appendix B (continued).

County/locality/date		Location Pos. N (NN° NN.NN´)	Pos.E (NN° NN.NN´)	Blue mussel µg/kg w.w.	µg/kg d.w.
SOGN AND FJORDANE					
*Florø N	04/09-93	61 36,12	05 03,45	390	2020
*Bremanger	04/09-93	61 46,33	04 56,30	54	286
*Måløy S	04/09-93	61 56,07	05 06,90	252	1537
*Måløy N	04/09-93	61 58.41	05 05.60	208	1051
MØRE AND ROMSDAL					
*Ålesund S	03/09-93	62 28,15	06 09,10	324	1976
*Ålesund N	03/09-93	62 28,53	06 09,10	420	2560
*Molde	02/09-93	62 44,20	07 10,00	40	227
*Kristiansund	02/09-93	63 06,90	07 44,20	268	1675
SØR-TRØNDELAG					
*Trondheim	30/08-93	63 26,85	10 25,73	73	415
NORD-TRØNDELAG					
*Namsos	30/08-93	64 27,85	11 29,00	37	263
NORDLAND					
*Brønnøysund	29/08-93	65 28,60	12 12,52	43	219
*Sandnessjøen	28/08-93	66 01,50	12 38,20	147	700
*Skrova	02/09-94	68 10,05	14 40,25	392	2190
*Narvik	27/08-93	68 25,55	17 25,70	31	161
*Ramsund	16/08-94	68 29,70	16 30,70	468	3019
TROMS					
*Harstad	16/08-94	68 47,74	16 33,63	736	4407
Feneset/Grytøya	02/09-94	68 56,10	16 39,00	63	391
*Finnsnes	17/08-94	69 13,65	17 59,50	42	247
*Tromsø	19/08-94	69 39,15	18 58,70	595	3542
*Skjervøy	19/08-94	70 01,85	21 00,50	96	582
FINNMARK					
*Alta	20/08-94	69 58,85	23 18,80	51	307
Elinheim/Sørøya	31/08-94	70 30,96	22 14,803	33	~200
*Hammerfest	20/08-94	70 40.20	23 41,00	375	2142
Smines/Magerøysund	30/08-94	70 58,35	25 48,50	7	36
*Honningsvåg	21/08-94	70 58,90	25 58,20	368	2056
*Mehamn I	22/08-94	71 02,45	27 50,60	112	704
*Mehamn Y	22/08-94	71 02,55	27 50,35	108	688
*Berlevåg	22/08-94	70 51,45	29 05,90	68	450
*Vardø	22/08-94	70 22,50	31 06,90	569	3951
Skagodden/Ekkerøy	02/09-94	70 04,15	30 10,10	40	242
*Vadsø	24/08-94	70 04,28	29 44,75	281	1799
*Kirkenes I [3)]	25/08-94	69 43,75	30 02,80	190	1397
*Kirkenes II [3)]	25/08-94	69 43,75	30 02,80	329	2350

[3)]Kirkenes: I=Mussels collected on stones. II=mussels collected on iron plate a few meters from Kirkenes I.