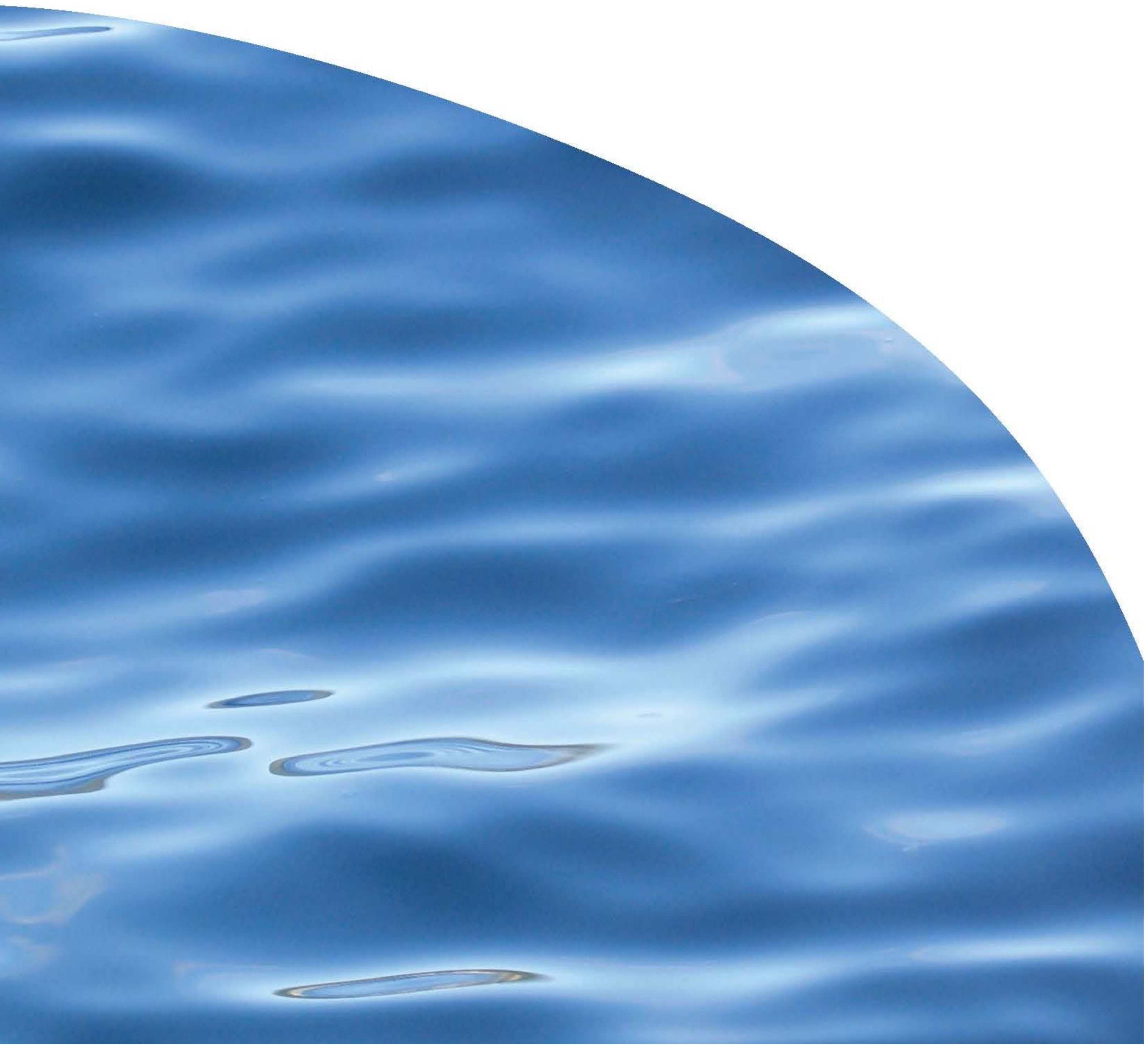
REPORT NO. 2715

ADDITION OF BIOCIDE DURING VESSEL BIOFOULING TREATMENT - AN ASSESSMENT OF ENVIRONMENTAL EFFECTS



ADDITION OF BIOCIDE DURING VESSEL BIOFOULING TREATMENT - AN ASSESSMENT OF ENVIRONMENTAL EFFECTS

DONALD MORRISEY

Prepared for Nelson City Council

CAWTHRON INSTITUTE
98 Halifax Street East, Nelson 7010 | Private Bag 2, Nelson 7042 | New Zealand
Ph. +64 3 548 2319 | Fax. +64 3 546 9464
www.cawthron.org.nz

REVIEWED BY:
Barrie Forrest

APPROVED FOR RELEASE BY:
Chris Cornelisen

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EXECUTIVE SUMMARY

Encapsulation with the addition of a biocide provides regulators, such as regional councils and unitary authorities, with a rapid (1 day or overnight), cost-effective method for treating the fouled hulls of vessels posing a high biosecurity risk. Treatment can be done on arrival, to reduce the risk of introduction of pest species, or before departure, to reduce the risk of spread to new areas.

Recent attempts to use the approach in the Top of the South have been frustrated by the need to obtain a resource consent, and the associated delays to treatment. The purpose of the present study is to generate the information on environmental effects of encapsulation with addition of a biocide to assess whether a consent is required and, if so, to minimise the consent processing time. The study was funded by an Envirolink Medium Advice Grant to Nelson City Council (NCC) and a Small Advice Grant to Tasman District Council (TDC), but the results will be useful to councils throughout New Zealand.

The treatment method is described and potential biocides are reviewed. Chlorine solution, at a concentration of free available chlorine (FAC) of 200 mg/L, is the recommended biocide based on its proven effectiveness, ease of use, and health and safety considerations. The most convenient method of creating this solution is to dissolve sodium dichloroisocyanurate ('dichlor', a compound commonly used for treating swimming pools) in sea water before adding to the encapsulated water. The target concentration should be maintained for at least 4 hours, topping up the FAC as required (FAC is consumed by oxidation of organic matter and other mechanisms during treatment). A look-up table is provided, giving the weights of dichlor required to treat different volumes of encapsulated water.

Environmental risks during treatment derive largely from spillage and leakage and can be managed to a low level by appropriate handling of materials. Risks to the environment from residual FAC at the end of treatment can be reduced to negligible levels by neutralisation with sodium thiosulphate (which is itself non-hazardous). A look-up table is provided, giving the weights of thiosulphate required to treat different residual concentrations of FAC in different volumes of encapsulated water. Neutralisation and reasonable mixing will ensure that FAC in water discharged to coastal waters is unlikely to have adverse environmental effects. Based on experimental studies, other water-quality variables, notably dissolved oxygen (DO), pH, dissolved sulphides and organic matter (OM) are not expected to be significantly affected by the short duration of treatment. To the extent practical, conspicuous amounts of OM, such as organisms killed by the treatment that fall off the hull, will be collected at the end of treatment and disposed of to land, as will any waste materials used in the treatment that are non-reusable.

The effects of treatment are assessed for compliance with the coastal marine water-quality standards of NCC and TDC. These are considered to be easily achievable with appropriate management of the treatment. Recommendations are made for consideration in setting consent conditions, including:

- Methods of treatment
- Management of encapsulated water at the end of treatment
- Water-quality criteria for discharged water
- Criteria for selecting locations for treatment and suggested suitable locations in the Top of the South
- Information to be provided before treatment and from monitoring during the treatment process.

Finally, a worked example is provided, based on the hypothetical treatment of a high-risk vessel that arrived in Port Nelson in 2014.

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GLOSSARY

Term	Definition
96-hr LC_{50}	Concentration of a toxicant that is lethal to 50% of the test organisms exposed for 96 hours (*i.e.*, acute toxicity).
14-d LC_{50}	Concentration of a toxicant that is lethal to 50% of the test organisms exposed for 14 days (*i.e.*, chronic toxicity).
°C	Degrees Celsius
µg/L	Micrograms per litre (parts per billion)
µm	Micron
ANZECC	Australia and New Zealand Environment and Conservation Council
Ca	Calcium
cm	Centimetre
DO	Dissolved oxygen
EC	Effective concentration – toxicant concentration causing an observable adverse effect (*e.g.*, death or serious incapacitation) in a given percentage of the test organisms.
FAC	Free available chlorine, composed of hypochlorous acid (HOCl) and the hypochlorite ion (OCl^-).
g/m^3	Grams per cubic metre
L/s	Litres per second
MAF	Ministry of Agriculture and Forestry
mg/kg	Milligrams per kilogram (parts per million)
mg/L	Milligrams per Litre (parts per million)
NCC	Nelson City Council
NIWA	National Institute of Water and Atmospheric Research
NOEC	No observed effect concentration – the highest concentration of a toxicant that produces no detectable response in the test organisms at a specific time of observation.
NRC	Northland Regional Council
O	Oxygen
TOS	Top of the South (Island)
US EPA	United States Environmental Protection Agency
Vector	The means by which an introduced species is transferred from one place to another.

1. INTRODUCTION

1.1. Background

The three Top of the South (TOS) councils (Marlborough District Council [MDC], Nelson City Council [NCC] and Tasman District Council [TDC]), together with the Ministry for Primary Industries and iwi, are the key agencies that form the TOS Marine Biosecurity Partnership. This Partnership is working towards reducing marine biosecurity risk in the TOS, recognising that marine pests can significantly impact the region's values. Despite considerable effort to manage the pathways that introduce or facilitate the spread of marine pests, high-risk vessels continue to arrive in the TOS from overseas, or from other parts of New Zealand, and must be managed. A recent study (Floerl *et al.* 2015, in press) has informed the three TOS councils on the feasibility, costs and benefits of implementing different vector treatment measures.

The biosecurity risk from the arrival of fouled boats must be dealt with rapidly. Options currently available are:

- Land-based: remove the boat from the water, followed by either water-blast or manually remove any biofouling, or leave the boat out of water for sufficient time so biofouling dries and dies. Facilities for this option are present at:
    - Waitapu Bay, Golden Bay (slipway and hardstand)
    - Port Tarakohe (haul-out and storage)
    - Port Motueka (slipways, haul-out)
    - Mapua (tidal grid)
    - Nelson (inspection grid, haul-out and storage, slipways)
    - Havelock (slipway, haul-out and storage)
    - Picton (slipway)
    - Waikawa (haul-out and storage, slipway).
- Water-based: clean the hull with brushes or other equipment (generally using commercial divers), or enclose ('encapsulate') the hull with an impermeable wrap, causing the biofouling to die from lack of oxygen. Encapsulation treatment can be expedited by the addition of a biocide. Commercial divers are available at Nelson and Picton.

In assessing these options, Floerl *et al.* (2015, in press) noted that:

> *In addition to marina and port infrastructure, the region has boat ramps, slipways and haul-out facilities, with Nelson and Picton being the largest providers. These facilities cater for small-to-medium craft (< 80 m) and are generally available at short notice (e.g. during a pest response) throughout the year. An exception is the Calwell Slipway, where advance bookings are required unless there is a cancellation.*

This was highlighted during the recent Voyager P response, where there was a 3-week delay before the boat could be slipped. At present, there are no land-based facilities for larger boats (> 80 m) for either maintenance or treatment activities.

The TOS is well placed in terms of specialised diving services in the region, with the three main operators having been involved with biosecurity-related activities. Of note is the considerable collective expertise in encapsulation methods, which has now been applied to wharf piles, marina pontoons and boats up to 110 m in length. Over the past decade, the range of in-water cleaning/treatment technologies has increased considerably to meet a growing and changing demand (e.g., due to advances in paint technologies). Some of the emerging treatment technologies are not presently available in the TOS (e.g. cavitation, floating docks) and nationally (e.g. ultrasonic methods). Once the performance and benefits of the new floating dock system operated by Northland Regional Council has been ascertained in more detail, this technology in particular could be a useful avenue for treating biofouling on small craft boat in the TOS, both as a pre-emptive maintenance measure and as a response option.

1.2. Aim of this study

An effective treatment to kill biofouling on exposed hull surfaces and internal piping is to encapsulate the hull and add a biocide to the volume of water trapped between the hull and the wrapping material (Coutts & Forrest 2005, 2007, Roche *et al.* 2014, Atalah *et al.* manuscript in preparation, Morrisey *et al*. manuscript in preparation). However, there are several challenges in using this treatment. A resource consent may be required to discharge water containing a biocide and the consenting process takes time. This may prevent a rapid response to the arrival of a high-risk vessel. This was demonstrated recently with the treatment of the 21-m fishing boat *Voyager P* in Nelson, when consent to use a biocide could not be obtained quickly. Encapsulation without the addition of a biocide was not completely effective and viable biofouling was left on the hull after treatment.

The aim of the present study is to provide the information on environmental effects of encapsulation with biocide required by NCC and TDC, and potentially other councils in New Zealand, to process consents more rapidly. It may also facilitate the implementation of a general (or 'blanket') consent for the treatment of high-risk vessels using wrapping and specified treatment chemicals, an approach that has been adopted by Northland Regional Council (NRC; consent number 036500.01.01, February 2014). The information provided in this report will benefit other councils in their consenting processes.

The study consists of the following elements:

- Description of the proposed activity, including recommendation of a preferred biocide.
- Description of the nature of the discharge from encapsulation with the recommended biocide.
- Description of any treatment of the encapsulated water prior to discharge to avoid or mitigate environmental effects.
- Description of the receiving environment in terms of recommendations for suitable treatment locations in the TOS.
- Assessment of effects on the environment.
- Recommendations for consent conditions.

1.3. Planning, policy and regulatory context

A detailed assessment of how the treatment methods recommended by this report align with council policy and planning, and how they comply with regulations, is beyond the scope of the present study. However, a brief overview of the planning, policy and regulatory context in which the methods might be used is provided here (see also Floerl *et al.* 2015, in press).

In addition to the information provided in the following sections, it should be noted that if a substance has not previously been approved for use as a biocide, approval may be required from the Environmental Protection Authority.

1.3.1. Biosecurity Act 1993

Under the Biosecurity Act 1993, regional councils provide leadership in “activities that prevent, reduce, or eliminate adverse effects from harmful organisms that are present in New Zealand (pest management) in its region”. Amongst other powers, each council has the power to provide for the assessment and eradication or management of pests, in accordance with relevant management plans (s 13).

Section 52 of the Act prohibits knowingly communicating, causing to be communicated, releasing, causing to be released, or otherwise spreading any pest or unwanted organism. Under s 122, councils can issue Notices of Direction requiring that fouled vessel be cleaned before entering, travelling within or leaving their jurisdiction. This power has been used by Northland Regional Council, for example, in their response to the Mediterranean fanworm (*Sabella spallanzanii*) and the seaweed *Undaria pinnatifida*[1].

1.3.2. Craft Risk Management Standard for vessel biofouling

The Craft Risk Management Standard (CRMS[2]), administered by the Ministry for Primary Industries (MPI), requires that vessels entering New Zealand complete a biofouling declaration and arrive with a 'clean hull' in accordance with specified biofouling thresholds. There are two different thresholds: 'long–stay vessels' (vessels staying in New Zealand for > 20 days) are not allowed to arrive with more than a slime layer and goose barnacles on their entire submerged hull surface. 'Short–stay vessels' (vessels staying ≤ 20 days) are allowed to have more fouling, but it is restricted to macroalgae and very low abundance of one type of sessile animal biofouling such as barnacles, tubeworms or bryozoans.

One way that fouled vessels can comply with the CRMS is to treat their hulls within 24 h of arrival, and encapsulation may provide a method for doing this. Confirmation of the acceptability to MPI of this method of treatment may be required because encapsulation kills fouling but does not necessarily remove it from the hull. MPI will provide a list of approved treatments for foulingon their website in the future.

The CRMS comes into force in May 2018, following a four-year voluntary lead-in period. The lead–in period is intended to allow for the development and implementation of improved biofouling management technologies and practices within the shipping industry.

1.3.3. Resource Management Act 1991

The purposes of the Resource Management Act (RMA) 1991 is to promote sustainable management of natural and physical resources while safeguarding, among other things, the life-supporting capacity of air, water, soil and ecosystems. The Act also requires that any adverse effects of activities on the environment be avoided, remedied or mitigated.

The following sections of the Act are particularly relevant to the treatment of fouled vessels by encapsulation and the addition of a biocide.

- Section 12(1)(d) stipulates that no person may deposit in, on, or under any foreshore or seabed any substance in a manner that has or is likely to have an adverse effect on the foreshore or seabed unless the discharge is allowed by a national standard or other regulations, a rule in a regional plan, or a resource consent. Fouling dislodged from the hull of a boat as a result of the treatments proposed in this study would fall under this rule. Section 12(1)(f) is also relevant in

[1] See http://www.nrc.govt.nz/Resource-Library-Summary/Environmental-Monitoring/State-of-the-Environment-Monitoring/Our-coast2/Marine-biodiversity-and-biosecurity/#A4.
[2] See http://www.biosecurity.govt.nz/files/regs/ships/crms-biofouling-standard.pdf

the present context because it states that no person may introduce or plant any exotic or introduced plant in, on, or under the foreshore or seabed. Again, this would apply to fouling algae dislodged from the hull of a boat. Whether this prohibition is applied may depend on the amount of material deposited.

- Section 15(1)(a) prohibits the discharge of contaminants or water into water unless the discharge is allowed by a national standard or other regulations, a rule in a regional plan, or a resource consent. Discharge to water may be direct (s (15(1)(a)) or indirect via discharge to land (s 15(1)(b)). The discharge of encapsulated water containing residual biocide following treatment of fouling would fall under this rule, whether it occurs by release directly in to the surrounding water body or via pumping onto the adjacent foreshore.
- Section 15A(1)(a) prohibits the dumping of any waste or other matter from any ship or offshore installation unless allowed by a resource consent.
- Similarly, s 15B(1) prohibits the discharge of water or contaminants from a ship or offshore installation into water unless permitted or controlled by regulations in the Act, a rule in a regional coastal plan, a resource consent or if, after reasonable mixing, the water or contaminant discharged is not likely to give rise to significant adverse effects on the receiving environment, including aquatic life.
- Discharges and dumping of waste from ships and offshore installations are controlled through the Resource Management (Marine Pollution) Regulations 1998. The regulations allow discharges made as part of normal operations of a ship or offshore installation, but this explicitly excludes the discharge of material derived from cleaning the exterior of the hull.
- Harmful substances defined under Regulation 3 of the Resource Management (Marine Pollution) Regulations 1998 include “drainage from spaces on a ship or offshore installation containing living animals” and waste water that is mixed with such drainage.
- The use of Section 330 of the Act has been proposed as a mechanism for taking emergency action to treat a vessel that arrives unexpectedly and with a high biosecurity risk (pers. comm. Jonno Underwood, Marlborough District Council). Section 330 applies where any natural and physical resource or area for which a local authority or consent authority has jurisdiction is affected by, or likely to be affected by, an adverse effect that requires immediate preventive or remedial measures. In such a situation, s 12 and s 15 (among others) do not apply to any activity undertaken to remove the cause of, or mitigate any actual or likely adverse effect of, the emergency.

1.3.4. New Zealand Coastal Policy Statement

Objective 1 of the New Zealand Coastal Policy Statement (NZCPS) is to safeguard the integrity, form, functioning and resilience of the coastal environment and sustain its ecosystems by:

- maintaining or enhancing natural biological and physical processes in the coastal environment and recognising their dynamic, complex and interdependent nature
- protecting representative or significant natural ecosystems and sites of biological importance and maintaining the diversity of New Zealand's indigenous coastal flora and fauna
- maintaining coastal water quality, and enhancing it where it has deteriorated from what would otherwise be its natural condition, with significant adverse effects on ecology and habitat, because of discharges associated with human activity.

Policy 12 of the NZCPS provides for the control of activities that could have adverse effects on the coastal environment by causing the release or spread of harmful aquatic organisms (HAO). These activities may include the introduction of structures likely to be contaminated with HAO, and the discharge of organic material from vessels (for example, during cleaning). Management of these activities may include conditions in resource consents.

Policy 23(1) requires that management of discharges to water should have particular regard to:

- the sensitivity of the receiving environment
- the nature of the contaminants to be discharged, the particular concentration of contaminants needed to achieve the required water quality in the receiving environment, and the risks if that concentration of contaminants is exceeded.
- the capacity of the receiving environment to assimilate the contaminants.
- avoid significant adverse effects on ecosystems and habitats after reasonable mixing
- use the smallest mixing zone necessary to achieve the required water quality in the receiving environment
- minimise adverse effects on the life-supporting capacity of water within a mixing zone.

1.3.5. Resource Management Plans

Nelson Resource Management Plan

Nelson City Council's Resource Management Plan, Coastal Policy CM6.3 (Discharges (general)) states that:

> "*Discharges to coastal water should not, after reasonable mixing, result in a breach of classification standards or a reduction in water quality and the discharge should not (either by itself or in combination with other discharges) give rise to any significant adverse effects on habitats, feeding grounds or ecosystems.*"

The water-quality class FEA (fisheries, fish spawning, aquatic ecosystems and aesthetic purposes) applies throughout the Coastal Marine Area. The coastal marine water-quality standards for the FEA class, to apply after reasonable mixing, are listed in Section 6.3.1 of this report.

Tasman Resource Management Plan

Rule 36.2.2.8 (Discharge of Water) of the Tasman Resource Management Plan states that:

> *The discharge of water into water is a permitted activity that may be undertaken without a resource consent, if it complies with the following conditions:*
>
> a. *The discharge does not cause erosion of the bed of any river or stream.*
> b. *The discharge does not contain more than 0.5 grams per cubic metre of free or residual chlorine.*
> c. *Except as provided for in condition (a), the discharge does not contain contaminants other than heat.*
> d. *When the natural temperature of the water is less than 20 degrees Celsius, the water temperature is not increased by more than 3 degrees Celsius and in any event does not exceed 20 degrees Celsius. When the natural temperature of the water is 20 degrees Celsius or greater, there is no increase in water temperature.*
> e. *Except as provided for by conditions (g) and (h), the rate of discharge does not exceed 5 litres per second.*
>   (Note that conditions (g) and (h) relate to discharges from dams and hydro-electric power generation).

If the discharge does not comply with these conditions, a resource consent is required.

Marlborough Sounds Resource Management Plan

Objective 9.3.2.1 of the Plan is to manage the effects of activities so that water quality in the coastal marine area is at a level which enables the gathering or cultivating of shellfish for human consumption (all marine waters in the district are currently classified to this standard). The policies to achieve this include:

- Avoid the discharge of contaminants into the coastal marine area where it will modify, damage or destroy any significant ecological value.
- No discharge, after reasonable mixing, (either by itself or in combination with other discharges) should limit the consumption of seafood from the coastal marine area.

Standards for the shellfish gathering and contact recreation standards are currently being reviewed.

2. DESCRIPTION OF THE PROPOSED ACTIVITY

This section describes the proposed activity in terms of the available options for encapsulating the hull of a fouled vessel, and the mechanisms by which fouling is killed during encapsulation. This treatment can be enhanced and accelerated by adding a biocide, and these types of biocide are also described. The section ends with a recommendation of the most appropriate biocide for routine use. Subsequent sections of the report are based on the use of this biocide.

2.1. Encapsulation methods

Encapsulation, with the addition of a biocide to the encapsulated water, is proposed for eliminating the biosecurity risk posed by hull biofouling. Encapsulation kills biofouling either by restricting the exchange of water, leading to deoxygenation as fouling organisms respire, or by enclosing organisms with an added biocide. When deoxygenation is the mechanism of control, microbial organisms will also consume oxygen as they decompose dead fouling organisms. Microbial decomposition will eventually also generate toxic dissolved sulphides.

Encapsulation may be achieved by several methods, including:

1. Divers wrapping the hull with strips of plastic sheeting, similar to silage wrap (0.75 m × 1,500 m × 25 µm). Strips overlap and are sealed with waterproof tape. It may be difficult (or impossible) to create a seal that prevents an exchange with the surrounding water, particularly if the hull shape is complex and/or has protrusions (such as keels and stabilisers). The volume of water encapsulated using this method may be small compared with other methods of encapsulation, particularly if the shape of the hull is simple and the wrap is tightly applied.
2. Enclosing the hull in a flat, plastic sheet that is passed under the hull and then secured on all sides above the water line (either to the superstructure of the boat, or to the adjacent berth). The boat sits in this 'bag' in a volume of water that depends on the size of the sheet. Sheets specifically designed for this purpose are currently in development. Other options include using silage covers (6–15 m × 300 m × 150 µm; Pannell & Coutts 2007, Coutts & Forrest 2007, Denny 2007; pers. comm. Diving Services New Zealand Ltd). Specifically-designed systems, such as the IMProtector (http://www.biofoulingsolutions.com.au/featured-projects/improtector), are made of material that is resistant to cutting, tearing and abrasion and are fitted with floatation collars and ballast chains (Aquenal 2009). They are towed into position around the hull from a support vessel. Divers are not necessarily required for deployment.
3. Enclosing the boat in a commercially available, purpose-built floating dock[3]. The dock consists of an inflatable 'collar' supporting an impermeable bag. Part of the

[3] See, for example http://www.incept.co.nz/categories/fab-dock.

collar (the 'gate') is deflated and lowered to allow the boat to enter the dock. The collar is then re-inflated to create a rim around the dock above water-level. This prevents water and any biofouling material dislodged from the hull from escaping. Divers are not necessarily required for deployment.

Figure 1. Examples of encapsulation using a floating dock and a plastic sheet (photo credits: Matt Smith, NIWA and Bruce Lines, Diving Services NZ Ltd).

Once the boat has been enclosed, encapsulated water may be pumped out to increase the rate of deoxygenation or to reduce the volume of biocide that must be added to achieve the target treatment concentration. In the case of floating docks, the floor of the dock may be fitted with ribs that can be inflated while the gate is open, expelling excess water from around the boat. Some docks also have a pump installed at floor level inside the dock. However, there is an optimal volume of water that must be encapsulated to ensure that biofouling organisms are exposed to oxygen depletion or lethal concentrations of biocide.

Although floating docks cost more initially, they are reusable. Plastic sheets (particularly those that are purpose-made for encapsulating boat hulls, such as the IMProtector) may also be recoverable and reusable after treatment, but plastic wrapping strip is generally not. This has implications both for cost and for environmental effects because wrapping strip must be unwrapped, recovered and disposed of after use.

2.2. Other methods of enclosing biofouling for treatment

Where biofouling is confined to a limited area of the hull, it may not be necessary to encapsulate the whole hull. One particular part of the hull where this may apply is sea chests of larger ships. These are cavities in the hull containing intakes for seawater for use as ballast, fire-fighting and other uses. They are covered by grills, flush with the hull, that prevent large debris from being entrained with the water.

Commonly used 'self-polishing' antifouling coatings rely on the flow of water to continually 'renew' the surface of the coating and maintain the rate of release of antifouling biocides. These antifouling coatings do not function properly when applied to the inside of sea chests because they are sheltered from water movement when the ship is under way. Consequently, biofouling often develops to a much greater degree than on more exposed surfaces of the hull. Fouling organisms inside sea chests are also sheltered from strong water movement and from larger predators.

Sea chests can be closed off using blanking plates while the ship is in the water. Biocidal solutions, such as chemical biocides, hot water or freshwater, can then be pumped into the sea chest to treat biofouling.

2.3. Use of biocides and other additives

Field and laboratory studies suggest that the likelihood of success of encapsulation in treating biofouling is increased, and the treatment time greatly reduced, by adding a biocide to the encapsulated water. Rapid treatment is important when the inconvenience and cost of voyage delays may act as a disincentive to treatment.

2.3.1. Natural and enhanced deoxygenation

The effectiveness of encapsulation for treating fouled ships and other floating structures has been demonstrated in a number of experimental and 'real' situations (Coutts & Forrest 2005, 2007, Roche 2014). Deoxygenation of the enclosed water will occur during encapsulation by the respiration of the fouling organisms and of microbes that decompose dead biofouling. The rate of deoxygenation depends on several factors, including the amount of biofouling, the amount of water enclosed, ambient temperature and the effectiveness of the encapsulation at preventing exchange of water with the surrounding environment. Prevention of exchange is particularly difficult if the hull shape is complex and wrapping is done with strips of material.

If concentrations of dissolved oxygen (DO) can be kept low enough for long enough, it will be effective at killing fouling organisms. However, experimental studies (Atalah *et al.* manuscript in preparation) have shown that this can take from days to weeks, depending on the rate of deoxygenation and the susceptibility of different types of fouling organisms. Bivalve molluscs and some species of bryozoans (including non-indigenous species), both common components of biofouling assemblages, appear to be particularly resistant to low DO concentrations and may require encapsulation for up to two weeks.

Rates of deoxygenation can be increased by adding additional substrate for microbial decomposition, such as sugar, molasses or whole milk (Clearwater *et al.* 2008). The amount of substrate required will be dependent on the ambient temperature and the biomass of biofouling. As a result, the rate of deoxygenation may still be slow or, conversely, the substrate may not all be used up and may cause unwanted deoxygenation when released into the surrounding environment.

An alternative approach is to add oxygen-scavenging agents, such as sodium thiosulphate and sodium sulphite, to remove oxygen from solution. Sodium sulphite is used to remove oxygen from boiler waters and during pulp and paper processing (Clearwater *et al.* 2008). Some suitable agents, such as sodium thiosulphate, have low toxicity but others (sodium sulphite, sodium bisulphite and sodium metabisulphite) are toxic and classified as harmful to aquatic life. This poses a risk to biological communities around the treatment site if residual chemicals are released after treatment, both from direct toxic effects and from unwanted deoxygenation.

2.3.2. Freshwater and hot water

The simplest biocides available are freshwater and hot water (salt or fresh). Rolheiser *et al.* (2012) used freshwater to control fouling organisms and predators on oyster farms. Both methods have also been trialled successfully for treating biofouling on aquacultured mussel seed-stock (Forrest & Blakemore 2006). However, some species of biofoulers are tolerant of freshwater and the required exposure time may be very long. Bivalves, in particular, can remain with their shells closed for several days when exposed to freshwater. Hot water is impractical for use with encapsulation if there is a relatively large amount of encapsulated water. Use of hot water is feasible for treating specific parts of the hull, such as seachests (Piola & Hopkins 2012). Very hot water may potentially damage the wrap and can also compromise the antifouling coating of the hull (Morrisey & Woods 2014), though this is not likely to be a problem on heavily fouled boats because the coating has clearly already failed.

2.3.3. Chemical biocides

Several easily-available, non-persistent biocidal chemicals have been trialled for control of biofouling. These include chlorine solution, acetic acid (CH_3COOH, usually at a concentration similar to that of vinegar, ca 5%), brine and lime (quicklime, CaO, or hydrated lime, $Ca(OH)_2$). The reaction products of these chemicals are also non-persistent.

Household cleaners and antiseptics can also be effective in treating marine pests (Dunmore *et al.* 2011). We have not considered these in the present context, however, because they may not break down so readily in the environment and may have persistent reaction products. These properties may create obstacles to the consenting process.

Piola *et al.* (2010) compared the effectiveness of acetic acid, hydrated lime and hypochlorite (bleach) at eradicating biofouling organisms. They, and an earlier study by Carver *et al.* (2003), concluded that acetic acid was the most effective. Low concentrations of acetic acid (5%) appeared just as effective at removing most taxa as the high concentrations (20%), even at very short exposure times (0.5 h). Sodium hypochlorite was the next most successful chemical in removing fouling biota, but it was only effective at the highest concentration (20%). Hydrated lime appeared the least effective chemical at removing fouling taxa. Only in a few instances was it able to remove the majority (75–100%) of biota, and only at high concentrations (10–20%) following long exposure times (4–6 h).

In an experimental study comparing the effectiveness of encapsulation with and without the addition of acetic acid (Atalah *et al.* manuscript in preparation), the recommended treatment time for bivalves and resistant bryozoans was reduced from > 14 d to 2 d when acetic acid was added (to achieve a concentration of 5% in the encapsulated water). During the treatment of biofouling on the launch *Columbus* in Nelson, difficulties in preventing exchange between the encapsulated and surrounding water maintained DO at concentrations too high to kill biofouling within a reasonable time-frame (pers. comm. Javier Atalah, Cawthron Institute). Addition of acetic acid, and repair to the wrapping, led to a rapid reduction in DO to lethal concentrations, presumably due to the death and decay of fouling organisms caused by the acid.

Of the potentially suitable biocides listed above, chlorine solution is recommended for the present purpose, despite the finding of some previous studies that acetic acid is more effective at treating some biofouling taxa. These earlier studies were done at a small scale: Piola *et al.* 2010 studied effects on biofouling on experimental panels measuring 20 cm × 20 cm. Treatment at the much larger scale of whole hulls presents significantly different logistical problems, including health and safety issues. Piola *et al.* (2010) also used commercial bleach solution, which typically contains 3–10% available chlorine, and this was diluted to 5–20% of the original concentration for their study. The biofouling was consequently exposed to a low concentration of available chlorine. Bleach also contains chlorine in a relatively unstable and easily degraded form, as discussed below.

A much higher initial concentration of available chlorine (200 mg/L), in combination with wrapping in polythene, was used in the successful treatment of *Didemnum vexillum* on barges in Shakespeare Bay, Queen Charlotte Sound (Coutts & Forrest 2007).

Chlorine was also successful in treating heavy biofouling (including large numbers of *Sabella spallanzanii* on the hull an 8-m long yacht by encapsulation (Morrisey *et al.* 2015). This operation made use of a floating dock (FAB Dock, http://fabdock.com), normally used to prevent biofouling on boats while at their berths. It was purchased by

NRC specifically for treating fouled boats. The trial was done in Westhaven Marina, Waitemata Harbour.

Chlorine solution was applied once, at an initial concentration of free available chlorine (FAC) of 200 mg/L. Chlorine in solution is consumed by reaction with organic matter, is volatilised and is also photolysed by UV light. In the floating dock trial, chlorine was added as a solution of sodium dichloroisocyanurate (dichlor), commonly used for chlorination of swimming pools. Commercial grades of dichlor (CAS 51580-86-0) are usually the dihydrate form and contain 55–56% available chlorine by weight. Dichlor reacts with water to produce hypochlorous acid and cyanuric acid. Cyanuric acid acts as a UV-light stabiliser for the chlorine. It has a low acute toxicity (see Section 3.3). Other common chlorine-containing chemicals, such as bleach, are not stabilised and degrade faster.

Although the concentration of FAC in the floating dock decreased from 200 mg/L to 50 mg/L after 2 h, and to < 10 mg/L after 16 h, in the floating dock trial (Morrisey *et al.* 2015), a single dosing of 200 mg/L of free available chlorine was effective in killing all biofouling after 16 h exposure, including fanworms, oysters and mussels. Supporting laboratory studies demonstrated that a 4-h exposure of *Sabella spallanzanii* (in their tubes) to this concentration killed more than 99% of adult worms and was recommended as a treatment regime for this species.

Chlorine is widely used as a cleaning or sterilising agent. A solution of chlorine can be prepared using easily-obtained, low-cost chemicals, such as dichlor. In contrast, the treatment of the launch *Columbus* in Nelson used 220 L of glacial acetic acid over the course of 7 d (though the large volume required may have been partly due to leakage from the wrapping). Glacial acetic acid is mildly corrosive to metals, corrosive to skin and is a strong eye, skin and mucous membrane irritant. Safe transport and handling of this amount of the liquid poses much greater problems than are involved with dichlor. Glacial acetic acid is also more expensive than dichlor: the 220 L of acetic acid used to treat the *Columbus* cost ca NZD$450 (pers. comm. Bruce Lines, Diving Services New Zealand Ltd) compared with ca NZD$35 for the 3.6 kg of dichlor used in the floating dock trial.

It is worth noting that sodium diacetate (in powder form) can be used as an alternative to acetic acid and has fewer logistical and safety problems (pers. comm. Barrie Forrest, Cawthron Institute). There is some evidence that the biocidal effects of acetic acid and, by extension, sodium diacetate are a function of the compound itself, rather than of the reduction in pH (Forrest *et al.* 2007).

2.3.4. Recommended biocide

Based on its demonstrated effectiveness, ease of use, and health and safety considerations, we recommend the use of chlorine solution as a biocide in combination with encapsulation. The initial target concentration of free available chlorine should be 200 mg/L and should be maintained for at least 4 h. Maintaining this concentration will almost certainly require monitoring of FAC concentration and periodic redosing.

The safest and most convenient method of creating the solution is to dissolve dichlor granules in seawater before adding to the encapsulated water. During the treatment, chlorine testing strips (designed for testing swimming pool water) can be used for convenient measurement of chlorine concentrations in the ranges of, for example, 0.5–10 mg/L and 0–600mg/L. The Materials Safety Data Sheet (MSDS) for dichlor is shown in Appendix 2.

Additional dichlor can be added if necessary to maintain the target concentration over the treatment period. At the end of the treatment, residual chlorine can be removed with a non-toxic neutralising agent (see section 4.1.2). Appendix 4 Table 2 contains a look-up table for dosing and re-dosing a given volume of encapsulated water with dichlor to achieve a concentration of 200 mg/L.

Dichlor is available as pellets and relatively small amounts are needed. In the yacht treatment trial in Auckland's Westhaven Marina (Morrisey *et al.* 2015), ca 3.6 kg of dichlor pellets were used in a single dose, added to 10 m^3 of water in the floating dock. This makes the treatment chemical relatively easy and safe to transport and handle. It can be mixed with seawater on site, minimising handling risks. Dichlor costs around NZD$10/kg.

Based on this recommendation, the remainder of this report is restricted to the use of chlorine solution (derived from dichlor granules) during encapsulation.

3. DESCRIPTION OF THE NATURE OF THE DISCHARGE

When treatment of a vessel hull is completed, the wrapping material will be removed and the water contained within it will be discharged into the surrounding environment. This section of the report describes those properties of the discharged water that must be considered when assessing potential environmental effects:

- The volume and rate of discharge
- The nature of the discharge, including the concentrations of oxygen, chlorine and other contaminants and pH
- The frequency of discharge at a given location.

3.1. Discharge volume and rate

The volume of water to be discharged to the surrounding water body after treatment is very difficult to estimate and little information is available from previous encapsulation treatments. It depends on the size and shape of the hull and the type of encapsulation. Wrapping in plastic strip or sheet generally encloses a relatively small volume, but can be greatly increased when the hull shape is complex or has extensions such as bilge keels.

The amount of water enclosed in a floating dock will depend on the volume of the dock relative to that of the boat being treated, and how much water is pumped out of the dock once the boat is inside. The volume of water displaced by a 30–40 m long hull may be 80–150 m^3.

FABdock, suppliers of the floating dock purchased by NRC, are able to provide docks for boats 5–35 m (15–100 ft: http://fabdock.com). NRC's floating dock is 18 m long, 6.6 m wide and is designed to accommodate boats up to 16 m long. It holds 200 m^3 of water when completely full, some of which will be displaced by the boat being treated. The 8-m yacht treated in the trial displaced ca 2 m^3, while a 16-m boat might displace 20–40 m^3. In the trial, water was pumped out of the dock to leave an estimated residual volume of 10 m^3 (Morrisey *et al.* 2015). Vertical ribs in the walls of the dock can be inflated once the boat is in the dock but before the gate is closed. This lifts the floor of the dock up and around the hull, minimising the volume of water that is enclosed.

A rough estimate of the water enclosed with an encapsulated hull can be derived from the area of the hull multiplied by the width of the gap between the hull and the encapsulating material (see Appendix 1). Estimated volumes of encapsulated water for different sizes of yacht and for a motor cruiser are shown in Appendix 1 Table 1, based on different sizes of gaps. The estimates for a tightly wrapped (5 cm gap) hull ranged from 1.1 m^3 for an 8-m yacht to more than 5 m^3 for a 30-m yacht.

These rough estimates suggest that the expected volumes of discharges from encapsulation treatments of vessels in the length range 8–30 m are likely to be of the order of less than 1 m^3 to a few tens of m^3.

The rate of discharge of water from encapsulation is also highly variable. Rapid removal of a wrapping sheet or opening of a floating dock may release the bulk of the water over, say 15 min. Removal of wrapping strips is likely to take much longer, releasing water over an hour or longer.

The rate of discharge can be controlled via the use of a pump and would maximise dilution and dispersion of any residual biocides or water of low DO and also help to volatilise residual chlorine and replenish DO. For example, pumping at 330 L/min (5.5 L/s) would take 30 min to empty the estimated 10 m^3 of water present in the floating dock during the treatment of the 8-m yacht.

3.2. Residual chlorine

In the floating dock trial (Morrisey *et al.* 2015), the concentration of FAC in the main body of water in the floating dock had decreased from 200 mg/L at the start of the treatment to 50 mg/L after 4 h and 8 mg/L after 16 h. Concentrations measured at several locations on the hull of the boat were 1–3 mg/L after 16 h.

The laboratory study accompanying the field trial included a pilot experiment that measured the rate of decrease in the concentration of FAC over 4 h in the presence of live *Sabella spallanzanii* and their tubes. Free available chlorine concentration decreased by ca 70% (to 40–70 mg/L) in the 200 mg/L treatment and ca 85% in the 10 mg/L and 1 mg/L treatments (to 1.5 mg/L and 0.15 mg/L, respectively).

If the encapsulation treatment is run overnight and the hull being treated is moderately or heavily fouled, we would expect residual FAC concentrations to be < 10 mg/L by the end of treatment. If, after 4 h treatment, the water is encapsulated for a further 4 h, a residual concentration of ca 50 mg/L would be expected.

Methods for measuring and neutralising residual chlorine are described in Section 4.1.

3.3. Residual cyanuric acid

The only persistent agent present in the water discharged after encapsulation will be cyanuric acid, derived from dichlor. A single addition of dichlor to create a FAC concentration of 200 mg/L would produce a cyanuric acid concentration of ca 164 mg/L. Cyanuric acid is not readily biodegradable (OECD 301C; 0% after 14-

day) and is stable in water. The bioconcentration factor to fish is low (< 0.5 in carp after 6 weeks) and the toxicity of this chemical to aquatic organisms is also low[4], as illustrated by the following data.

- The NOEC for reproduction and 48-EC_{50} for immobilisation of *Daphnia magna* are 32 mg/L and 1,000 mg/L, respectively.
- Both the 96-h LC_{50} and the 14-day LC_{50} for the fish *Oryzias latipes* are > 100 mg/L.
- The 72-h NOEC and 72-h EC_{50} for the alga *Selenastrum capricornutum* are 62.5 mg/L and 620 mg/L, respectively.

3.4. Dissolved oxygen

Dissolved oxygen concentrations in the encapsulated water during the floating dock trial (Morrisey *et al.* 2015) remained reasonably high throughout the treatment (around 80% of saturation, which is typically 7–8 mg/L at 20 °C). Chlorine is a general biocide and presumably, in addition to killing the biofouling, also kills the microbes that decompose dead biofouling and other organic material (consuming oxygen in the process).

In smaller-scale experiments in which fouled plates (20 cm × 20 cm) were encapsulated with and without the addition of 5% acetic acid, DO concentrations decreased to < 1 mg/L within 48 h in treatments without acetic acid (Atalah *et al.* manuscript in preparation). Dissolved oxygen concentrations were also reduced relative to controls in treatments to which acetic acid (5%) had been added, falling as low as 3 mg/L after 2 h and 2 mg/L after 4 h. Over longer periods (24 h and 48 h), however, DO concentrations recovered to 4–6 mg/L (ca 50–75%) in the acetic-acid treatment. Cover of live fouling organisms on the panels decreased from 80% to 0% after 2 h in the acetic-acid treatment and to 20% after 2 d in the no-acid treatment.

The lower rate of reduction in DO in the acetic acid treatment is consistent with the higher rate of mortality because there were fewer biofouling organisms and microbial decomposers alive to consume oxygen. Once all the biofouling was dead, DO concentrations recovered, presumably by diffusion from the surrounding water. The fact that DO concentration was initially reduced in the acetic-acid treatment contrasts with the lack of response of DO to application of chlorine in the floating dock study. This may indicate that 5% acetic acid did not kill biofouling as rapidly as dissolved chlorine at 200 mg/L. Alternatively, the much larger volume of water in the floating dock may have diluted any effects of consumption of oxygen, and the larger surface area of water and pumping to circulate the chlorine will have increased rates of replacement of any oxygen consumed.

[4] See the website of the International Programme on Chemical Safety, http://www.inchem.org/documents/sids/sids/108805.pdf, accessed 18 May 2015.

These studies suggest that if chlorine is applied at the recommended concentration, DO concentrations are unlikely to be significantly reduced. Mixing of the encapsulated water by pumping would further reduce the risk of hypoxia (in addition to ensuring that all parts of the hull are exposed to chlorine solution).

3.5. Organic matter

Because encapsulation treats biofouling by killing it in situ, the amount of waste released from the hull is generally small compared to methods that scrape the biofouling off the hull. Sessile organisms are likely to remain attached to the hull after treatment. However, experimental trials suggest that free-living organisms among the biofouling and tube-living animals that are able to leave their tubes, are likely to fall off the hull when they die and be contained within the encapsulation. Unless it is captured, this dead organic material will be dispersed into the water column and onto the seafloor when the wrapping is removed.

3.6. Dissolved sulphides

Anaerobic decomposition of organic matter may create toxic hydrogen sulphide, and this is one of the mechanisms by which encapsulation kills biofouling. In the study with fouled panels, however, detectable concentrations of sulphides did not develop until the fourth day of encapsulation (Atalah *et al.* manuscript in preparation). It is unlikely that concentrations large enough to create a risk to the surrounding environment would develop during the relatively short treatment time proposed for encapsulation with chlorine (see Section 2.3.4), particularly since this treatment may inhibit or prevent microbial decomposition of organic matter.

3.7. Salinity and pH

The salinity of the encapsulated water is not expected to change from that of the ambient water body, from which it derives.

Dichlor solutions are neutral in pH (close to pH7: Pinto & Rohrig 2003), whereas the pH of seawater is typically in the range 7.5–8.2. The addition of dichlor may cause a very slight reduction in pH of the encapsulated water. Chlorine neutralisation agents (see Section 4.1.2) form acidic products (hydrochloric and, in some cases, sulphuric acid).

Seawater has a large capacity to buffer pH and, given the relative weights of seawater, dichlor and neutralising agent in the encapsulation, any change in pH is likely to be insignificant.

3.8. Frequency of cleaning at a given location

It is assumed that treatment includes a minimum of 4 h exposure to FAC followed by 4 h without re-dosing to allow the degradation of residual FAC, and the use of a floating dock located at the same station for the duration of the treatment of several boats (so that mobilisation and demobilisation times are eliminated). The maximum number of boats that could be treated in a day would then be one.

One treatment per day would allow adequate mixing and dispersal of any residual treatment chemicals and encapsulated water following discharge. Any residual FAC and organic matter, reduced concentrations of DO, or altered pH will not be persistent in the receiving environment.

The only persistent agent present in the water discharged after encapsulation will be cyanuric acid, derived from dichlor. However, given the low bioaccumulation potential and low toxicity of this chemical (see Section 3.3), any accumulation of cyanuric acid in the environment around the treatment location is not expected to pose a significant environmental risk.

Based on these considerations, it does not seem necessary to impose restrictions on the frequency of treatment at a given location above that imposed by the time required to process a boat.

4. DESCRIPTION OF TREATMENT PRIOR TO DISCHARGE

Section 3 of the report discussed properties of the water discharged after encapsulation of a fouled vessel that may have adverse effects on the receiving environment. Section 4 describes ways in which these potential effects, although expected to be small (see section 3), may be further avoided, remedied or mitigated.

4.1. Residual chlorine

Based on the trial with the floating dock in Westhaven Marina (Auckland), residual concentrations of chlorine after overnight encapsulation (without re-dosing) may be in the order of 1–10 mg/L. This is substantially higher than guidelines values for the protection of aquatic life. For example, the ANZECC (2000) chronic trigger value is 3 µg/L, and the US EPA (2014) aquatic life acute value 13 µg/L (note that these refer to total residual chlorine, of which FAC is a component). The World Health Organisation's guideline for FAC in drinking water is 5 mg/L[5].

There are three options for reducing the residual chlorine concentration prior to discharge of the encapsulated water: (i) containing the water for longer to allow natural degradation of FAC; (ii) neutralisation of FAC using a chemical agent; and (iii) dilution by mixing with ambient water.

4.1.1. Degradation of free available chlorine

Chlorine in solution is consumed by reaction with organic matter, is volatilised and is also degraded by UV light (though this will be reduced in the present use because of the presence of stabilising cyanuric acid in dichlor).

The simplest method to reduce residual chlorine concentrations is to extend the period of the treatment until measured concentrations reach guideline values. However, this is not likely to be satisfactory in most situations because it involves delay to the boat being treated and makes the encapsulation equipment unavailable for treating other boats. Prolonged encapsulation may also result in reduced DO and increased sulphide concentrations. As a compromise, retaining the encapsulated water for 4 h after the last re-dosing would allow FAC concentration to degrade to ca 50 mg/L (see Section 3.2), reducing the amount of thiosulphate needed to neutralise it.

4.1.2. Neutralisation of free available chlorine

A faster alternative to natural degradation of residual FAC is to add a neutralising agent, such as:

[5] See http://www.who.int/water_sanitation_health/dwq/chlorine.pdf

- sodium thiosulphate ($Na_2S_2O_3$)
- sodium sulphite (Na_2SO_3)
- sodium bisulphite ($NaHSO_3$)
- sodium metabisulphite ($Na_2S_2O_5$)
- calcium thiosulphate (CaS_2O_3)
- ascorbic acid (vitamin C) or sodium ascorbate (vitamin C).

Most of these chemicals have an acute toxicity class listed on their MSDS and therefore carry an environmental risk. The exceptions are sodium thiosulphate and ascorbic acid/sodium ascorbate.

Sodium thiosulphate is recommended as a neutralising agent because it is not classified as a hazardous substance and is of relatively low toxicity (96 h LC_{50} 24,000 mg/L for mosquito fish compared with 660 mg/L for sodium sulphite). It also scavenges less oxygen than the other sodium compounds listed above. The MSDS for sodium thiosulphate is shown in Appendix 3.

Sodium thiosulphate is available in bulk from sellers of swimming pool supplies and is likely to be cheaper than sodium ascorbate. The use of sodium thiosulphate is suggested for the dechlorination of swimming-pool water before discharge to the stormwater system (*e.g.* Western Bay of Plenty District Council, undated).

In addition to scavenging DO, sodium thiosulphate forms hydrochloric acid as a result of the neutralisation reaction (as do the other chemicals listed above, other than ascorbic acid / sodium ascorbate). Therefore the minimum amount of thiosulphate required to neutralise residual FAC should be used. This can be estimated based on residual FAC concentration and the volume of encapsulated water and provided as look-up tables for ease of use on site (see Appendix 4 Table 3).

Mitigation of reduced DO and pH is discussed below.

4.1.3. Dilution

Following addition of sodium thiosulphate, any chlorine that might still remain in the encapsulated water (due to incomplete mixing or underestimate of the concentration of residual chlorine or of the volume of water) will be rapidly diluted by the surrounding water. Other chemical differences between the encapsulated water and the surrounding water body will also be mitigated by dilution. These may include residual cyanuric acid (from the dichlor), altered pH and DO (see section 4.2).

Dilution may be enhanced by pumping water out of the encapsulation before the dock is opened or wrapping removed, giving the encapsulated water more opportunity to mix with the surrounding water body.

4.1.4. Recommended treatment of residual chlorine

Tasman District Council's Resource Management Plan allows discharge of water into coastal waters if the concentration of FAC is less than 0.5 mg/L (see Section 6.3.2). Northland Regional Council holds a resource consent (036500.01.01) to discharge contaminants associated with the control and eradication of invasive marine pests using a floating pontoon or benthic mats and the application of chlorine as a biocide. Condition 9 of this consent requires that any discharge from the pontoon or at the outer edge of the mat shall have a total residual chlorine concentration not greater than 0.2 mg/L.

Guidance to NRC for their consent application (Stewart 2014) proposed that total residual chlorine concentrations should be reduced to as low as reliably measurable, and no more than 100 ppb (equivalent to 0.1 mg/L), prior to discharge to the surrounding water body. This maximum concentration does not take into account "reasonable mixing". This is presumably why NRC chose the value of 0.2 mg/L for their consent condition.

Guidelines for the disposal of swimming-pool water (Western Bay of Plenty District Council, undated) suggest that, if disposal to sewer or by soakage is not feasible, water may be discharged to the stormwater system if the FAC concentration is less than 0.5 mg/L. For comparison, the recommended concentration of FAC to protect the health of users of swimming pools is 1–3 mg/L (Centers for Disease Control and Prevention, 2013).

In the present context, we recommend that the concentration of residual chlorine should be measured prior to the discharge of encapsulated water. For consistency with the relevant rule in the Tasman District Resource Management Plan, if the concentration of residual chlorine exceeds 0.5 mg/L it should be reduced before the encapsulated water is released. This may be done by extending the treatment period to allow natural degradation of chlorine by reaction with organic matter and volatilisation, or by chemical neutralisation. Neutralisation (i.e. reducing the concentration to < 0.5mg/L) should be done using the minimum amount of sodium thiosulphate required to neutralise residual FAC. Appendix 4 Table 3 contains a look-up table showing the amount of sodium thiosulphate to be used to neutralise a given residual concentration of FAC in a given volume of encapsulated water.

Measurement of low concentrations of FAC (*i.e.* guideline concentrations) requires a test based on a colorimetric method, because the testing strips described in Section 2.3.4 are not sufficiently sensitive. Colorimeters for testing water in swimming pools are readily available and read FAC and TAC concentrations in the range 10 µ/L (*i.e.* around water-quality guidelines and equivalent to 0.01 mg/L or 10 ppb) to 5 mg/L. They can also measure cyanuric acid concentrations in the range 2–200 mg/L.

4.2. Dissolved oxygen

Reduction in DO by respiration is expected to be negligible. However, DO may be scavenged if sodium thiosulphate is added in amounts in excess of those required to neutralise residual FAC. Reduction in DO can be minimised by matching the amount of sodium thiosulphate added to the amount of FAC to be neutralised. This would be based on the measured concentration of FAC and the estimated volume of encapsulated water.

In most cases, DO concentration is expected to be > 80% and dilution by the surrounding water body is likely to be sufficient mitigation. The likelihood of adverse environmental effects will be further reduced by the suggested restriction that treatment should be done away from sensitive habitats (see Section 5).

If the measured concentration of DO in the encapsulated water is less than 80% of saturation (or 6 mg/L), this may be mitigated prior to release by stirring or by pumping the water out and allowing it to fall through air back into the surrounding water. Discharge during the flowing tide will also enhance dilution and dispersal.

4.3. Organic matter

Organic matter derived from biofouling may cause reduction in DO in the water body around the treatment area or on the seabed beneath. Release of large amounts of organic material should therefore be avoided if feasible, although this is unlikely to necessary after encapsulation treatments.

When the hull is encapsulated using plastic strips or sheets that are not intended for reuse, the wrapping and organic waste should be removed together and sent for disposal to land or recycling. Where a floating dock or reusable sheet is used, if feasible any conspicuous amounts organic waste should be collected as the wrapping is removed from the hull and disposed of to land. This can be done, for example, by divers using hand-nets. During the wrapping of the Voyager P (without biocide), organic debris was contained within the wrap and removed by the divers (pers. comm. Lauren Fletcher, Cawthron Institute).

Small amounts of residual organic waste should be dealt with by releasing the water from the dock during periods of (tidal) current flow, to maximise dispersion.

4.4. pH

Dilution and buffering by the surrounding water body is expected to provide sufficient mitigation for any differences in pH. This can be optimised by releasing encapsulated water during periods of (tidal) current flow and / or by pumping out of the dock to maximise dispersion.

5. DESCRIPTION OF THE RECEIVING ENVIRONMENT

This section of the report describes the receiving environment for water and contaminants discharged after encapsulation. Locations where encapsulation is carried out should be selected so that any adverse effects of the discharge are minimised.

Selection criteria for locations for treating fouled boats divide into those that facilitate rapid and efficient treatment (and thereby minimise biosecurity risk) and those that minimise potential adverse effects on the receiving environment from the discharge of treatment water.

5.1. Selection of treatment locations for rapid and efficient treatment

From the point of view of facilitating rapid treatment, criteria for selection of locations for treating biofouling on high-risk vessels include the following.

- Proximity to places of arrival of boats, particularly ports and marinas (including customs berths) to minimise the need to move infected boats after arrival. Such areas also have relatively modified habitats and biological communities, which mitigates the significance of any effects of treatment on the surrounding environment.
- For practical reasons, encapsulation is most easily done alongside a wharf or marina berth, where there is easy access, supporting infrastructure and usually some shelter from wind or water movement. Deployment of floating docks, in particular, is likely to be done from a berth.
- Avoiding locations where the surroundings create a physical risk to the integrity of the wrapping. This includes locations where:
    - excessive water movement will make the wrapping process difficult and may cause damage and tearing of the wrap
    - adjacent structures or the seabed could abrade or tear the wrapping, *e.g.* wharf piles or sheeting with protruding bolts or large numbers of oysters, over shallow, rough-textured seabed, or near riprap rock walls.

5.2. Selection of treatment locations for minimising environmental effects

Criteria that minimise potential adverse environmental effects relate to rapid mixing of discharged water with the surrounding water body to enhance dilution and dispersal. They include the following.

- Choosing a site with good water movement to maximise dilution of any residual chlorine or water with low dissolved oxygen concentration or altered pH
- Avoiding sensitive receiving environments, such as marine reserves, shellfish-gathering areas, marine farms and bathing areas
- In accordance with the NCC Resource Management Plan, the treatment location should be sited so that the mixing zone for water released from encapsulation is kept away from intertidal areas.

5.3. Mixing zones

Water quality standards and discharge consents usually allow a ‘zone of reasonable mixing’ around the point of discharge, within which the water-quality standards are not expected to be met. Within this zone there is also a ‘zone of initial dilution’ around the point of discharge, where relatively rapid dilution occurs.

It is not appropriate to specify a zone of reasonable mixing that would cover all potential locations for encapsulation treatments in terms of a maximum distance from the point of discharge beyond which a water-quality standard should be achieved. The appropriate size will depend on the volume of water discharged, and the patterns and strength of water movement at the time of discharge. The extent of mixing zones must also take into account any sensitive receiving environments located downstream.

The general requirements for mixing zones are that:

- the size of the zone should be minimised
- any adverse effects should be confined to the zone
- any adverse effects within the zone should be no more than minor.

Rather than specifying a maximum size of mixing zones for discharges from encapsulation, we recommend that encapsulation should be done at locations that are well-flushed by tidal or other currents. Discharge of encapsulated water should be done during the flowing tide. These factors will enhance the rate of mixing. The treatment locations suggested in Section 5.4.1 are all in heavily modified port and marina environments, with one of the selection criteria being a low likelihood of sensitive habitats occurring within the mixing zone.

5.4. Summary

Application of these criteria suggests that ports and marinas are the most suitable places to carry out treatment. They provide facilities likely to be needed for the work (including electrical supply, access to medical facilities if required, easy access to the boat from land or water and limited access for the general public), and are often relatively sheltered from the wind. Well flushed locations should be chosen. Ports and marinas are usually highly modified environments, dominated by artificial habitats with little or no particular ecological value.

However, boats may also need to be treated by encapsulation on swing moorings in more open water. This should not be done if there are sensitive receiving environments downstream of the treatment location unless suitable mitigation is possible (see Section 4.1.4). Such locations should also be avoided if water movement may cause damage to the wrap.

5.4.1. Suggested treatment locations in the Top of the South

Port Nelson and Nelson Marina

- East end of Kingsford Quay. Highly modified, artificial environment, reasonably well flushed, adequate depth, used for engineering work, restricted public access.
- Offshore ends of slipway jetty and dog-leg jetty in Slipway Basin. Highly modified, artificial environment, adequate depth, used for engineering work, restricted public access **but** limited flushing.
- Lay-up berths. Highly modified, artificial environment, well flushed, adequate depth, used for engineering work **but** public access.
- Fishing boat wharves on west side of Dixon Basin. Highly modified, artificial environment, reasonably well flushed **but** restricted depth, potential snags for wrapping material, public access and boat traffic.
- MPI wharf, Dixon Basin. Highly modified, artificial environment, reasonably well flushed, adequate depth, used for quarantining boats, restricted public access **but** boat traffic.
- Visitors' berth on offshore end of jetty in outer marina. Highly modified, artificial environment, reasonably well flushed, adequate depth **but** public access and boat traffic.

Port Tarakohe

1. Offshore marina berths and adjacent wharf. Highly modified, artificial environment, reasonably well flushed, adequate depth **but** public access.

Havelock

1. Offshore marina berths and adjacent wharf. Highly modified, artificial environment, reasonably well flushed, adequate depth **but** public access, boat traffic and limited flushing in inner basin.

Waikawa Marina

- Outer berths on jetties 8W–12W (northern basin). Highly modified, artificial environment, well flushed, adequate depth **but** public access and boat traffic.

Picton Port, Waimahara Wharf and Picton Marina

1. Outer berths on marina jetties 4–7 and 12 (inner marina). Highly modified, artificial environment, reasonably flushed, adequate depth **but** public access and boat traffic.
2. Marina jetties 1–3 (outer marina). Largely modified, artificial environment, well flushed, adequate depth **but** public access and boat traffic.
3. Town wharves. Largely modified, artificial environment, well flushed, adequate depth **but** public access, proximity to bathing beach and boat traffic.
4. Waimahara Wharf (when not in use by log ships). Highly modified, artificial environment, reasonably well flushed, adequate depth, restricted public access.

6. ASSESSMENT OF POTENTIAL EFFECTS ON THE ENVIRONMENT

This section assesses potential effects on the receiving environment, taking into account any treatment of the discharge and selection of appropriate locations to carry out encapsulations.

6.1. Effects during treatment

6.1.1. Spillage

Dichlor is considered a ‘hazardous substance’ under the Hazardous Substances and New Organisms Act 1996. It should be handled and stored according to the procedures in the MSDS.

The risk of spillage during mixing and addition of chlorine solution should be minimised by mixing the dichlor into seawater on site before pouring or pumping into the encapsulated water, and by due care and attention during the application process. Spillages on land of dichlor pellets, chlorine solution or sodium thiosulphate powder should be contained and cleaned up immediately.

Spillages of chlorine solution into water cannot realistically be contained and cleaned up but natural degradation, dispersal and dilution will reduce the concentration of chlorine. If a pump is available, pumping water from the spill site and releasing it downstream so that the stream of water falls through the air back into the sea will help to disperse and volatilise dissolved chlorine. Remediation of any spillages of dichlor granules or sodium thiosulphate powder must rely on natural dissolution, dispersal and decay.

6.1.2. Leakage

Leakage of encapsulated water and dissolved chlorine may occur from wrapping, a floating dock or a blanking plate as a result of an imperfect seal against the hull or between wrapping strips, or because of tearing of the wrapping.

To avoid tearing, the wrap should be of a sufficiently robust material to withstand physical stresses at the treatment location during deployment and treatment. When sharp biofouling and/or hull features are likely to be present, netting curtains (*e.g*., fish-farm smolt netting: Aquenal 2009) can be hung between the hull and the wrapping to shield the wrapping from tearing and abrasion. The wrapping, floating dock or blanking plate must be of a design and capacity suitable to minimise leakage.

Monitoring and detection of minor leaks is likely to be difficult or impossible, although dyes (*e.g*., rhodamine) could be added to the encapsulated water to assist detection.

If appropriately designed wrapping is used and treatment is done in an appropriate location to avoid features that might damage the wrap, the risk of more than minor leakage will be small. Small amounts of leakage will be mitigated by dilution and this would be expected to reduce environmental concentrations of chlorine or reduced DO to insignificant levels within a short distance from the source.

6.2. Effects after treatment

If the mitigation treatments described in section 4.1.4 are applied to the encapsulated water before it is released into the surrounding water body, effects on the environment are expected to be negligible. Any residual treatment chemicals or reduced concentration of DO in the water will be rapidly diluted by mixing with the surrounding water body, particularly if release is timed to coincide with periods of peak water movement. Assuming a concentration of 0.5 mg FAC/L in the discharged water, dilution by a factor of roughly 40 would achieve the US EPA water quality of 13 µg/L.

The fact that chlorine, sodium thiosulphate and any organic matter derived from the biofouling are not persistent contaminants further reduces the likelihood of long-term adverse environmental effects.

Cyanuric acid is the only persistent contaminant likely to be present in the encapsulated water. It is classed as “essentially non-toxic” (Huthmacher and Most 2005). As described in section 3.3, available data suggest that it is unlikely to have any significant adverse environmental effect:

- The bioconcentration factor to fish is low (< 0.5 in carp after 6 weeks).
- The NOEC for reproduction and 48-EC_{50} for immobilisation of *Daphnia magna* are 32 mg/L and 1,000 mg/L, respectively.
- Both the 96-h LC_{50} and the 14-day LC_{50} for the fish *Oryzias latipes* are > 100 mg/L.
- The 72-h NOEC and 72-h EC_{50} for the alga *Selenastrum capricornutum* are 62.5 mg/L and 620 mg/L, respectively.

Rates of release of copper from antifouling should not be affected by the treatment because there is no physical action on the hull surface that might abrade the antifouling coating. Where heavy biofouling is present, the copper in the antifouling coating is likely to be depleted and its release even less likely. No significant release of antifouling biocides is, therefore, expected to occur as a result of treatment by encapsulation with chlorine.

6.3. Compliance with coastal marine water-quality standards

6.3.1. Nelson City Council

Nelson City Council's Resource Management Plan, Coastal Policy CM6.3 (Discharges (general)) states that:

> "*Discharges to coastal water should not, after reasonable mixing, result in a breach of classification standards or a reduction in water quality and the discharge should not (either by itself or in combination with other discharges) give rise to any significant adverse effects on habitats, feeding grounds or ecosystems.*"

The water-quality class FEA (fisheries, fish spawning, aquatic ecosystems and aesthetic purposes) applies throughout the Coastal Marine Area. The coastal marine water-quality standards for the FEA class, to apply after reasonable mixing, are listed below.

1. The natural temperature of the water shall:
    a. not be changed by more than 2 °C, and
    b. not exceed 25 °C.
2. The concentration of dissolved oxygen shall exceed the higher of 6 mg/l or 80% saturation.
3. There shall be no significant adverse effects on aquatic life arising from the discharge of a contaminant into water, a pH change, the deposition of matter on the foreshore or seabed, or any other cause.
4. There shall be no:
    a. production of any conspicuous oil or grease films, scums or foams or floatable or suspended material, and
    b. conspicuous change in the colour or visual clarity, and
    c. emission of objectionable odour in the receiving water.

If the recommendations for treatment of encapsulated water prior to discharge (Section 4) and siting of encapsulation work (Section 5.4.1) are followed, these standards are unlikely to be breached. There is no reason to expect that encapsulation would give rise to oil or grease films, scums, foams or floatable or suspended material, nor to any change in colour or clarity beyond the immediate area of the treatment. Proper disposal of waste material (any biofouling dislodged from the hull, and plastic wrapping not intended for reuse) will avoid the possibility of objectionable odours.

6.3.2. Tasman District Council

Rule 36.2.2.8 (Discharge of Water) of the Tasman Resource Management Plan states that:

The discharge of water into water is a permitted activity that may be undertaken without a resource consent, if it complies with the following conditions:

a. *The discharge does not cause erosion of the bed of any river or stream.*
b. *The discharge does not contain more than 0.5 grams per cubic metre of free or residual chlorine.*
c. *Except as provided for in condition (aa), the discharge does not contain contaminants other than heat.*
d. *When the natural temperature of the water is less than 20 degrees Celsius, the water temperature is not increased by more than 3 degrees Celsius and in any event does not exceed 20 degrees Celsius. When the natural temperature of the water is 20 degrees Celsius or greater, there is no increase in water temperature.*
e. *Except as provided for by conditions (g) and (h), the rate of discharge does not exceed 5 litres per second.*
   (Note that conditions (g) and (h) relate to discharges from dams and hydro-electric power generation).

If the discharge does not comply with these conditions, a coastal permit is required. However, if the recommendations for treatment of encapsulated water prior to discharge (Section 4) and siting of encapsulation work (section 5.4.1) are followed, these conditions are expected to be met.

The proposed treatment of the encapsulated water prior to discharge (section 4.1) will reduce the (measured) concentration of FAC to less than 0.5 g/m^3 (equivalent to 0.5 mg/L).

Pumping water out of the encapsulation using a pump of 330 l/min (a standard size of portable water pump, equivalent to 5.5 L/min) would slightly exceed the maximum rate of discharge.

6.4. Residual biosecurity risk

This section of the report addresses the fact that a residual biosecurity risk may remain after a fouled vessel has been treated by encapsulation. Although not directly relevant to an assessment of the environmental effects off encapsulation treatments, it does inform the recommendations for consent conditions presented in section 7. It is also important that the viability of fouling is checked before the wrapping is removed to avoid having to re-wrap and treat the hull if the initial treatment was not successful.

The assumption that encapsulation with the addition of chlorine solution has been effective in killing biofouling may not be justified for a number of reasons. The target strength of FAC may not have been achieved, duration of exposure may have been less than the 4 h recommended, water may not have been adequately mixed, or species that are unusually resistant to chlorine may have been present on the hull.

The hull should be inspected by suitably qualified person (*i.e.* with experience in assessing the viability of a range of motile and sedentary organisms) after cleaning. The type of inspection required will depend partly on the types of fouling organisms that the treatment was targeting. For larger organisms, such as the fanworm *Sabella spallanzanii*, assessment of viability could be done by in-water visual inspection by divers, or from the surface using a video camera on a pole or remote operated vehicle. For other taxa, it will be necessary to collect samples to confirm that they are not viable. This may be done by divers, either after the wrap has been removed or by cutting holes in the wrap to remove a sample from the hull (and resealing the hole if further treatment is required). Alternatively, test plates on which fouling has been allowed to develop can be suspended inside the wrapping and withdrawn at the end of treatment to check whether fouling has been killed. This last approach assumes that the fouling on the plates is representative of that on the hull, which may not be the case when, for example, the plates have locally-derived fouling and the vessel has come from another port.

7. RECOMMENDATIONS FOR CONSENT CONDITIONS

This section contains recommendations for consideration in setting consent conditions. It is expected that they will be refined by NCC and TDC in accordance with their requirements.

- Written notification of intention to carry out treatment shall be given to council. The notice period, and the person to report to, should be appropriate to the needs of council consents and biosecurity staff in the case of planned treatment. In the case of unplanned treatment (for example, the unannounced arrival of a fouled vessel), notification should be provided as soon as practical.
- Notification should include:
    - a description of the equipment (wrapping, pontoon or blanking plate – see Section 2.2) so its adequacy for the conditions can be assessed. For equipment or methods used repeatedly, these descriptions can be lodged with, and assessed by, the council in advance of their being used
    - information on the experience and expertise of the contractor performing the treatment. This information can be lodged with, and assessed by, the council in advance
    - a statement that dichlor granules and solution will be handled in accordance with the MSDS and with any applicable regulations prepared under the Hazardous Substances and New Organisms Act 1996. Notification shall include a contingency plan for dealing with any spillage of dichlor granules or solution on land.
- Only chlorine should be used as a biocide, added in the form of sodium dichloroisosyanurate (dichlor) granules pre-dissolved in seawater and applied to give an initial concentration of free available chlorine (FAC) of 200 mg/L. The target concentration should be maintained for at least 4 h. This will require periodic measurement of FAC concentration and addition of more dichlor solution as required.
- Any discharge of contaminated water from the encapsulation shall meet the following criteria:
    - the total residual chlorine concentration shall not exceed 0.5 mg/L. If the residual concentration exceeds this standard, excess FAC should be neutralised using the minimum required amount of sodium thiosulphate. Alternatively, the encapsulation may be left in place until the FAC concentration reduces to 0.5 mg/L.
    - the dissolved oxygen concentration should not be less than 80% of saturation after reasonable mixing. This standard is likely to be met by mixing with surrounding water soon after release into a flowing tide. Re-oxygenation may be enhanced by aerating the encapsulated water prior to

discharged or discharging by pumping and allowing water to fall through air into the surrounding water.

- All wrapping material and, to the extent practical, any conspicuous amounts of organic matter, including dead or dying organisms, dislodged from the hull during treatment must be collected and removed from the treatment site and disposed of to land or reused.
- The viability of fouling should be checked after treatment to ensure that treatment was effective.
- Treatment facilities should preferentially be located in ports or marinas, preferably close to points of arrival of boats where this does not interfere with port or marina operations. They should be located away from sensitive receiving environments. The locations listed in Section 5.4.1 may be included as suggestions.
- Other locations, such as swing moorings, may be used unless there are sensitive receiving environments downstream and suitable mitigation is not possible. These should be assessed on a case-by-case basis.
- Facilities should be in well-flushed locations but avoid places or times when water movement may be sufficiently strong to damage the wrapping.
- Location of facilities should also avoid natural or man-made features likely to damage the wrapping material. Best practice should be used in deploying the wrapping material to minimise the risk of damage.
- Encapsulated water should be discharged during a flowing tide to maximise mixing.
- For each discharge event, the following information shall be recorded and the information provided to NCC.
    - o The weight of dichlor added and the weight of any sodium thiosulphate used to neutralise residual FAC.
    - o The concentration of FAC and DO at the start of treatment, at the end of treatment before neutralisation of residual FAC (if required), and prior to discharge of water from the encapsulation.
    - o The estimated volume of encapsulated water that is discharged.
    - o The DO concentration of the ambient water at the time of discharge for comparison with the encapsulated water.
    - o The date, time and location of the treatment.
    - o The results of inspections of the hull during cleaning to determine whether biofouling has been killed.
- A review condition should be included to enable changes to the conditions as a result of information obtained from monitoring of previous treatments.

8. WORKED EXAMPLE OF THE TREATMENT OF A VESSEL

8.1. Description of the proposed activity

The worked example describes a hypothetical treatment of the hull of a trawler (similar in size to the *Voyager P*: see section 1.2) by encapsulation with the addition of chlorine (in the form of dichlor) at a concentration of 200 mg/L. Encapsulation is by enclosing the hull in a single plastic sheet, with the edges of the sheet secured above the water line on all sides. The work is done on Kingsford Quay.

8.1.1. Vessel dimensions

The hull of the trawler is 28.5 m long at the water line, based on the length between perpendiculars (LBP), beam 8.3 m and draft 2.67 m.

Using the formula for estimating the total wetted surface area (TWSA) of the hull of a trawler (see Appendix 1):

$$\text{TWSA} = (2 \times \text{Length} \times \text{Draft}) + (\text{Beam} \times \text{Draft})$$
$$\text{TWSA} = (2 \times 28.5 \times 2.67) + (8.3 \times 2.67)$$
$$\text{TWSA} = 174.4\ \text{m}^2.$$

8.1.2. Amount of dichlor added

Given that the estimated TWSA of the hull is 174.4 m^2, and assuming a gap between the hull and the wrapping of 5 cm:

- the volume of encapsulated water will be approximately 9 m^3
- the weight of dichlor required to provide a concentration of 200 mg FAC/L is 3.27 kg (see Table 2 of Appendix 4) and is dissolved in 30 L of seawater before adding to the encapsulated water (distributed around the hull and mixed as much as possible)
- During treatment it is important to ensure that the chlorine reaches all parts of the hull, which may require active mixing and stirring
- Assuming that the concentration of FAC has decreased to ca 100 mg/L after 2 h, a further 1.64 kg (*i.e.*, 50% of the original dose) of dichlor must be added to reinstate the target concentration.

8.1.3. Duration of treatment

Following the recommendation in section 2.3.4, the hull will be exposed to the target concentration of FAC (200 mg/L) for 4 hours. However, we assume that due to degradation of FAC, the encapsulated water will need to be re-dosed after 2 hours, depending on measured concentration of FAC. The wrapping will then be left in place for a further 4 hours after the last addition of dichlor for the concentration of FAC to decrease by degradation to ca 50 mg/L.

Consequently, treatment may take 7–8 hours. In practice it may be more convenient to leave the wrapping in place overnight following the last addition of dichlor.

8.1.4. Assessment of viability of fouling after treatment

The viability of the target organisms will be assessed at the end of treatment (see section 6.4) but before the wrapping is removed, to determine whether further treatment is required.

8.2. Description of the receiving environment

Kingsford Quay consists of a concrete deck on wooden piles and is approximately 250 m long (Inglis *et al.* 2005). According to the navigational chart, the water depth in front of the western end of the wharf is dredged to 9.5 m, rising to 6.5 m in front of the eastern third of the wharf's length (Figure 2). Kingsford Quay is bounded to the west by McGlashen and Brunt Quays and to the east by the Slipway Basin. McKellar Quay faces Kingsford Quay across the Basin.

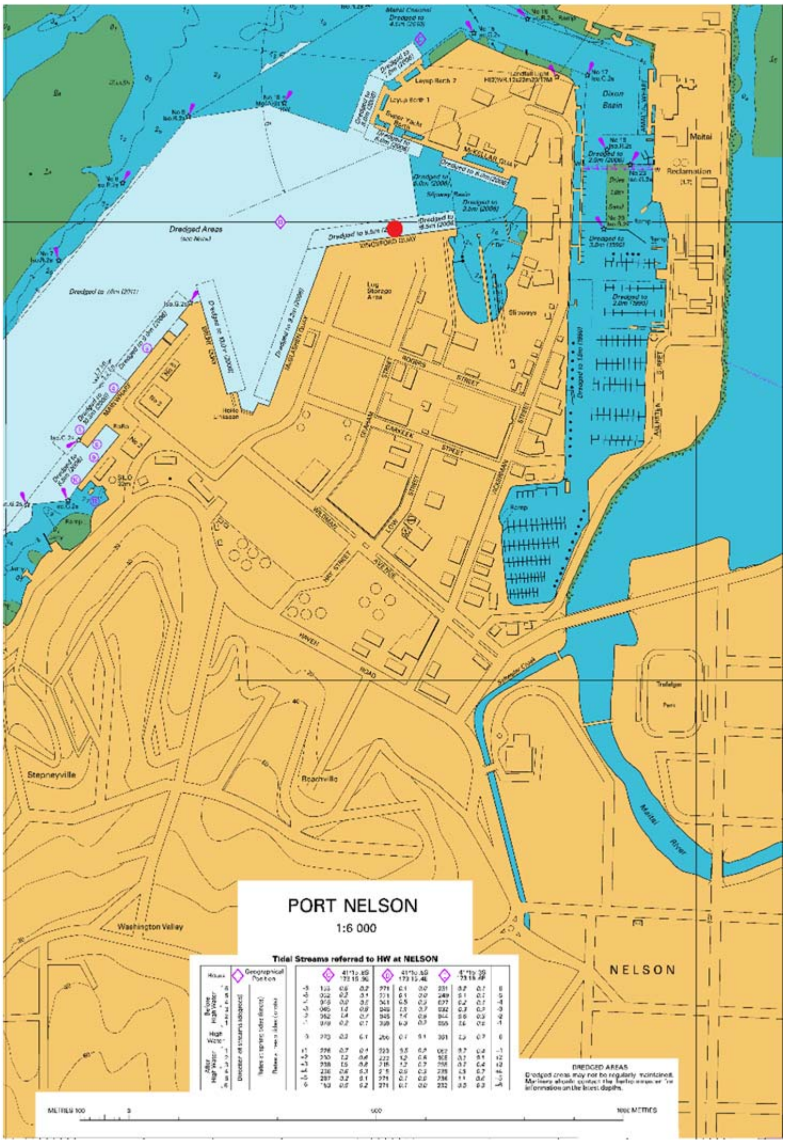

Figure 2. Navigational chart of Port Nelson, showing Kingsford Quay and adjacent areas. The location of the hypothetical treatment is shown by a red dot. Source: Land Information New Zealand (LINZ) and licensed by LINZ for re-use under the Creative Commons Attribution 3.0 New Zealand licence.

The environment in and around Kingsford Quay is, therefore, highly modified and, apart from the seabed, consists largely of artificial structures. The area of seabed around these wharves and out to ca 225 m to the north are periodically dredged for navigational purposes. Further north still, the outflow channel of the Maitai River is dredged to 4.5 m. To the west, beyond the dredged area of the swing basin and ca 450 m from Kingsford Quay, lies an intertidal bank of shell and sand.

The navigational area of the harbour is well flushed by tidal currents. The navigational chart states that flood-tide and ebb-tide velocities along the face of the Main Wharf (west of Kingsford Quay) are 1.7 kn (82 cm/s) and 1.2 kn (58 cm/s), respectively. The flood-tide current velocity around Kingsford Quay is 30–45 cm/s (APASA 2006).

8.3. Nature of the discharge

8.3.1. Volume of discharge

Given that the estimated TWSA of the hull is 174.4 m^2, and assuming a gap between the hull and the wrapping of 5 cm, the volume of encapsulated water to be discharged will be approximately 9 m^3.

8.3.2. Residual chlorine

Assuming that the wrapping is left on the hull for at least 4 h after the last addition of dichlor, the residual FAC concentration will be ca 50 mg/L (see section 3.2).

8.3.3. Residual cyanuric acid

Cyanuric acid will be present in the encapsulated water, its concentration dependent on the amount of dichlor added:

- Total amount of dichlor added is 3.27 + 1.64 = 4.91 kg (see section 8.1.2)
- Cyanuric acid represents 45% by weight
- Amount of cyanuric acid added is 2.21 kg
- Volume of water is 9,000 L
- Concentration of cyanuric acid at the end of treatment is 246 mg/L.

8.3.4. Dissolved oxygen, organic matter, dissolved sulphides and pH

These variables are not expected to change significantly during the period of encapsulation (see sections 3.4–3.7), however:

- There may be a small decrease in DO because the hull is heavily fouled and the respiratory demand of the fouling organisms correspondingly high
- Dissolved oxygen will be measured prior to discharge of the encapsulated water and compared with the ambient concentration
- Organic material dislodged from the hull during treatment may be present in suspension or settled on the floor of the wrapping. This is likely to include dead or dying fouling organisms
- The concentration of dissolved sulphides is not expected to increase during the relatively short duration of treatment
- pH may be reduced slightly by the addition of dichlor, which is of lower pH than seawater (see section 3.7) but this effect will be small because of the amount of dichlor added relative to the volume of encapsulated water.

8.4. Treatment prior to discharge

8.4.1. Neutralisation of residual chlorine

Residual FAC will be measured and neutralised (*i.e.*, reduced to < 0.5mg/L) prior to discharge:

- A residual FAC concentration of 50 mg/L, for example, will require 837 g of sodium thiosulphate to neutralise (see Appendix 4 Table 3).
- This will reduce the concentration of FAC to below the environmental guideline of 0.5 mg/L proposed in section 4.1.4.

The FAC concentration will be confirmed by measurement after neutralisation. Residual FAC in the discharged water will also be subject to dilution and degradation by mixing (see section 4.1).

8.4.2. Organic matter

Conspicuous amounts of organic matter dislodged from the hull during treatment, including organisms, will be collected during removal of the wrapping and disposed of appropriately (*e.g.*, to landfill).

8.5. Assessment of effects on the environment

8.5.1. Spillage

Risk of spillage will be minimised by mixing the dichlor into seawater on site before pouring or pumping into the encapsulated water, and by due care and attention during the application process (see section 6.1.1). Any accidental spillages on land of dichlor pellets, chlorine solution or sodium thiosulphate powder will be contained and cleaned up immediately.

Dispersal and dilution will reduce the concentration of any spillage of chlorine solution into the water body surrounding the treatment site. Remediation of any spillages of dichlor granules or sodium thiosulphate powder will rely on natural dissolution, dispersal and decay.

8.5.2. Leakage

Wrapping materials must be well sealed before adding the chlorine solution and must be sufficiently robust to resist tearing and abrasion by contact with the vessel and wharf (see section 6.1.2). Small amounts of leakage will be mitigated by dilution and this would be expected to reduce environmental concentrations of FAC or reduced DO to insignificant levels within a short distance from the source.

8.5.3. Dilution of discharged contaminants by mixing

Residual contaminants in the encapsulated water are expected to be diluted rapidly by mixing into the ambient water body:

- If, at the end of treatment, the bow and stern parts of the wrapping are opened simultaneously during a flowing tide (with a velocity of, say, 30 cm/s: see section 8.2), the tidal current will flush the encapsulated water out of the wrapping relatively rapidly.
- This 'slug' of water would have an initial cross-sectional area of ca 9 m × 3 m (*i.e.*, the beam and draft of the hull).
- Simplistically, as it is carried along and mixed with the ambient water in a tidal current of 30 cm/s, a 100-times dilution of the encapsulated water would be achieved at about 35 m downstream of the vessel[6] and ca 120 s after release.
- This estimate assumes that complete mixing has occurred within this time, which is likely to be an over-estimate of the rate of mixing. However, it does indicate that dilution of contaminants, and the associated replenishment of any depletion of DO or pH, will be reasonably rapid if removal of the wrapping occurs during the flowing tide, as recommended in section 7.
- The zone of reasonable mixing is likely to be of the order of tens of metres in diameter. The receiving environments that are exposed to incompletely mixed water are, therefore, the highly modified ones of the wharf area.
- Significant reduction in the concentration of DO is not expected during treatment, but mixing and aeration of the encapsulated water with ambient water is expected to restore rapidly any depletion of DO that does occur during treatment.
- Cyanuric acid and any dissolved sulphides generated during encapsulation (the latter are not expected to be significant, given the duration of treatment: see section 3.6) will be diluted rapidly. Cyanuric acid is of low toxicity (see section 3.3) and is not expected to have any adverse effect on aquatic life.
- Any uncaptured organic material will be rapidly diluted and dispersed into the receiving environment and is not expected to have any adverse effects (any biological material is expected to have been killed by the treatment).

8.5.4. Removal of other waste materials

All wrapping and other materials used during the treatment will be collected and removed from the treatment site for reuse or appropriate disposal.

[6] Based on the encapsulated volume of 9 m^3 and a receiving volume of 9 m × 3 m × 35 m = 945 m^3.

8.5.5. Summary of environmental effects

There is a low risk of effects on the surrounding environment during treatment from spillage and leakage. The residual concentrations of contaminants in the discharged water are expected to be negligible following treatment to neutralise FAC and, if practical, to collect organic matter dislodged from the hull. Discharge of encapsulated water will be done on a flowing tide and residual contaminants will be diluted by mixing into the receiving water body. The risk of significant, adverse environmental effects during or after treatment is, therefore, expected to be low.

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11. APPENDICES

Appendix 1. Estimation of volume of encapsulated water.

A rough estimate of the water enclosed with an encapsulated hull can be derived from the area of the hull multiplied by the width of the gap between the hull and the encapsulating material. The antifouling coating industry uses formulae to estimate the total wetted surface area (TWSA) of a hull (Floerl *et al.* 2008). Different formulae are used for regular yachts (up to 20 m long) and superyachts (more than 20 m):

$$TWSA_{yacht} = 2 \times \text{Length} \times \text{Draft}$$
$$TWSA_{superyacht} = (2 \times \text{Length} \times \text{Draft}) + (\text{Beam} \times \text{Draft})$$

The formula for superyachts also applies to trawlers (Inglis *et al.* 2010).

Estimated volumes of encapsulated water for different sizes of yacht and for a motor cruiser are shown in Table 1, based on different sizes of gaps between hull and encapsulating material. The largest gap included in Table 1 is 1 m. A gap this large might be used if diver access to the hull was required, for example, for checking on the viability of biofouling after treatment. Generally, however, the gap would be kept as small as possible to minimise the volume of biocide required. Note that these values are underestimates because they do not allow for distortions to the wrapping caused by protrusions from the hull.

The estimates for an 8-m yacht range from 1.1 m^3 for a tightly wrapped hull to more than 22 m^3 for the same boat with a 1-m gap around it. Equivalent values for a 30-m yacht are 5.4–108 m^3. For a cruiser, which has a relatively shallow draft, the estimates are much smaller than those for a yacht of the same length.

Table 1. Estimated volume of encapsulated water for different sizes and types of recreational boats and for the trawler used in the worked example. Volumes are shown for different widths of the gap between the hull and the encapsulating material. 'LWL' length at waterline, 'TWSA' total wetted surface area.

					Width of gap (m)					
					Encapsulated volume (m^3)					
Type	**LWL (m)**	**Draft (m)**	**Beam (m)**	**TWSA (m^2)**	**0.05**	**0.1**	**0.2**	**0.3**	**0.5**	**1.0**
Yacht	8.0	1.4	2.5	22.4	1.1	2.2	4.5	6.7	11.2	22.4
Yacht	16.8	3.0	4.8	99.1	5.0	9.9	19.8	29.7	49.6	99.1
Cruiser	16.0	1.1	4.9	35.2	1.8	3.5	7.0	10.6	17.6	35.2
Super-yacht	30.0	1.6	7.5	108.0	5.4	10.8	21.6	32.4	54.0	108.0
Trawler	28.5	2.67	8.3	174.4	8.7	17.4	34.9	52.3	87.2	174.4

Appendix 2. Material safety data sheet for dichlor.

Paramount Pools & Spas
a division of PoolQuip Limited

North Island:
PO Box 12840, Penrose, Auckland, New Zealand
282 Neilson Street, Onehunga, Auckland, New Zealand
Phone: 0064 9 634 9097 E-Mail: info@poolquip.co.nz

South Island:
PO Box 8622 Riccarton, Christchurch, New Zealand
75 Blenheim Road, Riccarton, Christchurch New Zealand
Phone: 0064 3 343 3441 E-Mail: paramount.chc@xtra.co.nz

If you have a Chemical Emergency phone 111 and ask for Fire
In case of Poisoning contact The National Poisons Centre on 0800 POISON (0800 764 766)
The most current version of this document is available online at www.poolquip.co.nz

MATERIAL SAFETY DATA SHEET (MSDS)

1.0 Product & Company Information

Revision Date:	April 2011
Product Name:	**Sodium Dichlorosisocyanurate Dihydrate**
Other Names:	Pool Master Super Chlor, Spa Master Sanitizer, Dichlor, SDIC
Uses:	For the sanitization of Swimming Pool Water and Spa Pool Water
Distributor Details:	As per header and any of our authorised retailers and distributors

2.0 Hazard Data

Hazardous according to criteria of NOHSC/ASCC.
Classified as Dangerous Goods According to NZS 5433:1999.

Risk Phrases & Safety Phrases:

R22	Harmful if swallowed
R31	Contact with acids liberates toxic gas
R36/37	Irritating to eyes and respiratory system

R50/53	Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment
S2	Keep out of reach of children
S8	Keep container dry
S26	In case of contact with eyes, rinse immediately with plenty of water and seek medical advice
S41	In case of fire and/or explosion, do not breathe fumes
S60	This material and it's container must be disposed of as hazardous waste
S61	Avoid release to the environment. Refer to special instructions / MSDS

ERMA New Zealand Approval Code: HSR001324

HSNO Hazard Classification: 5.1.1B 6.1D 6.1E 6.3A 6.4A 9.1A 9.2A 9.3C

3.0 Composition

Chemical Name:	Sodium Dichloroisocyanuric Dihydrate
CAS Number:	51580-86-0
Percentage Rating:	100% (65% active chlorine)

4.0 First Aid Measures

Description of necessary measures according to routes of exposure.

Swallowed:	Immediately rinse mouth with water. If swallowed, do NOT induce vomiting. Give a glass of water. Seek medical attention immediately.
Eyes:	Immediately flush eyes with water for at least 15 minutes. Do NOT interrupt flushing. Take care not rinse contaminated water into the non-affected eye or onto the face. Seek immediate medical attention.
Skin:	If skin contact occurs, remove contaminated clothing and wash skin with running water. If irritation occurs seek medical advice.
Inhaled:	Remove victim from area of exposure – avoid becoming a casualty. Remove contaminated clothing and loosen remaining clothing. Allow patient to assume most comfortable position and keep warm. Keep at rest until fully recovered. If patient finds breathing difficult and develops a blush discolouration of the skin (which suggests a lack of oxygen in the blood – cyanosis), ensure airways are clear of any obstruction and have a qualified person give oxygen through a face

	mask. Apply artificial respiration if patient is not breathing. Seek immediate medical advice.
Advice to Doctor:	Treat symptomatically. Delayed effects from exposure to chlorine (decomposition product) can include shortness of breath, severe headache, pulmonary oedema and pneumonia.
Aggravated medical	

5.0 Fire Fighting Measures

Extinguishing Media	Water spray (large quantities)
Hazards from Combustion Products	Non combustible, but will support combustion of other materials
Special Protective Precautions and Equipment for Fire Fighters	Sodium dichloroisocyanurate is a powerful oxidising agent and decomposes violently upon liberating oxygen. In case of fire, area should be evacuated and specialist fire fighters called in. Only large quantities of water should be used as an extinguishing agent. If excess water is not available DO NOT attempt to extinguish the fire, use the available water to prevent the spread of fire to adjacent property. Attending fire fighters should keep upwind if possible and wear full protective equipment including rubber boots and self-contained breathing apparatus. A fire in the vicinity of sodium dichloroisocuanurate should be extinguished in the most practical manner but avoid contaminating this material with the fire fighting agent, including water. Decomposes on contact with water evolving toxic chlorine gas and in the presence of small amounts of water, the explosive gas nitrogen trichloride. Once fire is extinguished, wash area thoroughly with excess water. Ensure that drains are not blocked with solid material. Maintenance of excess water during clean up operation is essential. Combustible material involved in the incident should be removed to a safe open area for controlled burning or for further drenching with water prior to collection for disposal.
Hazchem Code	2WE

6.0 Accidental Release Measures

Emergency Procedures	Clear area of all unprotected personnel. If contamination of sewers or waterways has occurred, advise local emergency services.
Methods and Materials	Wear protective equipment to prevent skin and eye contact and

for Containment and Clean Up	breathing in vapours. Air supplied masks are recommended to avoid inhalation of toxic material. Do NOT return spilled material to original container, and do NOT mix fresh with recovered material. Do NOT add small amounts of water to sodium dichloroisocyanurate. Collect and transfer to large volume of water - do NOT use a metal container. To neutralise, as sodium sulfite (2.4Kg/Kg product). If no active chlorine remains, add soda ash (1.1Kg/Kg product) to effect complete neutralisation. Where a spill has occured in a confined space or an inadequately ventillated enclosure and the material is damp and evolving chlorine, the rate of chlorine evolution may be reduced by covering the thinly spread solid with soda ash.

7.0 Handling & Storage

Precautions for Safe Handling	Ensure an eye bath and safety shower are available and ready for use. Observe good personal hygiene practices and recommended procedures. Wash thoroughly after handling. Avoid skin and eye contact and breathing in dust. Keep out of reach of children.
Conditions for Safe Storage (Including any compatibles)	Store in a cool, dry, well-ventilated area. Keep containers tightly closed when not in use. Inspect regularly for deficiencies such as damage or leaks. Protect against physical damage. Store away from incompatible materials such as flammable, organic and combustible materials, ammonium salts, nitrogenous material, acids, water, reducing agents, strong bases, calcium hypochlorite, metals and sources of ignition. Protect from direct sunlight, moisture, food and feedstuffs. Keep dry, reactive with water, may lead to drum rupture. This product is hygroscopic. **This product has a UN classification of 2465 and a Dangerous Goods Class 5.1 (Oxidizers) according to The Australian Code for the Transport of Dangerous Goods by Road and Rail.**
Container Type	Use corrosion-resistant structural materials. Containers made of inert plastics are preferred.

8.0 Exposure Controls / Personal Protection

National Exposure Standards	No value assigned to this specific material by the New Zealand Occupational Safety and Health Service (OSH). However, Exposure Standard(s) for decomposition product(s): Chlorine: WES-TWA 0.5ppm, 1.5mg/m3, WES-STEL 1ppm, 2.9mg/m3 WES – TWA = Workplace Exposure Standard – Time Weighted Average. The eight hour, time weighted average exposure is designed to protect the worker from the effects of long-term exposure. WES – STEL = Workplace Exposure Standard – Short Term Exposure Limits. The 15 minute average exposure standard. Applies to any 15 minute period in the working day and is designed to protect the worker

against adverse effects of irritation, chronic or irreversible tissue change, or narcosis that may increase the likelihood of accidents. The WES-STEL is not an alternative to the WES-TWN; both short-term and eight-hour, time weighted average exposures should be determined.

These Exposure Standards are guides to be used in the control of occupational health hazards. All atmospheric contamination should be kept to as low a level as is workable. These exposure standards should not be used as fine dividing lines between safe and dangerous concentrations of chemicals. They are not a measure of relative toxicity.

Biological Limit Values	
Engineering Controls	Ensure ventilation is adequate and that air concentrations of decomposition product(s) is/are controlled below quoted Exposure Standards. Avoid generating and breathing in dusts. Use with local exhaust ventilation or while wearing dust mask. Keep containers closed when not in use.
Personal Protection	RESPIRATOR: Wear an approved respirator with suitable filter for organic gases and vapours if engineering controls are inadequate (AS1715/1716). EYES: Chemical goggles to prevent splashing in the eyes (AS1336/1337). HANDS: Butyl rubber gloves break through time 4hr (AS2161). CLOTHING: Chemical-resistant coveralls and safety footwear (AS3765/2210).

9.0 Physical and Chemical Properties

Appearance	Crustalline Powder, granules or tablets
Formula	C3HCI2N303.Na
Odour	Chlorine Odour
Vapour Pressure	Not Applicable
Vapour Density	Not Applicable
Boiling Point	Not Applicable
Melting Point	240 deg C
Solubility in Water	250g/L @ 25 Deg C
Specific Gravity	2.03 (Water = 1)
Flash Point	Not Applicable
pH	6.5 (1% solution)
Rate of Solid Materials	Not Known
Decomposition Temperature	240 Dec C
Additional Information	

10.0 Stability and Reactivity

Chemical Stability	Powerful oxidising agent. Sodium dichloroisocyanurate reacts with water and acids evolving toxic chlorine gas and in the presence of small amounts of water, the explosive gas nitrogen trichloride. Decomposes in

	alkaline conditions evolving carbon dioxide, nitrogen and chloramines gases.
Conditions to Avoid	Avoid exposure to moisture, avoid exposure to heat. Avoid exposure to sunlight.
Incompatible Materials	Incompatible with combustible materials, ammonium salts, nitrogenous materials, acids and water.
Hazardous Decomposition Products	Chlorine
Hazardous Reactions	Sodium dichloroisocuanurate reacts with water and acids evolving toxic chlorine gas and in the presence of small amounts of water the explosive gas nitrogen trichloride. Decomposes in alkaline conditions evolving carbon dioxide, nitrogen and chloramine gases.

11.0 Toxicological Information

Toxicity Data	Oral LD50 Rat: 1355-1400mg/Kg
Health Effects – Acute	
Swallowed	Can result in nausea, vomiting, diarrhoea and gastrointestinal irritation.
Eye	Ajn eye irritant
Skin	Contact with skin may result in irritation
Inhaled	Material is irritant to the mucous membranes of the respiratory tract (airways). Inhalation of high concentrations may result in shortness of breath, chest pain, severe headache and lung damage including pulmonary oedema. Effects may be delayed.

12.0 Ecological Information

Ecotoxicity	Avoid contaminating waterways
Persistence and Degradability	No information available on persistence/degradability for this product
Mobility	Completely soluble in water.
Environmental Fate (Exposure)	Do NOT let product reach waterways, drains and sewers.
Bioaccumlative Potential	No information available on bioaccumulation for this product.

13.0 Disposal Considerations

Disposal	Dispose of in accordance with all local, state and federal regulations. All empty packaging should be disposed of in accordance with Local, State and Federal Regulations or recycled/reconditioned at an approved facility.
Special Precautions for Land Fill or Incineration	Contact a specialist disposal company or the local waste regulator for advice. This should be done in accordance with 'The Hazardous Waste Act.

14.0 Transport Information

Land and Sea Transport

UN Number	2465
Shipping Name	Sodium Dichloroisocyanurate
Dangerous Goods Class	5.1
Packing Group	II
Hazchem Code	2WE

15.0 Regulatory Information

Classified as hazardous according to HS (minimum degrees of hazard) regulations 2001.

HSNO Hazard Classification	5.1.1B 6.1D 6.1E 6.3A 6.4A 9.1A 9.2A 9.3C
ERMA Approval Code	HSR001324

16.0 Other Information

None

Appendix 3. Material safety data sheet for sodium thiosulphate.

SIGMA-ALDRICH

sigma-aldrich.com

SAFETY DATA SHEET

according to Regulation (EC) No. 1907/2006
Version 5.2 Revision Date 23.07.2014
Print Date 02.06.2015
GENERIC EU MSDS - NO COUNTRY SPECIFIC DATA - NO OEL DATA

SECTION 1: Identification of the substance/mixture and of the company/undertaking

1.1 Product identifiers

Product name	:	Sodium thiosulfate
Product Number	:	S7026
Brand	:	Sigma
REACH No.	:	A registration number is not available for this substance as the substance or its uses are exempted from registration, the annual tonnage does not require a registration or the registration is envisaged for a later registration deadline.
CAS-No.	:	7772-98-7

1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses : Laboratory chemicals, Manufacture of substances

1.3 Details of the supplier of the safety data sheet

Company	:	Sigma-Aldrich New Zealand Co. PO BOX 106-406 1030 AUCKLAND NEW ZEALAND
Telephone	:	0800 936 666

1.4 Emergency telephone number

Emergency Phone # : NZ: 0800 928 888 Int'l +44 8701 906777

SECTION 2: Hazards identification

2.1 Classification of the substance or mixture

Not a hazardous substance or mixture according to Regulation (EC) No. 1272/2008.
This substance is not classified as dangerous according to Directive 67/548/EEC.

2.2 Label elements

The product does not need to be labelled in accordance with EC directives or respective national laws.

2.3 Other hazards - none

SECTION 3: Composition/information on ingredients

3.1 Substances

Synonyms	:	Sodium thiosulphate
Formula	:	$Na_2O_3S_2$
Molecular Weight	:	158,11 g/mol
CAS-No.	:	7772-98-7
EC-No.	:	231-867-5

No components need to be disclosed according to the applicable regulations.

SECTION 4: First aid measures

4.1 Description of first aid measures

If inhaled
If breathed in, move person into fresh air. If not breathing, give artificial respiration.

In case of skin contact
Wash off with soap and plenty of water.

In case of eye contact
Flush eyes with water as a precaution.

If swallowed
Never give anything by mouth to an unconscious person. Rinse mouth with water.

4.2 Most important symptoms and effects, both acute and delayed
The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

4.3 Indication of any immediate medical attention and special treatment needed
no data available

SECTION 5: Firefighting measures

5.1 Extinguishing media

Suitable extinguishing media
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

5.2 Special hazards arising from the substance or mixture
no data available

5.3 Advice for firefighters
Wear self contained breathing apparatus for fire fighting if necessary.

5.4 Further information
no data available

SECTION 6: Accidental release measures

6.1 Personal precautions, protective equipment and emergency procedures
Avoid dust formation. Avoid breathing vapours, mist or gas.
For personal protection see section 8.

6.2 Environmental precautions
Do not let product enter drains.

6.3 Methods and materials for containment and cleaning up
Sweep up and shovel. Keep in suitable, closed containers for disposal.

6.4 Reference to other sections
For disposal see section 13.

SECTION 7: Handling and storage

7.1 Precautions for safe handling
Provide appropriate exhaust ventilation at places where dust is formed.
For precautions see section 2.2.

7.2 Conditions for safe storage, including any incompatibilities
Store in cool place. Keep container tightly closed in a dry and well-ventilated place.
Do not store near acids.

Keep in a dry place.

7.3 Specific end use(s)
Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

SECTION 8: Exposure controls/personal protection

8.1 Control parameters

Components with workplace control parameters

8.2 Exposure controls

Appropriate engineering controls
General industrial hygiene practice.

Personal protective equipment

Eye/face protection
Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Skin protection
Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

The selected protective gloves have to satisfy the specifications of EU Directive 89/686/EEC and the standard EN 374 derived from it.

Full contact
Material: Nitrile rubber
Minimum layer thickness: 0,11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

Splash contact
Material: Nitrile rubber
Minimum layer thickness: 0,11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

Body Protection
Choose body protection in relation to its type, to the concentration and amount of dangerous substances, and to the specific work-place., The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

Respiratory protection
Respiratory protection is not required. Where protection from nuisance levels of dusts are desired, use type N95 (US) or type P1 (EN 143) dust masks. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

Control of environmental exposure
Do not let product enter drains.

SECTION 9: Physical and chemical properties

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: powder Colour: white
b)	Odour	no data available

c)	Odour Threshold	no data available
d)	pH	6,0 - 8,5 at 50 g/l at 20 °C
e)	Melting point/freezing point	52 °C - Decomposes on heating.
f)	Initial boiling point and boiling range	no data available
g)	Flash point	no data available
h)	Evapouration rate	no data available
i)	Flammability (solid, gas)	no data available
j)	Upper/lower flammability or explosive limits	no data available
k)	Vapour pressure	no data available
l)	Vapour density	no data available
m)	Relative density	1,667 g/cm3 at 20 °C
n)	Water solubility	210 g/l at 20 °C
o)	Partition coefficient: n-octanol/water	no data available
p)	Auto-ignition temperature	no data available
q)	Decomposition temperature	no data available
r)	Viscosity	no data available
s)	Explosive properties	no data available
t)	Oxidizing properties	no data available

9.2 Other safety information
no data available

SECTION 10: Stability and reactivity

10.1 Reactivity
no data available

10.2 Chemical stability
Stable under recommended storage conditions.

10.3 Possibility of hazardous reactions
no data available

10.4 Conditions to avoid
no data available

10.5 Incompatible materials
Strong acids, Strong oxidizing agents

10.6 Hazardous decomposition products
Other decomposition products - no data available
In the event of fire: see section 5

SECTION 11: Toxicological information

11.1 Information on toxicological effects

Acute toxicity
LD50 Oral - rat - > 8.000 mg/kg

LD50 Intraperitoneal - mouse - 5.200 mg/kg

Skin corrosion/irritation
no data available

Serious eye damage/eye irritation
no data available

Respiratory or skin sensitisation
no data available

Germ cell mutagenicity
no data available

Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.

Reproductive toxicity
no data available

Specific target organ toxicity - single exposure
no data available

Specific target organ toxicity - repeated exposure
no data available

Aspiration hazard
no data available

Additional Information
RTECS: XN6476000

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

SECTION 12: Ecological information

12.1 Toxicity

Toxicity to fish LC50 - Gambusia affinis (Mosquito fish) - 24.000 mg/l - 96 h

12.2 Persistence and degradability
no data available

12.3 Bioaccumulative potential
no data available

12.4 Mobility in soil
no data available

12.5 Results of PBT and vPvB assessment
PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

12.6 Other adverse effects

no data available

SECTION 13: Disposal considerations

13.1 Waste treatment methods

Product
Offer surplus and non-recyclable solutions to a licensed disposal company.

Contaminated packaging
Dispose of as unused product.

SECTION 14: Transport information

14.1 UN number

ADR/RID: -	IMDG: -	IATA: -

14.2 UN proper shipping name
ADR/RID: Not dangerous goods
IMDG: Not dangerous goods
IATA: Not dangerous goods

14.3 Transport hazard class(es)

ADR/RID: -	IMDG: -	IATA: -

14.4 Packaging group

ADR/RID: -	IMDG: -	IATA: -

14.5 Environmental hazards

ADR/RID: no	IMDG Marine pollutant: no	IATA: no

14.6 Special precautions for user
no data available

SECTION 15: Regulatory information

This safety datasheet complies with the requirements of Regulation (EC) No. 1907/2006.

15.1 Safety, health and environmental regulations/legislation specific for the substance or mixture

no data available

15.2 Chemical Safety Assessment
For this product a chemical safety assessment was not carried out

SECTION 16: Other information

Further information

The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

Appendix 4. Look-up tables for dosing encapsulated water with chlorine and for neutralising residual chlorine with sodium thiosulphate.

Table 2. Amount (kg) of dichlor required to provide different concentrations of FAC for different volumes of encapsulated water ('Volume'). The column for 200 mg/L would be used to set up the treatment initially and other columns used to restore the concentration during treatment, based on the difference between the measured concentration and the target concentration (200 mg/L). The volume of encapsulated water in the worked example (section 8, trawler) is highlighted.

	Difference between measured and target FAC concentration (mg/L)									
Volume (L)	25	50	75	100	125	150	175	180	190	200
1000	0.05	0.09	0.14	0.18	0.23	0.27	0.32	0.33	0.35	0.36
2000	0.09	0.18	0.27	0.36	0.45	0.55	0.64	0.65	0.69	0.73
3000	0.14	0.27	0.41	0.55	0.68	0.82	0.95	0.98	1.04	1.09
4000	0.18	0.36	0.55	0.73	0.91	1.09	1.27	1.31	1.38	1.45
5000	0.23	0.45	0.68	0.91	1.14	1.36	1.59	1.64	1.73	1.82
6000	0.27	0.55	0.82	1.09	1.36	1.64	1.91	1.96	2.07	2.18
7000	0.32	0.64	0.95	1.27	1.59	1.91	2.23	2.29	2.42	2.55
8000	0.36	0.73	1.09	1.45	1.82	2.18	2.55	2.62	2.76	2.91
9000	0.41	0.82	1.23	1.64	2.05	2.45	2.86	2.95	3.11	3.27
10000	0.45	0.91	1.36	1.82	2.27	2.73	3.18	3.27	3.45	3.64
15000	0.68	1.36	2.05	2.73	3.41	4.09	4.77	4.91	5.18	5.45
20000	0.91	1.82	2.73	3.64	4.55	5.45	6.36	6.55	6.91	7.27
25000	1.14	2.27	3.41	4.55	5.68	6.82	7.95	8.18	8.64	9.09
30000	1.36	2.73	4.09	5.45	6.82	8.18	9.55	9.82	10.36	10.91
35000	1.59	3.18	4.77	6.36	7.95	9.55	11.14	11.45	12.09	12.73
40000	1.82	3.64	5.45	7.27	9.09	10.91	12.73	13.09	13.82	14.55
45000	2.05	4.09	6.14	8.18	10.23	12.27	14.32	14.73	15.55	16.36
50000	2.27	4.55	6.82	9.09	11.36	13.64	15.91	16.36	17.27	18.18
55000	2.50	5.00	7.50	10.00	12.50	15.00	17.50	18.00	19.00	20.00
60000	2.73	5.45	8.18	10.91	13.64	16.36	19.09	19.64	20.73	21.82
65000	2.95	5.91	8.86	11.82	14.77	17.73	20.68	21.27	22.45	23.64
70000	3.18	6.36	9.55	12.73	15.91	19.09	22.27	22.91	24.18	25.45
75000	3.41	6.82	10.23	13.64	17.05	20.45	23.86	24.55	25.91	27.27
80000	3.64	7.27	10.91	14.55	18.18	21.82	25.45	26.18	27.64	29.09
85000	3.86	7.73	11.59	15.45	19.32	23.18	27.05	27.82	29.36	30.91
90000	4.09	8.18	12.27	16.36	20.45	24.55	28.64	29.45	31.09	32.73
95000	4.32	8.64	12.95	17.27	21.59	25.91	30.23	31.09	32.82	34.55
100000	4.55	9.09	13.64	18.18	22.73	27.27	31.82	32.73	34.55	36.36

Table 3. Amount (g) of sodium thiosulphate required to neutralise (*i.e.* reduce the concentration to < 0.5mg/L) a given residual concentration of FAC for different volumes of encapsulated water ('Volume'). Values are based on a mass ratio of 1.86:1 sodium thiosulphate to FAC. The volume of encapsulated water in the worked example (section 8, trawler) is highlighted.

	Residual FAC concentration (mg/L)									
Volume (L)	1	2	3	4	5	10	15	20	30	50
1000	2	4	6	7	9	19	28	37	56	93
2000	4	7	11	15	19	37	56	74	112	186
3000	6	11	17	22	28	56	84	112	167	279
4000	7	15	22	30	37	74	112	149	223	372
5000	9	19	28	37	47	93	140	186	279	465
6000	11	22	33	45	56	112	167	223	335	558
7000	13	26	39	52	65	130	195	260	391	651
8000	15	30	45	60	74	149	223	298	446	744
9000	17	33	50	67	84	167	251	335	502	837
10000	19	37	56	74	93	186	279	372	558	930
15000	28	56	84	112	140	279	419	558	837	1395
20000	37	74	112	149	186	372	558	744	1116	1860
25000	47	93	140	186	233	465	698	930	1395	2325
30000	56	112	167	223	279	558	837	1116	1674	2790
35000	65	130	195	260	326	651	977	1302	1953	3255
40000	74	149	223	298	372	744	1116	1488	2232	3720
45000	84	167	251	335	419	837	1256	1674	2511	4185
50000	93	186	279	372	465	930	1395	1860	2790	4650
55000	102	205	307	409	512	1023	1535	2046	3069	5115
60000	112	223	335	446	558	1116	1674	2232	3348	5580
65000	121	242	363	484	605	1209	1814	2418	3627	6045
70000	130	260	391	521	651	1302	1953	2604	3906	6510
75000	140	279	419	558	698	1395	2093	2790	4185	6975
80000	149	298	446	595	744	1488	2232	2976	4464	7440
85000	158	316	474	632	791	1581	2372	3162	4743	7905
90000	167	335	502	670	837	1674	2511	3348	5022	8370
95000	177	353	530	707	884	1767	2651	3534	5301	8835
100000	186	372	558	744	930	1860	2790	3720	5580	9300