



Project no. 510658

TBTIMPACTS

Assessing impacts of TBT on multiple coastal uses

Specific Targeted Research Project

Specific measures in support of international co-operation

Final Activity Report

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TITLE: ASSESSING IMPACTS OF TBT ON MULTIPLE COASTAL USES

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Final activity report

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Publishable executive summary

Antifouling paints are applied on hulls of ships and boats to control growth of fouling organisms and to reduce their deleterious effects. TBT paints replaced copper-based paints due to a superior performance in terms of efficacy and duration. However, TBT has been described as the most toxic substance ever introduced in marine environment. International Maritime Organization (IMO) at a convention, approved of the resolution, which includes complete prohibition of organotin compounds in anti-fouling systems by 2008. Signature of about 25 nations whose combined flagged fleet equals 25 % of the world fleet is necessary for the convention to come into force. However, concerns have been raised that the hostility towards the use of TBT appears to be based on a biased assessment. Little thought has been given to a technical solution to control TBT inputs to the environment. Long-term biocidal properties of existing alternatives are largely untested as also their environmental impacts. The indicator used for determining environmental impacts such as imposex has been challenged by scientists. Hence the project attempted to study implications of TBT pollution and its ban, costs and benefits of TBT based antifoulants and other alternatives, suggest alternative antifouling strategies, develop tools such as indicators, quality control programmes and policies for monitoring and managing environmental impacts of organotin compounds and raise awareness towards this. It developed a biomonitoring system to regulate TBT impacts that exist in coastal environments.

General description

The work was divided into six WorkPackages (WP), as shown in fig 1, according to their scientific and technological objectives. Of these, five WPs (WP1- WP5) were fully research activities and WP6 was also involved with participatory action research, awareness raising and dissemination activities. These WPs are as follows :Policy review (WP1), Environmental impacts (WP2), Alternative antifouling strategies (WP3), Cost benefit analysis and scenario building (WP4), Decision tools (WP5), and Awareness raising and dissemination (WP6).

In WP1, participant 2 carried out a review of government policies and programmes in place in India, while European counterpart (Participant 5) did the same for European states. Participant 5 also reviewed international mechanisms and best practice approaches. Together they worked on gap analysis and suggested better policies (WP5). Environmental impacts of TBT (WP2) was studied by participant 3 in India and 1 in Europe. Participant 3 also studied effect of TBT on biochemical composition of bacteria and production of exopolymer by micro-organisms to overcome TBT. Participant 6 helped in this WP by studying impacts on mangrove ecosystem, analysing fishing practices, and transfer of TBT to higher trophic levels. Participant 7 provided a detailed information on alternative antifouling paints that exist (WP3). Participants 4 and 6 worked on alternative antifouling strategies. Using the information derived from WP2 and WP3, participant 2 developed questionnaires for survey of shipping industry and paint manufacturers and developed a method for cost benefit analysis of organotin based and other antifouling paints (WP4). Participant 7 built scenarios under different situations. Decision tools (WP5) consisted of identifying indicators and safer fishing grounds (Participants 2,3,and 6), a quality control programme for data validation and for harmonization among Indian and European laboratories (Participants 1 and 3), waste disposal strategy ((Participant 4 and 7) and policy recommendations (Participant 2 and 5), Awareness raising campaigns and dissemination activities were carried out from M 25 – 48 by participant 2 with the help of participants 4 and 7. Participant 2 carried out an extensive literature review for various aspects of antifouling under study in different WPs

and is responsible for synthesizing information from all participants (further details provided in project management section).

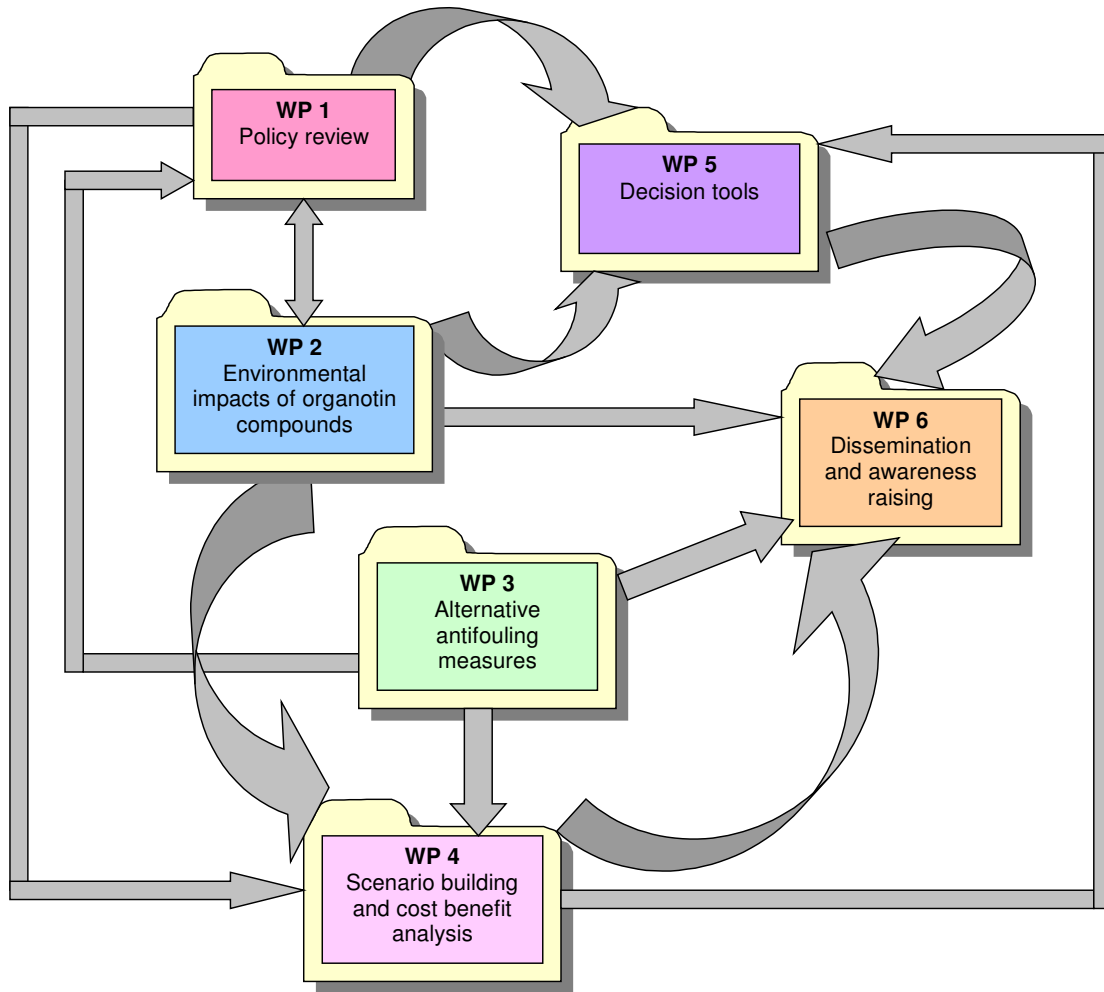


Fig 1. Diagrammatic representation of the work-packages

The dissemination activities focused on the implications of TBT and its ban, environmental distribution of TBT in Europe and India, alternative antifouling strategies and research gaps.

List of deliverables:

1. Report on policies in India
2. State of art report on policies in European Countries
3. International best practice approaches
4. Gap analysis
5. Report on policy review (State of art report on policies in India and European Countries, International best practice approaches and a gap analysis)
6. A report on environmental distribution of TBT in European and Indian coastal waters, sediments, fish and other biota
7. Report on environmental impacts of TBT on biochemical composition of microorganisms
8. State of art report on contribution of major harbours in terms of public exposure to TBT
9. State of the art information on the impact of TBT on mangrove ecosystems
10. Identification of safer zone for fishing
11. Historic data on alien species invasion
12. A document providing knowledge on alternative antifouling paints
13. Alternative antifouling strategies
14. A working model of ceramic-based diffusible antifouling delivery for protection of moving surfaces against biofouling
15. Identified micro-organisms that can detoxify TBT
16. Scenarios on: environmental impacts of using TBT based organotin compounds and other existing as well as more efficient alternatives likely to be developed in future
17. Cost benefit analysis of using antifouling compounds
18. Indicators of coastal health
19. Fatty acid biomarkers
20. Report on Sentinel organisms
21. Quality control programme
22. Waste disposal strategy

23. A simple biomonitoring system to assess coastal health
24. Recommendations of better policies for improved coastal health as well as human health.
25. Newsletters
26. Workshops
27. Booklet/special issue of a journal
28. Website dissemination

List of publications

1. Asha Giriyan and Prajwala Pangam (2006) A review of antifouling strategies: alternatives to TBT' In Sonak S (ed) **Multiple dimensions of Global Environmental Change** Teri Press, New Delhi, pp 726.
2. Sonak S., Sonak M., Giriyan A (2008) Shipping hazardous waste: implications for economically developing countries **International Environmental Agreements** 8:143–159 DOI 10.1007/s10784-008-9069-3
3. Sonak S, Pangam P, Giriyan A, Hawaldar K (2009) Implications of the ban on organotins for protection of global coastal and marine ecology **Journal of Environmental Management** 90: S96–S108
4. Gipperth L (2009) The legal design of the international and European Union ban on tributyltin antifouling paint: Direct and indirect effects **Journal of Environmental Management** 90: S86–S95
5. Mukherjee A, Mohan Rao K.V., Ramesh U.S. (2009) Predicted concentrations of biocides from antifouling paints in Visakhapatnam Harbour **Journal of Environmental Management** 90 (2009) S51–S59
6. Jadhav, S, Bhosle, N.B., Massanisso, P., Morabito, R. (2009) Organotins in the sediments of the Zuari estuary, west coast of India. **Journal of Environmental Management** 90: S4-S7.
7. Meena R.M, Garg A, Jadhav S. (2009) Seasonal variation in organotins in the waters of the Dona Paula Bay, west coast of India **Bulletin of Environmental Contamination & Toxicology** 82(5): 586-589.
8. Sonak S, Giriyan A, Pangam P, (2010) A method for analysis of costs and benefits of antifouling systems applied on ship hull **Journal of Ship Technology** 6 (1) 73-83.
9. Rajagopal S, Pollux BJA, Peters JL, Cremers G, Moon-van der Staay SY, van Alen T, Eygensteyn J, van Hoek A, Palau A, bij de Vaate A, van der Velde G (2009) Origin of Spanish invasion by the zebra mussel, *Dreissena polymorpha* (Pallas, 1771) revealed by Amplified Fragment Length Polymorphism (AFLP) fingerprinting. *Biological Invasions* (In press).
10. Anita Garg, Ram M. Meena, Narayan B. Bhosle (In Press) Distribution of butyltins in water and sediments of the Mandovi and Zuari estuaries, west coast of India **Environmental Monitoring and Assessment** (DOI 10.1007/s10661-009-0975-9

Project objectives

The project 'TBTimpacts' addresses the following objectives:

Objective 1

To assess **current policy concerns** and developments with regards to ban on using organotin compounds in antifouling paints by IMO and its implications to the fishing, aquaculture, shipping and cruise tourism industry.

- Review current national, EU and international coastal policies and programmes in place
- Analyse gaps in policies
- Suggest better policies/Management strategies to the National Government

Objective 2

To assess the **impacts of organotin based and other existing antifouling paints on coastal environment** such as water, sediment, mangrove ecosystem, fish and other biota.

- Environmental distribution of TBT in European and Indian coastal waters and sediments
- Evaluate effect of TBT on the biochemical composition of micro-organisms
- Assess impact of TBT on breeding and feeding grounds of fish
- Assess impact of TBT on marine animals including fish
- Assess environmental impacts of other existing antifouling paints through literature review, questionnaire surveys and interviews of key informants

Objective 3

To investigate **alternative antifouling strategies** which will be safer to fish and marine biodiversity

- Inventory of existing alternative antifouling paints

- Investigate other novel antifouling measures
- Isolation of micro-organisms for biodegradation of TBT

Objective 4

To analyse costs and benefits of using and not using organotin compounds, especially from a developing country perspective

- Assess the environmental and economic implications of the IMO led policy changes to ban TBT
- Arrive at the costs and benefits of using organotin compounds and alternatives
- Build scenarios for current conditions, forecast changes considering the developments at international level and assuming invention of more efficient alternatives

Objective 5

To **generate decision tools** for better coastal health in the context of organotin based antifouling paints.

- Establish a baseline data of the level of organotin in coastal ecosystems (waters, sediments, mangroves and animals) in order to monitor trends in concentration of TBT in coastal environments
- Develop indicators of coastal health such as fatty acid biomarkers and sentinel organisms
- Produce quality control tools for validation of analytical data
- Individuate safer fishing areas in the context of organotin compounds
- Develop a waste disposal strategy for TBT
- A simple biomonitoring system to regulate TBT impacts and help implementation of legislation

Objective 6

To create awareness and build capacity

- Awareness raising campaigns amongst fishers and aquaculture farmers documenting impacts of TBT on marine organisms and implications to human health
- Dissemination of information on safer fishing areas to the fishers and aquaculture farmers and on alternatives to organotin compounds to shipping and cruise tourism industry
- Establish e-mail forum involving relevant stakeholders to discuss the divide on TBT issue
- Sensitising national governments on the issue
- Strengthening institutional capacity through better policy suggestions
- Help capacity building of research institutions by appropriate transfer of technical knowledge

Work-package description

During the course of the project, various activities were carried out. All deliverables were accomplished and the end results achieved as per the timetable.

Work Package 1

Objectives

1. To study existing coastal policies in India and Europe and
2. To analyse for best practices

Description of activities

The activities under work-package 1 are carried out by TERI (Partner 2) and UGOT (Partner 5). Partner 2, TERI, carried out a review of coastal and marine policies in India in the first year. The document included an overview of the coastal and marine sector of India, a description of the legal framework in India, and authorities, departments and institutions governing coastal resources in India. The report prepared by Partner 5, UGOT, provided a general background on the law making procedures. Two regulative levels, the international and the regional European Union are described and compared.

On international level the report focused on the AFS Convention and at the EU level, it focused on biocide regulation by the EC. The differences between the regulative levels, reasons and consequences of these differences were analysed.

In the second and the third year, a review of regulations relevant to the organotin prohibition was carried out. A paper titled 'Exporting hazardous waste: where has environmental equity gone' was presented at the synthesis conference of Institutional Dimensions of Global Environmental Change (IDGEC) held at Bali, Indonesia from 6th Dec to 9th Dec 2006 by TERI. A paper titled 'Shipping hazardous waste: implications for developing countries' was published in the journal 'International Environmental Agreements: Politics, Law and Economics' (Annex I). Policy mapping and stakeholder mapping was carried out in the third year.

In the final year of the project, a review of the AFS Convention, as well as related international conventions and a gap analysis was carried out by TERI. Partner 5 carried out a review of European regulations. Two papers titled 'Implications of the ban on organotins for protection of global coastal and marine ecology' by TERI and 'The legal design of the international and European Union ban on tributyltin antifouling paint: Direct and indirect effects' by UGOT are published in the special issue of the journal. Copies of the special issue of the journal are annexed (Annex II). Recommendations for improved policies are suggested and communicated to the Government of India. These are also published in the newsletters. Copies of the newsletter are attached (Annex III).

Deliverables

D1.1 State of art report on policies in India,

D1.2 State of art report on policies in European Countries

D1.3 International best practice approaches

D1.4 Gap analysis

D1 State of art report on policies in India and European Countries, International best practice approaches and a gap analysis

Milestones and expected results

1. Report on policies in India - M-7
2. State of art report on policies in European Countries - M-7
3. International best practice approaches - M-9
4. Gap analysis – M- 10
5. Report on policy review – M- 44

Plans for the coming year

Research papers published in the journal will serve to sensitize academicians beyond project duration. Similarly, newsletters and journal copies have been and will be disseminated to relevant stakeholders.

Work Package 2

Partners associated with this work-package are ENEA (Partner 1), TERI (Partner 2), NIO (Partner 3), and RU (Partner 6).

Objectives:

1. To study environmental impacts of TBT in Indian and European marine environments
2. To evaluate the effect of TBT on the biochemical composition of microorganisms
3. To examine the possibility of production of exopolymers by microorganisms to overcome TBT pollution
4. To analyse historic data on alien species (surface-attached) invasion in European waters with an aim to correlate with TBT ban

5. To analyse fishing practices in India that could potentially endanger public health by way of consumption of TBT through fish and fish products

Description

ENEA worked on building a database with data on the distribution of organotin in Europe with the help of a sub-contractor of TERI, Quality Consult. TERI has carried out a review of environmental impacts of TBT. NIO worked on evaluation of the effect of TBT on the biochemical composition of microorganisms and examining the possibility of production of exopolymers by microorganisms to overcome TBT pollution. RU conducted activities related to the transfer of TBT to higher trophic levels and analyse historic data on alien species invasion.

Specifically following activities have been carried out:

The database containing data on the distribution of organotin in European environments has been built by ENEA (Partner 1). This was uploaded on the website with a searchable engine by TERI, Partner2. The information considered in the database is: Country, location, year of sampling, matrix; level of TBT, DBT, MBT, MPhT, DPhT, TPhT, others OTs; unit, QC tools applied, Authors, Project or Monitoring programme, Journal or Grey literature. This structure was discussed and validated in the project meetings of all partners.

This database is filled with the papers collected from 1997 to 2006 and evaluated.

Three main sources of information are considered to fill in the database:

- Scientific literature
- European Commission funded Projects
- Grey literature.

The collection of information has been done by using the ENEA library database, utilizing the words “organotin, TBT, butyltin...” in the library database search engines. About 2000 papers published from 2002 to 2006 have been found in research literature databases (SCOPUS and ISIWEB) using the specific keywords. The database covers over

230 scientific disciplines and more than 20,000 related scientific journal, 5000 books, etc According to the DoW as well as the decisions taken at the kick off meeting, only the articles where appropriate quality control tools have been used in collecting the data were considered as source for the database. Moreover, considering the end of this project activity, the years between 1997 and 2006 have been considered as the period of time for the data collection. More than 3200 papers published from 1997 to 2006 have been found utilizing the keywords specified before.

A preliminary evaluation of these papers, based on the abstract reading, has been carried out by QC that, following the indication of ENEA (i.e. the occurrence in the abstract of particular keywords), selected a first set of about 500 papers. The ca 500 papers were fully read and the applied quality control tools were evaluated, and more than 200 papers have been finally selected by ENEA for the inclusion in the database. In figure 1 has been reported the numbers of papers selected from different journals: Marine Pollution Bulletin was the journal with the higher number of papers selected for the inclusion in the database.

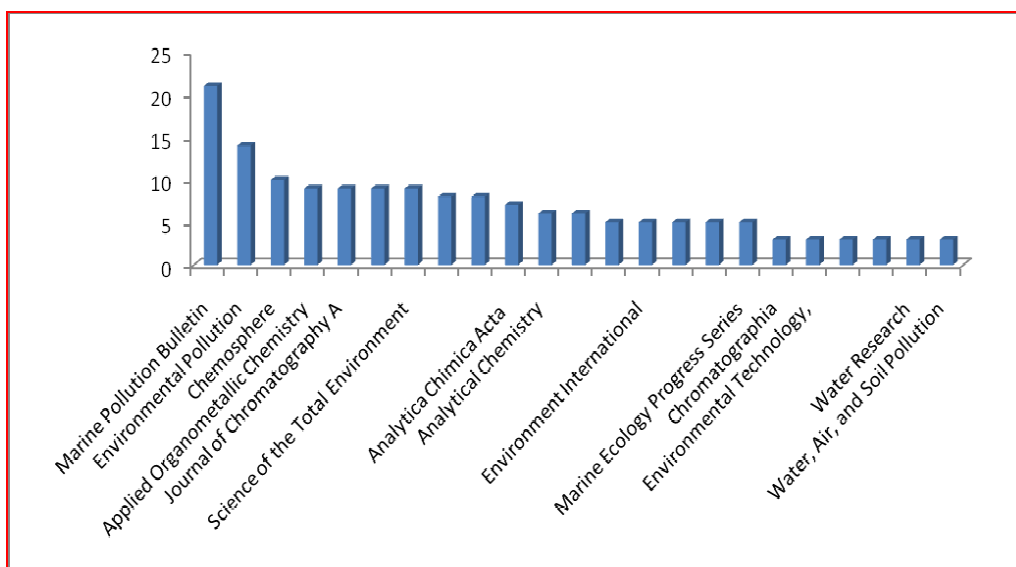


Fig 1. Numbers of papers selected from different journals

The numbers of records present in the final revision of the database are 708.

European Commission funded Projects

There are projects financed by the EC in the past that collected or produced data on organotin distribution in Europe. The “Cordis” database and “Life Projects” were searched with this aim and about twenty projects, that have somehow treated topics in connection with organotin compounds, have been found. Only some of this projects have data on presence of organotin compounds in the environment and, after the further evaluation of the quality control tools, the projects selected as source for the database have been four. Details have been presented in the individual partner report of ENEA, Partner1.

Grey literature

Several colleagues belonging to the scientific community working in the organotin field were asked to provide their grey data and to suggest names/institutions in their countries where the same request could be made. In addition, a free searching on the web have been conducted with the aim to find further data on organotins distribution in Europe. All details and the analysis of data present in the DB have been reported in the deliverable prepared by ENEA “The environmental distribution of TBT in European coastal waters, sediments, fish and other biota”.

The DB filled with the data has been uploaded on the project web site and the on-line search engine has been settled up by TERI in collaboration with ENEA (<http://www.teriin.org/teri-wr/projects/tbtsearch/search.php>). With the on-line search engine it is possible to extract information from the DB on the organotins level looking in several fields as: Matrix, Country, Sampling, Reference, Authors etc. Moreover, it is also possible to obtain information using the fields specified before and the operators “and” an “or”.

Organotins were monitored in waters, sediments and various organisms collected from various locations along the west and east coast of India by NIO, Partner 3. Effect of TBT on biochemical composition of bacteria as well as on exopolysaccharides production by

bacteria and PLFA composition in bacteria and in sediments is studied by NIO. Detailed analytical results are provided in the individual partner report by NIO, Partner 3. A paper titled 'Organotins in the sediments of the Zuari estuary, west coast of India' has been published in the special issue of the Journal of Environmental Management, which is annexed to the report (Annex II). Another paper titled "Seasonal Variation in Organotins in the Waters of the Dona Paula Bay, West Coast of India." Ram M Meena, Anita Garg, Sangeeta Jadhav is published in the Bulletin of Environmental Contamination and Toxicology (Annex IV).

RU conducted field studies between May 2005 and August 2008 at Kakinada mangroves on the east coast of India in order to identify possible sentinel organisms for the TBT impact studies and study transfer of TBT to higher trophic levels. A series of laboratory experiments were also conducted exposing five commercially very important fish species and two important benthic species to varying combinations of TBT (at concentrations representative of those in areas influenced by commercial shipping, such as major estuaries and ports in India – in this case Kakinada harbour, India).

It was found that

1. The proportions of MBT, DBT and TBT among different species and body parts (i.e. liver, whole body, muscle tissue etc. in fishes) were significantly different.
2. Significant seasonal variations in the Butyltin concentration in fishes, mussels (*Perna viridis*) and oysters (*Crassostrea madrasensis*)
3. Seasonally mediated physiological changes such as dilution due to growth and metabolic compensation, may play important roles in forming different BT accumulation patterns among seasons and organisms

Further, analysis of historic data on alien species invasion through literature review was undertaken by RU to see if ban on TBT has any relationship with the introduction of alien species. The conclusion of the review is as follows:

1. Last 15 years TWO fold increase in invasive species (30 to 60) were recorded in River Rhine
2. Significant relationship was also recorded between numbers of invasive species increase in surface area of river catchments connected to the river Rhine due to constructions of canals.
3. The increase in number of invasive species in River Rhine after 1985 is possibly due to many factors including TBT ban, Sandoz accident in River Rhine 1997/1998, canal construction, abolishing VAT for used boat, Lifting the recreational boats etc.

Publications

Rajagopal S, Pollux BJA, Peters JL, Cremers G, Moon-van der Staay SY, van Alen T, Eygensteyn J, van Hoek A, Palau A, bij de Vaate A, van der Velde G (2009) Origin of Spanish invasion by the zebra mussel, *Dreissena polymorpha* (Pallas, 1771) revealed by Amplified Fragment Length Polymorphism (AFLP) fingerprinting. *Biological Invasions* (In press).

Deliverables:

29. A report on environmental distribution of TBT in European and Indian coastal waters, sediments, fish and other biota
30. Report on environmental impacts of TBT on biochemical composition of microorganisms
31. State of art report on contribution of major harbours in terms of public exposure to TBT
32. State of the art information on the impact of TBT on mangrove ecosystems
33. Identification of safer zone for fishing
34. Historic data on alien species invasion

Milestones and expected results

1. Report on TBT concentrations in Indian and European marine environments – M-24, M- 40
2. Environmental impacts of TBT in marine biota - M-40
3. State of art report on contribution of major harbours in terms of public exposure to TBT and its contribution to public exposure through fish route- M- 32
4. Historic data on alien species invasion – M-34
5. State of the art information on the impact of TBT on breeding and feeding grounds of fish- M-36

Plans for the coming year

- The database completed by ENEA with the help of Quality Consult, subcontractor of TERI is uploaded on the website by TERI with an on-line search engine. This will continue to be in public domain and disseminated through website.
- Research papers by individual partners and jointly will be submitted to the suitable journals.

Work Package 3

Objectives

1. To carry out an inventory of alternatives to organotin compounds
2. To evaluate novel antifouling strategies for ship hull application
3. Identification of microorganisms that can detoxify TBT

Description

This workpackage involved assessing and formulating alternative antifouling strategies and the activities were carried out by TERI (Partner 2), NIOT (Partner 4), RU (Partner 6) and NSDRC (Partner 7). TERI and NSDRC produced a document on the existing alternatives through literature review and information collected directly from the shipping and paint manufacturing industry. NIOT isolated and characterized microbes that

detoxify TBT. RU explored the possibility of using diffusible antifoulants delivered through porous ceramic surfaces for potential application on ship hull.

An inventory of alternative antifouling compounds that exist was carried out by Participant 7 (NSDRC). TERI carried out a literature review on existing antifouling strategies. Based on this information, a chapter was been written by Asha Giriyan and Prajwala Pangam on alternative antifouling strategies and published in an edited volume. The inventory of antifouling compounds carried out by NSDRC was published in the second issue of the newsletter. This list was later updated during the project duration. The update list is annexed to the report (Annex V).

NIOT (P4) carried out a literature review on

- Quantity of waste generated from dry dockyards
- Treatment process

The samples collected from the coastal and estuarine waters of India were analyzed for the presence of *Skeletonema* Sp. as described in the literature. NIOT (P4) isolated TBT degrading microbes and these cultures were identified by IMTECH Chandigarh and RC NIO Kochi. Natural populations of microalgae were also tested for TBT degradation potential by NIOT.

RU used a model to use porous surfaces to serve as a biocide (e.g. chlorine) delivery vehicle and studied their usefulness for ship hull application. Further, RU tested porous membrane studies with mussels *Perna viridis*. The model to use porous surfaces to serve as a biocide (e.g. chlorine) delivery vehicle and study their usefulness for ship hull application is described in detail in the partner 6 report. The study shows promising results. About 60 - 75% of chlorine can be easily saved by using porous ceramic surfaces in comparison with existing continuous chlorination for controlling mussel fouling in industrial cooling water systems. The flow velocity of the seawater is the most important factor in surface fouling control with porous ceramic surfaces (refer methodology for details). Flow velocity between 1.5 m to 3 m keeps injected biocide near the surface area.

The study also shows that the biocide concentrations in receiving waters (outfall area) can be easily managed under discharge limits advocated by different environmental agencies. Some chapters were published in a book

Deliverables

1. Inventory on alternative antifouling compounds
2. Demonstration of practical applicability of antifouling strategies successful elsewhere for ship hull usage
3. Identified micro-organisms that can detoxify TBT

Milestones and expected results

1. A document on alternatives to tin based antifouling paints – M- 18, M-30
2. A working model of ceramic-based diffusible antifouling delivery for protection of moving surfaces against biofouling – M- 36
3. Micro-organisms for detoxification of TBT identified – M- 38

Plans for the coming year

- Research papers by individual partners and jointly will be submitted to the suitable journals.
 - Following papers will be published as chapters in an edited volume titled '*The Zebra Mussel in Europe*' (edited by G. van der Velde, S. Rajagopal & A. bij de Vaate). Backhuys Publishers BV, Leiden, The Netherlands.
1. Rajagopal S, G. van der Velde, H A Jenner (2009) Turning the heat on *Dreissena polymorpha*: temperature as a control option.
 2. Rajagopal S, G. van der Velde, H A Jenner (2009) Chlorination for *Dreissena polymorpha* control: old war-horse for the new pest?
 3. Van der Velde G, Rajagopal S, bij de Vaate A (2009) From zebra mussels to quagga mussels: an introduction to the Dreissenidae.
 4. Bij de Vaate A, Rajagopal S, Van der Velde G (2009) The zebra mussel in Europe: Synthesis. In: *The Zebra Mussel in Europe*

5. Rajagopal S, G. van der Velde, H A Jenner (2009) Zebra mussel and industrial cooling water systems.

Work Package 4

Objectives

1. To build scenarios for current conditions, forecast changes considering the developments at international level and assuming invention of more efficient alternatives
2. To analyse costs and benefits of using and not using organotin compounds

Description

TERI and NSDRC (Partners 2 and 7) are associated with this work-package. This work-package drew on other work-packages. After an extensive literature review by TERI, questionnaires were developed for various stakeholders such as shipping industry, dry-docking and ship repairs, paint manufacturing industry and fishing community.

The set of questionnaires developed by TERI was used to assess costs and benefits of using and not using organotin compounds. Data was collected through the existing literature, questionnaire survey, as well as through interviews to the shipping and paint manufacturing industry with the help of NSDRC (Partners 7). The questionnaires developed were piloted to a small sample of the respective stakeholders and modified incorporating feedback received during piloting of the questionnaires. Statistical analysis of these responses was carried out.

Interviews with shipping industry were also conducted to help analyzing costs and benefits of using and not using organotin compounds. Response from shipping industry was not very encouraging. Costs and benefits of using antifouling paints were assessed based on the response from the shipping and paint manufacturing industries. A paper on a method to assess cost and benefits of antifouling system and its application is prepared and will be submitted to a suitable journal such as 'Journal of Ship technology'. The paper is annexed to the report (Annex VI). Some scenarios were presented by NSDRC with the help of other partners and shipping industry and a paper titled 'Predicted concentrations of biocides from antifouling paints in Visakhapatnam harbour' is published in the special issue of the Journal of Environmental Management (Annex II).

Deliverables

1. Scenarios for current conditions, forecast changes considering the developments at international level and assuming invention of more efficient alternatives
2. Cost benefit analysis of using antifouling compounds

Milestones and expected results

1. Scenarios – M- 32
2. Cost benefit analysis – M-38

Plans for the coming year

A paper on methods to assess costs and benefits of antifouling paints is prepared (Annex VI). This paper will be submitted for publication in any academic journal.

Work Package 5

Objectives

1. To generate decision tools for improved coastal health and restoration of degraded coastal ecosystem
2. To develop strategies for long term monitoring of marine environment

Description

All partners are associated with this work-package. The work-package focused on three types of decision tools.

1. Indicators of coastal health for assessing and monitoring of coastal waters in the context of organotin compounds
2. A quality control programme for validation of analytical data
3. Policy recommendation at national, regional and international level.

Indicators were identified from the literature review and secondary data by TERI (Partner 2). NIO (Partner 3) identified fatty acid biomarkers to indicate TBT pollution. RU (Partner 6) identified sentinel organisms, which can be used to monitor near shore-fishing grounds for TBT contamination. ENEA, TERI and NIO (Partners 1, 2 and 3) together developed a quality control programme for validation of analytical data. A series of Proficiency Testing schemes (PTs) were carried out within the frame of the project. In order to do this, ENEA worked with Quality Consult, who was subcontracted by TERI to support ENEA. ENEA, TERI and NIO had a task of developing a simple biomonitoring system for monitoring of organotin compounds. TERI and UGOT (Partners 2 and 5) together worked towards policy review and recommendations for good approaches. NIOT and NSDRC (Partners 4 and 7) worked on the waste disposal strategies.

Participants 1 (ENEA), 2 (TERI) and 3 (NIO) worked to carry out inter-laboratory exercises for evaluation of accuracy and uncertainty of data in the second year. The inter-laboratory exercises were organized by Quality Consult, an Italian Proficiency Testing (PT) provider that was subcontracted by TERI. TERI collected information on laboratories in India and other parts of Asia on laboratories working on TBT analysis. ENEA also contacted some laboratories in Europe for more participation in these

exercises. Inter-comparison exercises were completed by the end of 2008. Results are provided by ENEA in the individual partner report (Partner1).

Since there was not much response from Indian laboratories for analytical exercises due to lack of capabilities to analyze TBT, a training programme was held by NIO and ENEA to train Indian laboratories in TBT analysis. More than twenty scientists from 11 different Indian laboratories participated in the training programme held at NIO, Goa on 19 and 20 November 2007. The details of this training programme were provided in the third year report.

Further, imposex analysis as an indicator of the organotin pollution was challenged by several scientists. A report on indicators of organotin pollution was earlier prepared by TERI. A simple biomonitoring system for monitoring of organotin compounds was suggested by TERI. This was presented at the final partner meet and was finalized with the feedback from partners. The final biomonitoring system comprised of decline in population at the first level, imposex analysis at the second level and sediment analysis as well as bioaccumulation in organisms at the confirmatory level. A paper on indicators and the biomonitoring system will be prepared after the conclusion of the project.

Identification of biomarkers for TBT contamination was a task by NIO (P2). In the laboratory experiments conducted to identify biomarkers in bacterial cultures in the presence of TBT, NIO observed synthesis of some new PLFAs in response to TBT. Such PLFAs, if found in natural conditions can be used as a signature for the TBT contamination of the environment.

RU conducted laboratory studies in February 2006 after identifying suitable sentinel organisms. Various sessile, benthic and fish species were collected from the Kakinada bay and Godavari mangroves in order to identify possible sentinel organisms for the TBT impact studies. *Perna* sp., *Mytilopsis sallei* and *Brachidontes* sp. were used as potential sentinel organisms for the TBT studies based on their availability, featuring different mobility, habitat and behaviour. The standard procedures were used to quantify

tributyltin (TBT), triphenyltin (TPhT), dibutyltin (DBT), diphenyltin (DPhT), monobutyltin (MBT) and monophenyltin (MPhT).

Shipyards waste containing TBT was procured from Vizag (copper slag blast) by NIOT. A waste disposal strategy was developed by NIOT with the help of NSDRRC. Based on the studies carried out by NIOT for treatment of liquid effluent and solid wastes, the following waste disposal options are suggested. (1) Thermal degradation for solid-wastes – Incineration of the solid wastes up to about 2 hours at 270°C. (2) Biodegradation of liquid effluents – Two options are suggested -: Option 1: Pretreatment using *P. putida* in the liquid effluent. It is observed that *P. putida* flocculates and settles the total solids including paint scrap containing TBT within 6 hours. Option 2: When a local effluent treatment plant is available, the activated sludge at MLSS 20% can be added along with the *P. putida* to the liquid effluent. This enables flocculation and settling within 30 minutes. The solids obtained at the end of options 1 or 2 can be dried in sludge drying beds and incinerated at 270°C as carried out for copper slag. The decant can be treated separately by passing through activated carbon or biologically.

TERI and UGOT worked on a document on policy review. Mapping of conventions related to organotin prohibition as well as stakeholder mapping was done. AFS convention was thoroughly reviewed and a gap analysis was done. As given in WP1, papers are published individually by TERI and UGOT in the special issue of the journal. Recommendations from the project are disseminated to all stakeholders through the third issue of the newsletter. Additionally, Ministry of shipping, Government of India was contacted by TERI and the representatives were informed about the AFS Convention, and were sensitized towards the need to sign the Convention.

Deliverables

D1 Indicators of coastal health

D2 Quality control programme

D3 Waste disposal strategy

D 4 A simple biomonitoring system to assess coastal health

D5 Recommendations of better policies for improved coastal health as well as human health.

Milestones and expected results

1. Identification of sentinel organisms – M- 30
2. Identification of fatty acid biomarkers - M-36
3. Indicators of coastal health in the context of organotin compounds – M-38
4. Quality control programme – M- 40
5. Waste disposal strategy for TBT – M- 41
6. A simple biomonitoring system to assess coastal health – M- 42
7. Recommendations of better policies for improved coastal health as well as human health – M-44

Plans for the future

Some papers will be published after the conclusion of the project.

Work Package 6

Objectives

1. To raise awareness in policy makers, industry, general public and relevant users of the coast especially coastal fishers on the impacts of organotin compounds and
2. To provide information on places which are least impacted with TBT and presumably safe for fishing from the context of TBT impacts.

Description

TERI had a major role in the awareness raising activities. Different outputs were planned for different stakeholders. These include website for general public; newsletters with issues individually targeting general public, shipping industry, fishing industry and policy makers; group meetings with fishers; workshops for different stakeholders etc. Special issue of a peer reviewed international journal was published for dissemination among the academicians.

In particular, awareness activities were carried out through

1. Newsletters
 2. Stakeholder meets and focus group discussions
 3. Workshop presentations and discussions
 4. Publications
 5. Web-site
-
1. Three issues of a newsletter on the project background and the environmental impacts of TBT are published and disseminated to a number of stakeholders.
 2. Several meets of concerned stakeholders were organized with an aim of raising their awareness on the implication of TBT and the ban. Awareness raising activities were carried out by TERI along the coast of India among fishers, shipping and paint manufacturing industry. Visits to Siridao, Cutbona, Malem, Dona Paula, Panaji, Marmugao, Cacara coasts (in Goa) Mumbai (in Maharashtra), Betkul, Ankola and Tadri in Karwar, Mangalore (in Karnataka), Vishakhapatnam (in Andhra Pradesh), Sosiya, Alang, Surat (Gujarat) were held.
 3. The impacts of TBT and the ban were briefly discussed with the participants of the respective conferences during the following presentations
 - Presentation by Dr Sangeeta Sonak at a conference on “Proactive Micro-Adaptation: Implications for International Climate Negotiations and

Sustainable Development” held at Hotel Villa Fontaine Shiodome, Tokyo on 13th and 14th July 2005 organized by International Global Environmental Strategies (IGES), Japan.

- Presentation by Dr Sangeeta Sonak at a conference on sustainable coastal zone management held at Hotel Rain tree, Chennai, India on 10th September 2005 by British Council, Chennai
- A presentation was made by Ms Asha Giriyan at a conference on science policy interactions organized by the National Institute of Oceanography with inputs from all partners on the AFS convention, impacts of TBT, alternative antifouling strategies and the research gaps. This was aimed at promoting gaps concerning TBT research that are being identified as major constraints in implementation of TBT ban.
- Presentation by Ramya Balaji on ‘Biochemical Studies on TBT Degrading Microbes Isolated from Indian Waters’- Proceedings of International Conference on Recent Advances in Marine Antifouling Technology (RAMAT) 2006, pp.242-251. Ramya Balaji, P.Venkateswaran, G.Dharani, Vijaya Ravichandran and Rajat Roy Choudhary.
- A paper titled ‘Exporting hazardous waste: where has environmental equity gone’ was presented by Dr Sangeeta Sonak at the synthesis conference of Institutional Dimensions of Global Environmental Change (IDGEC) held at Bali, Indonesia from 6th Dec to 9th Dec 2006.
- Ms. Asha Giriyan attended and presented a poster titled “Prohibition of organotin compounds in antifouling paints: The AFS Convention”. at the ‘*International Conference on Biofouling and Ballast Water Management*’ held on February 05 to 07, 2008. This was organized by National Institute of Oceanography, Dona Paula, Goa, India.
- Oral paper presentation by Lena Gipperth at the Fifth WIOMSA Scientific Symposium, 22-26 Oct, Durban South Africa. Effects of international and EU policies on TBT antifouling in the West Indian Ocean.

- Ms. Prajwala Pangam presented a poster for the workshop on “Antifouling Paint Effects on Fisheries” organized by National Institute of Ocean Technology, held on 26 – 27 September, 2007 at Chennai, India.
 - Presentations on the AFS Convention and organotin prohibition were made at the University of Plymouth, UK and the University of Cadiz, Spain by Dr Sangeeta Sonak during April to June, 2008.
 - Presentation by Ramya Balaji on ‘Screening of treatment methodologies for TBT wastes generated in Shipyards’- Proceedings of International Conference on Ocean Engineering, (ICOE) 2009, Rajat Roy Chaudhury, Vijaya Ravichandran and Ramya Balaji.
4. A chapter on alternative antifouling strategies entitled ‘A review of antifouling strategies: alternatives to TBT’ written by Asha Giriyan and Prajwala Pangam was published in the book volume entitled ‘Multiple dimensions of Global Environmental Change’ edited by S Sonak. The volume published a section on ‘TBT in marine environment’ with five chapters. Prof Roberto Morabito and Dr Paolo Massanisso of ENEA, Dr N B Bhosle of NIO and Dr Aditya Mukherjee of NSDRC also published papers in this volume. Dr Claude Alzieu, who detected the TBT problem for the first time in France and published the first paper also kindly contributed to this volume. The volume was supported by the Asia Pacific Network as a part of the project entitled ‘Role of institutions in global environmental change’. A few copies (about 300) of the volume were disseminated free of charge to the relevant players including policy makers. Copies of the book were forwarded to the European Commission with the first year report.
5. A web page was created to disseminate the project findings. The link is < <http://www.teriin.org/teri-wr/projects/multiple.htm> >
The website displays summary of the project, bulletin and all presentations.
6. Special issue of a peer reviewed international journal ‘Journal of Environmental Management’ was published in February 2009. The special issue published twelve

papers from the Consortium as well as outside Consortium. Print copies of the issue are enclosed with the report.

7. Four workshops were held by the project partners. TERI provided technical support to the two workshops organized by NSDRC. The other two workshops were organized by NIOT. These workshops were aimed at dissemination of project results for the fishing, aquaculture, shipping and the paint manufacturing industry as well as for policy makers and academicians. The workshops were attended in large numbers by the stakeholders. The sessions were extremely interactive.

Deliverables

1. Newsletter
2. Workshops
3. Booklet/special issue of a journal
4. Website dissemination

Milestones and expected results

Newsletters – Three

Workshops - Four

Booklet – Special issue of the journal

Website dissemination - updated routinely

Plans for the coming year

The project partners are trying to sensitize the policymakers in India on the issue of the ban particularly to the Government of India to sign the AFS convention. Efforts will be made to conduct awareness raising and dissemination exercises.

The focus will be on dissemination of information, sensitizing relevant stakeholders on the implications of TBT and its ban. The project partners are trying to sensitize policymakers in India on the issue of the ban and there are indications that the Government of India will sign the AFS convention in near future. If partners succeed in getting funds, efforts will be made to conduct awareness raising and dissemination exercises in other countries as well.

Consortium management

During the course of negotiations, several challenges were faced by the consortium. In the beginning, a change in the partners was required. Vasterharvet had to be replaced by the University of Gothenbörg. Further, another partner had to withdraw its participation on account of its internal administrative delays. A replacement was immediately found to work on the work-package committed by the earlier member. A long time was spent between the European Commission (EC) Officers and the then co-ordinator (TERI) on the negotiations. On account of the immense support from the EC officers involved, the negotiations were successfully concluded. The response from all partners was also positive and very encouraging.

During this period of the proposal submission, consortium building and negotiations, TERI had taken the lead role as a co-ordinator. At the end of the negotiations, it was realized that the financial co-ordinator had to be a European partner. There was a suggestion from EC that the co-ordination activities be split between TERI and a suitable European partner, ENEA, with TERI retaining scientific co-ordination and ENEA looking after the financial co-ordination. This required transfer of the administrative responsibilities and a part of the budget to ENEA. With the mutual consent, the transfer of responsibilities of financial co-ordination from TERI to ENEA took place. EC officers need to be commended for their patience and co-operation during the lengthy procedures of negotiations.

Further, above-mentioned constraints posed delay in the formal procedures. Signing of the project contract was delayed. EC was requested to allow starting of the project activities before the contract was signed. The contract was signed much later after the

project activities actually began. Despite the delay and the challenges faced in the initial period, due to the immense co-operation from all partners, project activities have progressed according to the schedule.

ENEA and TERI together carried out co-ordination and management responsibilities. There was very good interaction and cordial association between the financial and Scientific co-ordinators. Co-operation from all partners was also good.

ENEA (Participant 1) was the financial co-ordinator. Financial reports were submitted every year by ENEA. TERI (Participant 2) was the scientific co-ordinator and was responsible for technical communication between Commission and other contractors. Scientific reporting to the European Commission (EC) was carried out by TERI. This involved ensuring that periodic scientific reports and other deliverables are communicated to EC, documentation and reporting of meetings, workshops etc. Each team had appointed a team leader, who was responsible for providing technical and administrative information as well as for decision making for that team.

As scientific co-ordinator, TERI (Participant 2) held major responsibility for the management activities, which included work orientation for the entire project, organising partner meetings, scheduling workshops, ensuring that the deliverables dates were met and facilitating interactions between partners, especially from different disciplines. An overview of the scientific co-ordination is provided in fig2.

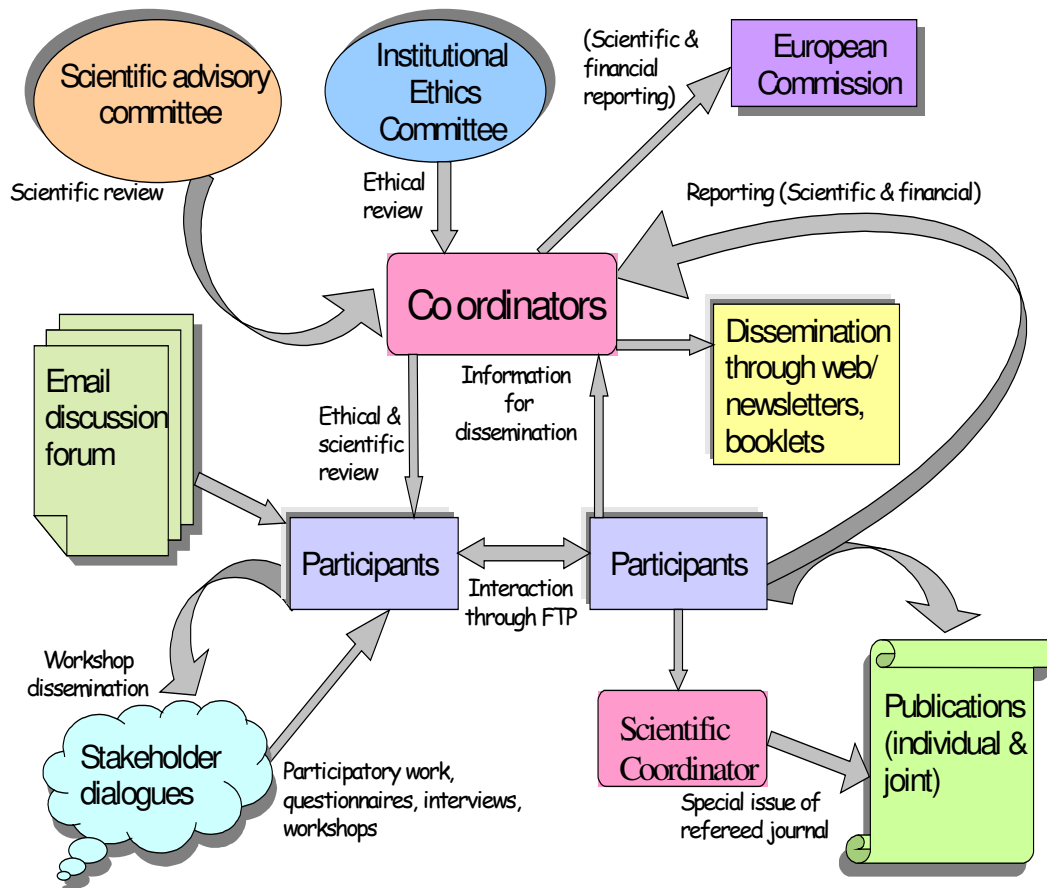


Fig 2. An overview of the scientific co-ordination

Five partner meetings were held during the project duration. The meets were hosted by the local partners and co-ordinated by TERI. First meet was held in Goa during 17th – 19th Sept 2005 and was hosted by TERI. Second meet was held at Gotrborg, Sweden from 8th to 10th May, 2006 and was hosted by UGOT. Third meet, hosted by ENEA was held in Rome, Italy from 8th to 10th May 2007; whereas fourth meet hosted by RU was

held at Nijmegen, Netherlands from 11th to 13th March 2008. The last meet was held in Goa, India during 20th to 22nd Jan 2009 and was hosted by TERI. Most partners participated in all meetings. The only exception was lack of participation by NIOT in a meeting held at Rome, Italy. The deliberations at the meetings were generally very fruitful. Several presentations were made at each meet. These presentations are uploaded on the project website. Minutes of the meeting are enclosed with the report (Annex VII).

An FTP (File Transfer Protocol) was created by TERI for sharing of data and for greater interaction between all partners during project duration.

Other issues

The progress reports were reviewed for ethical issues by an Institutional Ethics Committee, operating at TERI. The Committee was set-up as per the guidelines framed by Indian Council of Medical Research and consisted of one retired judge, one sociologist, two doctors (one clinician, one medical person), one philosopher, one layperson from community, one member Secretary from TERI and an environmentalist (The Chair). The members of IEC were apprised of the project activities and were updated on the progress of the reports throughout the project duration.

The project was highly multi-disciplinary as well as trans-disciplinary. In the beginning, it appeared that all partners spoke a different language. Since different disciplines were involved, it was quite difficult to take strides towards other disciplines. However, as the project progressed, a common language was shared by all partners. In this context, it was rightly agreed by all partners that it was not just in terms of final destination that the project was successful, but the journey that was traveled together by all partners was truly a good learning experience.

Plan for using and disseminating the knowledge

Public participation and awareness is a part of the research project. One entire work package (WP6) was devoted to this. Awareness raising was carried out through workshops, websites, newsletters, research papers and publication of a book.

Participatory works such as open and semi-structured interviews, focus group discussions, diagramming, mapping etc. helped to get inputs from various stakeholders. These participatory methods helped creating awareness at wide levels of society.

Dissemination of research findings was done, free of cost, through workshops at local level for general public, researchers, industry and policy makers; through research publications for researchers at international level; newsletters for policy makers, researchers, industry and general public at local, national and international level and public discussion meetings for general public at local level.

Specifically, the following dissemination activities were carried out for various actors

- Policy makers: interviews, multi-stakeholder workshops, research papers and newsletters
- Researchers: journal publications, multi-stakeholder workshops, newsletters, website
- Industry (shipping, cruise tourism, fishing and aquaculture): workshops targeting specific industries, interviews, focus group discussions, workshops, research papers, and newsletters
- General Public: multi-stakeholder workshops, newsletters, website, public dissemination meetings
- A **special issue** of a peer-reviewed journal '**Journal of Environmental Management**' was published to disseminate knowledge to the researchers at international level.

A website was set-up for the project. The link is <<http://static.teriin.org/teri-wr/projects/tbtimpacts.htm>>. The project website set-up a fully referenced database. Additionally, a searchable library mainly dedicated to the issue of TBT ban and

alternative antifouling strategies is made available on the web. Relevant presentations by partners are displayed. Project web-site is regularly updated by TERI (Participant 2) after receiving information/ research results from all participants.

Dissemination meetings were held to disseminate research findings to public at large. Multistakeholder workshops were held to introduce dialogues between various actors relevant to the project objectives. Workshops were organised in the third and fourth year of the project to disseminate the research outputs. The workshops were hosted by Participants 4 and 7 i.e. NIOT and NSDRC. Participant 4 hosted two workshops, one specifically for fishing and aquaculture industry and the other for multistakeholders. Similarly Participant 7 hosted two workshops, one specifically for shipping and paint manufacturing industry and the other for multistakeholders.

In addition dissemination activities were also carried out through newsletters and websites. The newsletters were disseminated to the international community, which involved industry, policy, NGO and research community.

Finally TERI as scientific coordinator played a critical role to oversee all activities, synthesize all information and ensure proper dissemination to the relevant stakeholders.