The Impact of Tributyltin in the Cook Inlet Watershed

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From the shores of England to the watersheds of Alaska, all marine environments face degradation with the exposure of tributyltin, commonly known as TBT. Since the introduction of TBT in the 1960s, boat hulls and fishing equipment have become more hydrodynamic by eliminating microbial organisms' growth on marine equipment therefore increasing efficiency. However, in the late 1970s and 1980s, the environmental cost of such efficiencies became apparent with the loss of marine habitat. Bottom dwelling primary consumers began to develop mutations that could cause death and disease, and secondary and tertiary consumers also experienced similar health declensions due to TBT exposure. In Alaska's Cook Inlet the effects of TBT were recorded officially in 1986 with conformational research conducted in 2006. This watershed houses a diverse ecosystem and is an important economic area for Alaska. The recorded disturbance that the toxin, TBT, causes to this critical inlet is detrimental to the habitat and organisms, as well as Alaskan residents. However, since Alaska banned TBT in 2001, little research or remediation has been conducted. While it is illegal now to sell marine antifoulants containing TBT and illegal to apply the toxic coating, TBT continues to exist in sediments, water supply, older vessel hulls, and products that eventually become intermixed with the marine ecosystem. This biocide, that plagues the watershed and diminishes marine populations, will continue to do so despite the ban; the Cook Inlet needs active prevention measures in order to eliminate this toxin and revive this crucial habitat and economic seascape.

Table of Contents

Introduction

Tributyltin is a commonly known biocide that prevents the growth of a broad range of organisms. TBT was introduced into products in the 1960s, as an accessible pesticide in the agriculture industry. Since then, it has been adapted for use in pesticides, buoys, marine hulls, fishing equipment, paper, cleaning products, disinfectant, sheetrock, and refrigeration systems (Bray et. al., 2006). In the 1970s, the negative effects of TBT on the marine environment were evidenced in the degradation of finfish, crustacean, and mollusk populations (Santillo et. al., 2000). In 1982, France's Ministry of the Environment enforced a two year ban on paints containing TBT. Following suit, the European Union, Canada, New Zealand, and other countries began regulating TBT (Allan et. al., 2006).

Tributlytin's consequences were detected in Alaska in 1989, yet the issue was never studied on a broad scale. In 2006, many sites in Alaska were evaluated using blue mussels and dog winkle populations as indicators. Unsurprisingly, at major ports, high concentrations of TBT were recorded [Figure 1]; more specifically, the harbor in Homer, Alaska reported concentrations of 40 ng/g (Tallmon, 2012).

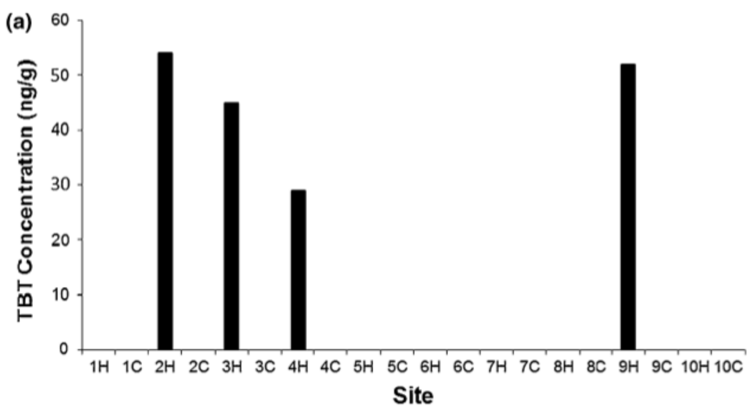

Figure 1 (Tallmon, 2012); 3H and 4H represent Homer and Seward

On the other end of the inlet, in Seward harbor, endocrine disruption in the *Nucella lima*, commonly referred to as the dog winkle, was reported in correlation to toxic marine coatings. Additionally the *Mytilus trossolus* or blue mussels in these areas developed deformed and brittle shells. These alarming reports were found in many areas of the Cook Inlet, one of Alaska's most active watersheds (*Nature of Conservancy*, 2003).

In Cook Inlet's marine environment, TBT prevents the growth of organisms, such as barnacles, on fishing equipment and boat hulls, causing ocean equipment to be more cost-effective. While TBT is currently banned from being repainted onto boat hulls, the TBT currently existing in the environment and on older equipment is undeniably devastating to species' health and population. In order to protect the economic future of the Cook Inlet region and the environmental future of the Cook Inlet ecosystem, steps must be taken to reduce the impact of TBT. Active procedures of removal, making environmental and cost-effective solutions available to the marine industry, and creating a forum of discussion around toxic chemical use are all keyed to protecting the Cook Inlet, thus minimizing future damage to our part of the ocean.

<u>Description of the Cook Inlet</u>

Geographical Description

From the Gulf of Alaska to the entrance of Knik Arm, Alaska's Cook Inlet is 290 kilometers long (Joling, 2012). Cook Inlet is a northeast-trending forearc basin above the Aleutian subduction zone located in Southcentral Alaska. The discontinuous and complex basin was probably formed by right-transpressional deformation on oblique-slip faults in the Mesozoic era; the most recent

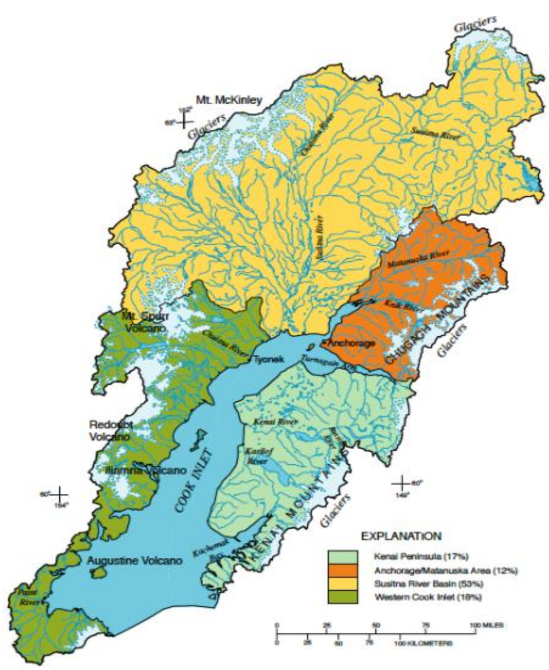

Figure 2 (Brabets, 1999)

changes most likely occurred in the Miocene time. The Aleutian-Alaska subduction zone, which remains an active fault line, had an essential role in the formation of Cook Inlet (Haeussler et. al., 2000). The subduction zone also played a crucial role in forming many mountain ranges that surround the inlet: the Aleutian Range, the Kenai Mountains, and the Chugach Mountains. Active volcanoes, such as Mt. Redoubt, Augustine, and others, are a part of the mountain ranges and active fault lines found around Cook Inlet (Brabets, 1999).

In addition to volcanoes, glacial rivers are prevalent in the Cook Inlet. Matanuska River, Susitna River, and Knik River are all major waterway that feed into the basin [Figure 2]. The deposits from these rivers create silty mudflats, which are exposed during the low tides of the inlet (Cook Inlet, n.d.). Over 60 of these large bays, coves, and estuaries create the diverse geography of Cook Inlet, one of the largest and most active watershed in Alaska, in addition to being the most densely populated area in Alaska [Figure 1].

Ecological Description

The multitudes of estuaries, bays, and shore lands in the Cook Inlet allow for vast geographical and ecological diversity. Traditionally the home of the Dena'ina Athabascans, Cook Inlet was given the native name Tikahtnu and sustained the native lifestyle by supplying a rich variety of sea life, including salmon, pacific cod, steelhead trout, beluga whales, and seabirds [Figure 3]. Due in part to this productive ecology, the Cook Inlet region is now home to approximately 400,000 people who all have the potential to affect the diverse watershed (Cook Inlet, n.d.). The

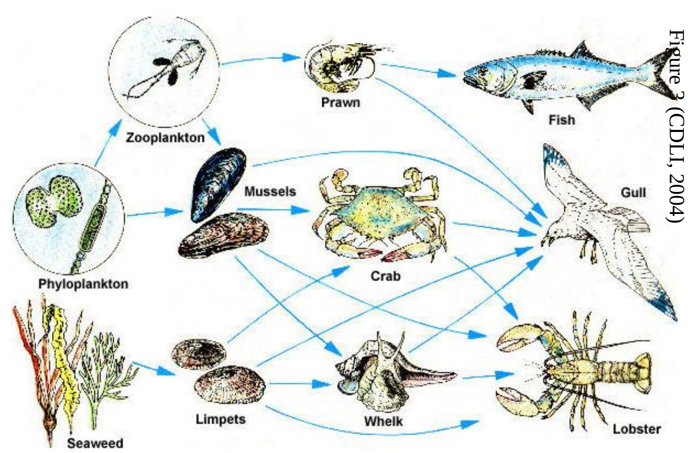

Figure 3 (CDLI, 2004)

ecosystem also consists of a plethora of sea snails, mussels, vegetation, and mammals [Figure 3]. Kelp, seaweed, and lichen are dominant vegetation types in the region, providing nutrients for primary consumers, such as dog winkles and blue mussels, which serve as indicator species and are a crucial link in the food chain (US Department of Fish and Game, 2007). Sandpipers, salmon, otters, and other consumers of the Cook Inlet ecosystem feed off of these organisms and continue to contribute to the watershed's diversity (Nature of Conservancy, 2003). This productive and intricate ecosystem is still essential to human development today as it was to the early inhabitants, and, of course, a vital home to millions of aquatic and avian organisms.

Economy of the Cook Inlet

Transportation is important to the marine economic sphere. In 2010 alone, there were over 500 commercial port calls. The most prominent forms of marine transportation are ferries, containers, and cargo ships; ferries boast the longest annual operating time at 225 days annually (International, 2011). A major component of the transportation industry in Alaska is fishing. Commercial fishing is also the state's largest employer, creating 78,000 direct and indirect jobs; Alaska alone accounts for 60 percent of the United States Commercial Fishing industry. Of the 3.6 billion dollar Alaskan industry, 60 million is accounted for in the Cook Inlet alone. The total economic value, including commercial and non-commercial, is estimated to be 280 million dollars annually. The sport fishing industry, almost matching the commercial and non-commercial use, is valued at 279 million dollars in the inlet. In the Cook Inlet region 43,000 pounds of wild resources are harvested annually for subsistence; of this number, approximately 70 percent consisted of salmon (Helvoigt et. al., 2010). The large economic scale of Cook Inlet makes the watershed a productive and important area for Alaska and its residents.

<u>Tributyltin</u>

Chemical Properties

Tributyltin is an organotin compound used in antifoulant paints. Organotins consist of one to four organic compounds attached to a tin atom via a covalent bond. When there are fewer than four carbon-tin bonds, the organotin cation will bond with an anion such as oxygen resulting in one of the permutations of TBT. The seven permutations are: tributyltin benzoate, tributyltin chloride, tributyltin fluoride, tributyltin linoleate, tributyltin methacrylate, tributyltin naphthenate, and tributyltin oxide (Mergel, n.d.). Tributyltin oxide, TBTO, is the most common form of TBT used and tested. The chemical formula for TBTO is $C_{24}H_{54}OSn_2$ [Figure 4] (Data Sheet on Pesticides, n.d.).

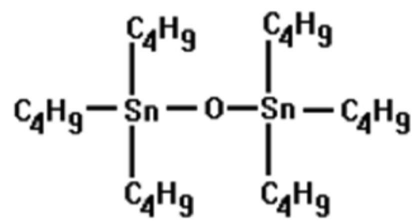
Figure 4 (Data Sheet on Pesticides, n.d.)

Antifouling paints work by either providing an unstable surface for attachment of organisms, while poisoning the organism with toxic organotins (Bray et. al., 2006). Other uses of TBT include: use as a biocide, preservatives for wood, textiles, paper, leather, and electrical equipment; it was also used as an anti-yellowing agent in plastics and use as a biocide. Tributyltin oxide is the most common form of TBT used on the hulls of boats and wooden docks.

Since TBT is a non-polar, hydrophobic substance, is drifts through the water and accumulates on the ocean floor. The low water solubility but high fat solubility of TBT allows it to easily bio accumulate in organisms. Removing TBT from the environment can be done by thermally treating the contaminated sediment (Challinor, 2007). When heated to 400 degrees Celsius 99 percent of TBT will degrade into dibutyltin, monobutyltin, and inorganic tin, which can then be treated as industrial waste and disposed of.

Effects on Indicator Species

Tributyltin has been shown to have negative effects on different aquatic organisms in many areas of the food chain. This chemical has had its most noticeable effect on *Nucella lima*, commonly known as the dog winkle. Dog winkles are part of the family Muricidae, and the class Gastropoda. Their shell size is between 19 and 51 millimeters in diameter (Nucella lima, 2010). The shell of the dog winkle is primarily formed by calcium, similar to most species of snail (Dubilier, n.d.). These gastropods are bottom-dwellers, which live primarily in the mud, silt and sediments at the bottom of the ocean. Scientists and researchers conducted a study in the summer of 2008 and discovered that imposex was occurring in dog winkles. Imposex is a disorder found in different species of sea snail, in which the females develop male genitalia [Figure 5]. In severe cases of imposex, the females' oviducts are blocked by the growth of the male penis. This reduces, and can eventually halt, the production of ovules. Without ovules it is impossible for reproduction to occur, which in turn drastically reduces the population. TBT is the only chemical responsible for this change in the dog winkles. In the experiment conducted by David Tallmon on May 8^{th}, 2009, fifty dog winkles were collected from the mouth of Homer Harbor in Homer, Alaska. The percent of females displaying imposex were between 36 and 87.5 percent (Tallmon, 2012). It was discovered that the cause of the endocrine disruption and imposex was TBT.

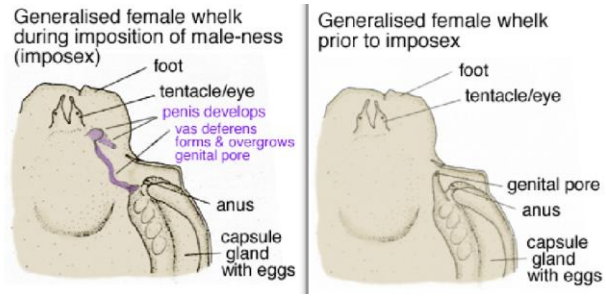

Figure 5 (Bright and Ellis, 2002)

TBT has also had an impact on the *Mytilus trossulus*, or the blue mussel. The blue mussel, is an edible mussel living in the Pacific Ocean. Their distinguishing characteristic is the spiral-blue pattern on the oval shaped shell. (Dubilier, n.d.) The mussels use byssal threads to attach themselves to coral, rocks or the bottom of the ocean. There is TBT in the water, or sediment at the bottom of the ocean, and the mussel absorbs it through its valve. TBT weakens the shell making it more vulnerable to predators. When predators ingest TBT infected mussels, the chemical accumulates in the liver and intestines of the consumer.

Marine Application of Tributyltin

Unknown to most consumers, TBT has an impact on the marine economy. In the paint sector, prevention techniques and new technologies have a direct financial effect. To completely eliminate TBT antifoulants from equipment, the paint must either be removed or sealed completely to prevent further leaching. There are other paints created specifically for the prevention of leaching: they lock TBT paint in and therefore stop it from permeating into the ocean, thus nullifying the problem. (TBT Sealer, n.d.). Antifoulants unique problems have brought about new innovation, for a larger market. These new solutions also save marine equipment owners money, from the need of fewer reapplications of the coating compared to TBT antifoulant paint. The elimination of TBT allows for the expansion of the coating industry and the long-term savings of marine equipment owners.

History of the Ban on Tributyltin Antifoulants

In March of 2000, the Alaskan senate voted to ban the sale, distribution, and use of the antifoulants. The ban went into effect January 1st 2001. According to legal documents, it is also illegal to "rent, sell, lease or import a vessel, fishing gear, or other item intended to be partially or completely submerged in the water, if the vessel, gear, or item has been painted or treated with TBT-based marine antifouling paint or coating." (Clean Water Act, Id. § 46.03.715(e)) Seven years later, on January 1st 2008, the rest of the world banned the use of TBT.

<u>Comparison between Cook Inlet and the Port of Antwerp</u>

The Port of Antwerp is one of the most important ports in Europe; it is not only in the center of Europe, but it is also in the middle of the Scheldt-Maas-Rhine delta (Strategic Location, 2013). More specifically, the port is located 100 kilometers inland from the North Sea on the Scheldt River [Figure 6]. The Port of Antwerp is less-than half the size of Alaska's Cook Inlet [Figure 2], being 13,057 hectares in surface area of the whole port (Heylen, 2011).

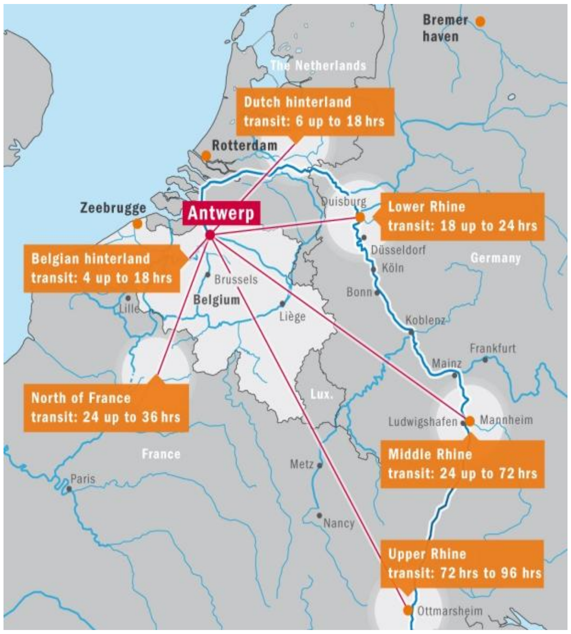

Figure 6 (Strategic Location, 2013)

The Port of Antwerp, Europe's second largest and the world's fourth largest port, is extremely busy throughout the year: over the course of a single day, 45 sea ships, 168 barges, and 220 freight trains pass through or around it (Heylen, 2011). The Port of Antwerp handles about 189 tons of maritime goods over the course of a year, and over 140,000 people make a living directly or indirectly because of it (Port of Antwerp, 2013). As a result, the port has become inundated with TBT.

The main organisms affected by tributyltin are the *Littorina litorrea*, and the *Nucella lapillus*, periwinkles and dog whelks respectively (Wolf, 2001). These organisms are very similar to the ones affected by TBT in the Cook Inlet. They are bottom-dwelling organisms that experience intersex and imposex when exposed to TBT antifoulants [Figure 3]. Also, similarly to the Cook Inlet, these organisms play an important role in the ecosystem's food chain.

In most of the sediment in the Port of Antwerp, the TBT concentration is relatively low; measured at less than 100 µg/kg dry weight. However, there are areas where TBT is much higher in concentration; for example, near the Antwerp Shipping Repair Site, the measurement is more than 40 mg/kg dry weight (Heylen, 2011).

In order to overcome the problem of TBT in the sediments, the city of Antwerp has taken action by implementing a plan called “TBT Clean”. It is separated into four steps for the complete removal of TBT from the water system: the first step is to find a good alternative for TBT antifoulants. The second step is to remove the sediments in areas of heavy TBT pollution through dredging. The third step is the actual treatment of the sediments through several different methods to determine which is the most effective. These methods include: thermal treatment, washing and separation, bioremediation, electro-chemical treatment, and phytoremediation. The fourth step is to simply reuse the treated sediments to improve the area. Some important uses of treated sediments are for landscaping, dike reinforcement, and construction work (Thues, n.d.).

Cook Inlet, however, has only banned the use of TBT on new boats; however, in areas of high traffic like Cook Inlet and the Port of Antwerp, more aggressive action is necessary. Antwerp is already well on its way to a future without TBT pollutants, and the Cook Inlet, with a similar plan, could be too.

Future Impact

TBT has the capability to inflict major damage on marine life, indicated by the dog winkle and blue mussel populations. It has already been proven to cause imposex in dog winkles, and to weaken the shells of blue mussels (Salazar, 1996). TBT destruction has been recorded in other species as well; for example, lobster larvae have shown decreased growth at just 1.0 µg/kg, TBT. Oysters develop brittle shells and deformations. Finfish eggs are killed within days at 5.0

µg/kg of TBT exposure. Survival of algae is limited, at just 0.33 to 1.03 µg/kg. This toxin has the ability to remain in the suspended water for months and the sediments for two years before breaking down naturally (Tributyltin, 1993). The chronic exposure to TBT will continue to inflict damage on the ecosystem. Inhibition to survival, brittle shells, infertility from imposex, and non-viable ovum contribute to declining population and overall watershed health.

The effect of TBT on humans has not been researched extensively; however, in research conducted on rats, TBT has proved to be an obesogen and carcinogen (Moltzen, 2010). Observations of human/TBT interaction also show skin and lung irritation to be a side-effect. Looking at the effect the toxin has on all other organisms, it can be concluded that human health would be affected. However, complications go beyond health concerns. Toxic antifoulants injure species that are important parts of the food chain, involving the Cook Inlet's seafood industry [Figure 3]. If TBT continues to be a part of this ecosystem, these jobs will decrease in number and pay, thus potentially having a heavy impact in the Cook Inlet and Alaskan economy.

The harmful effects were realized within ten years of its introduction. These effects will continue to multiply as TBT is being used. The degradation of the environment, health consequences, and economic inhibitors will continue as TBT remains in the Cook Inlet.

Management Plan

Since TBT was first introduced in the 1960s, there has been a major degradation in marine ecosystems (Johnston et. al, 2000). This degradation has become apparent through the decline of the mussels and dog winkles in the Cook Inlet, which is a region of high ship traffic (Helvoigt et. al., 2010). Other physical signs such as discoloration and loss of vegetation allow scientists to better understand the immense impact of TBT. Around the world in places like the Port of Antwerp, TBT damage is just as imposing; the difference is, in Antwerp, they are striving not just too passively ban TBT, but to actively recover damaged marine habitats (Pensaert, 2003). In the Cook Inlet, active steps such as contained dredging, replacement substances, and awareness of harmful organotins need to be employed to remove the forty years of TBT exposure. These steps will improve the economy of the region, increase ecosystem health, and create a protected ocean for residents of Cook Inlet.

Dredging

The majority of the TBT introduced into the marine environment becomes a part of the ocean sediment. Settled TBT affects bottom-dwelling organisms and is released when ocean floor disruptions occur. Sediments have a higher concentration near shores where marine activity is extensive (Davoren, 2008). Sediment in affected areas has been known to contain 40 mg/kg compared, to 300 μg/kg in suspended water samples (Life, 2004). For organisms such as mussels and snails, this TBT level is mutilating and potentially deadly. Although seemingly counterintuitive, dredging is a viable solution for TBT removal.

Dredging of heavily affected areas releases TBT, however, if conducted with a controlled procedure, the TBT can be entirely removed (Challinor, 2007). Areas that have implemented this procedure have deemed it successful and showed that it outweighs the negative effects of disrupting the environment (Life, 2004).

The dredging process begins with the surveying of TBT concentrations [Figure 1]. Levels of 0.0003 μg/g must be detected in order to follow EPA guidelines, and then each area must be carefully examined to determine how deep the sediment the TBT is; TBT has been found as deep as 1.25 meters. Suction dredging can then be employed to maximize sand removal and minimize turbidity; the turbidity must be monitored closely to avoid the release of TBT into the water samples and to decrease environmental impact (Environment Protection Authority, 2001).

Remediation of soil is best done with thermal treatment, which will degrade the TBT. The incinerated sand is useful for erosion projects near waterways: through these projects, the soil is restored and used for vegetative purposes, eventually destined to return to the ocean. As is essential to all projects, monitoring and recording of progress would need to be scientifically completed during and after the restoration efforts.

The Cook Inlet contains many active ports, such as Homer Bay, Valdez, and Anchorage's mudflats [Figure 2]. A study conducted on suspended water samples in 2006 shows that there is over 40 µg/kg of TBT in many parts of Cook Inlet. Due to the toxicity of TBT and its close proximity to the surface of the sediments, dredging would be a feasible undertaking. Additionally, the ecosystem is similar to that of Antwerp Bay [Figure 6]. Antwerp Bay experimented with dredging as a means to remove TBT in 2003 and 10 years later the port has become more ecologically productive. Marine organisms are developing less imposex and the negatively affected areas are quickly regenerating. Scientists have concluded that the impact of contained dredging has proved to result in a positive effect on the marine environment (Life, 2004).

Of course, the key to successful dredging projects is proper containment and rehabilitation; due to the intensity of the project, port managers at each damaged site should be trained in specific TBT dredging processes. Regions that need dredging include areas of high traffic such as: the city of Seldovia, the Port of Anchorage, Nikiski Industrial Facilities, and the Port of Homer (Eley, 2012). Dredging also provides an excellent opportunity for continued study of the program, especially in the initial stages. Local universities like the University of Alaska Southeast and the University of Alaska Fairbanks should be included in the project for joint management and funding. During the reimplementation phase, local school groups or non-profits like Alaskans for Palmer Hay Flats can provide a source of labor and community involvement. Treatment is estimated to cost 20.31 US dollars per ton and Dredging is approximately 20.22 US dollars per ton (Life, 2004). Besides University funding, supporters such as British Petroleum and Conoco Philips would supplement the funding from the state. By community involvement, careful monitoring, and removal of TBT the marine systems of the Cook Inlet could begin to be rejuvenated from this toxin.

Paint Alternatives

In Cook Inlet, shipping is a major industry. From ferries to cargo, Alaskan ports are essential for travel and supplies. Following the International Maritime Ban of 2001, the EPA created standards that went into effect in 2004. The standards require freshwater bodies to contain less than 72 µg/L, and saltwater bodies to contain less than 0.0074 µg/L. Alaska mandates that all vessels submerged in water have coatings without TBT, and any with coatings above the TBT base layer have a lower leach rate less than those determined by the EPA (Savarse et. al., 2005). As a result, Cook Inlet marine equipment and vessels in the can no longer renew coats of TBT based paints. However, ship hulls with TBT-based paint still leech into the ecosystem. Additionally, the common replacement for TBT-based paint contains copper as its active biocide, which has been proven to be just as harmful to the environment. Discoloration, unhealthy mutations, and death are associated with the introduction of copper-based paints (Lydecker, 2012). After active projects such as dredging occur, precaution must be taken not to reintroduce TBT or other toxic chemicals. This entails completely removing TBT from marine equipment and finding substitutes that do not contain toxic chemicals, such as copper, as a replacement.

A coating solution must prevent organism growth on hulls to be considered an effective replacement marine paint. The prevention of growth allows ships to be more hydrodynamic, which increases efficiency. Ecospeed® provides a “TBT-free, copper-free and biocide-free solution,” as an effective marine coating (Hydrex, 2011). Ecospeed® paint is also more cost-effective than traditional solutions, since the paint is a one-time application (Verte, 2012). This product does allow for marine growth, however, it can be removed in the water, without harm to the coating or to the environment. Traditional non-toxic marine paints are also available. Ecological Coatings LLC has a line of paints called the 4000 Series which contains a low quantity of volatile organic compounds, VOCs, and has been tested for safety of indicator species, such as mussels, snails, etc (Ecological Coatings, LLC, 2013). Antifoulant paint has become an important topic in the marine research industry, providing more alternatives for a more productive and safer marine shipping economy.

For proper prevention, the policy listed in Alaska’s statute needs to be reformed to ban all toxic chemicals, such as copper; all new ocean instruments and ships would be required to use coatings that are proven to be safer for the environment. Recreating the marine paint system is also unique because alternatives to traditional toxins are cheaper in the long run. In the case of Ecospeed® the cost is 140 to 160 dollars per square meter, which is notably cheaper than the cost of traditional copper paints at 206 dollars per square meter (Green, 2013) However, long-term maintenance of Ecospeed® is dramatically cheaper than the alternatives (Hydrex, 2011). Additionally, boat owners need to be prompted to remove any TBT-based paints. The cost of completely sanding and repainting a hull is approximately 10,000 US dollars (Moran, 2012); this can be expensive for many boat owners. In order to aid the process, the state should offer a subsidy based on a tier system, taking into account the profits of the ship. Through legislative action requested by the Department of Environmental Conservation, the policy could be adjusted and monetary support issued (Alaska Department of Environmental Conservation, 2013). These efforts will help continue to keep TBT and other harmful antifoulants out of the Cook Inlet.

Education Plan

Tributyltin has become a prevalent compound since the beginning of its use in the 1960s. Used predominantly as an organic biocide, TBT is also a preservative in textiles, paper, pesticides, and refrigerants. The waste from these products fills landfills with approximately 53,000 tons annually; 40% of which (US Environmental Protection Agency, n.d.) consists of paper in South Central Alaska alone (Central peninsula landfill, 2013). Harmful compounds such as TBT continue to plague the ecosystem and environment due to lack of available information. Consumers, ship-owners, and those who work closely with material waste need to be aware of side effects and problems associated with TBT.

Many programs exist in public schools and universities that bring people into the local environment. Alaska Youth for Environmental Action, for example, unites students from all around Alaska (Alaska Youth for Environmental Action, 2011). Seaside communities like Homer have visitor centers that provide programs for student involvement. The Alaskans for Palmer Hay Flats conserves the mudflats of Cook Inlet with a community focus (Alaskans for Palmer Hay Flats, 2012). All of these programs are committed to bringing community into the environment. Through these organizations, a toxic chemical awareness program could be initiated. This would give the opportunity to teach our youth, bring citizens to the ocean to see shoreline damage, and inform consumers about the human and environmental dangers of toxic compounds. This effort could be lead by the Division of Environmental Health (Floyd, 2011), using financial support from the Ernest Hollings annual grant program (Alexander, 2013). The approximate cost of education material would be 10,000 US dollars. The use of educative media will act as a catalyst, promoting community education and involvement in the reversal of the damage caused by TBT.

Tributyltin is not only used as a biocide in the marine industry, but is found in clothing, paper, and assorted packaging. These materials are used day in and day out within homes, schools, and eventually thrown into landfills or begin to biodegrade into our water systems. From the landfill and the underground water sources, as per the water cycle, the leaching of TBT is destined to not only affect human water supply, but to go into the oceans (World Watch Institute, n.d.). Settlements near the coast are more likely to affect the water systems with their choices; Cook Inlet towns like Homer, Valdez, Seward, Anchorage, Wasilla, and Palmer, play a particular role in the Cook Inlet's health. To prevent the ignorance of consumers, the state of Alaska should, much like other health warnings, create an advertisement campaign to inform consumers. An advertisement explaining TBT and where it's used will help society make informed choices. This advertisement could be brought about in conjunction with the educational awareness program headed by the Division of Environmental Health (Floyd, 2011).

Using our available resources to spread awareness by television, newspaper, and bulletin, the marine environment and humans stand a better chance at avoiding the harmful effects of TBT.

Conclusion

The Earth is being rapidly affected by man's industrial changes. Cook Inlet has always been a crucial ecosystem for many marine organisms and in recent centuries has become an important one for humans as well. Man's impact on the environment is a responsibility that should not be taken lightly; thus, precautions must be taken to protect and ensure its future. Being one of the busiest ports in Alaska, the use of TBT in Cook Inlet was widespread and impacted the area greatly. While TBT may have fit the needs of the world's economy well at the time, the chronic effects won't just kill multitudes of organisms, they could eventually be very detrimental to humanity. Now that research has been completed and technology developed, people need to be made aware that there are other options that are just as effective as TBT without the dire consequences. Through active prevention and remediation such as dredging, the use of paint alternatives, and educating communities, TBT can become one less issue facing the future of the oceans.

References

Allan. B. and J. Etzkon. (2006). A Global Problem for the Marine Enviroment.In *Marine Antifoulants: Tributyltin*. Pg. 6

Alaska Department of Environmental Conservation. (2013, May 05). In *Division of Water*. from http://dec.alaska.gov/water/Compliance/law.htm 11/23/13

Alaskans for Palmer Hay Flats. (2012). Fall 2012. Alaskans for Palmer Hay Flats Seasonal Newsletter. From http://www.palmerhayflats.org/newsletters/newsletter_autumn_2012.pdf

Alaska Youth for Environmental Action. (2011). In *2011 Annual Report*. Pgs. 1-4. from http://ayea.org/WordPress/wp-content/uploads/AYEA-Annual-Report-web.pdf

Alexander, A. (2013). Ernest f. Hollings Ocean AwarenessTtrust Fund 2013. In *National Marine Sanctuary Foundation*. from http://www.nmsfocean.org/our-grants.

Brabets, T., et al. (1999). Water Quality Assessment of the Cook Inlet Basin, Alaska. *USGS*. pp 6,9,10,13,14,15.

Bray, S., and W. Langston. (2006). Tributyltin pollution on a global scale. an overview of relevant and recent research: impacts and issues. In *Report to Dr. Simon Walmsley WWF UK*. Pgs. iii-iv, 1-4.

Bright & Ellis. (2002). Learn about Whelks & Relatives. In *Whelks & Relatives*. from http://www.asnailsodyssey.com/LEARNABOUT/WHELK/whelImpo.php. 11/10/13

Cape International. (2011).Cook Inlet Vessel Traffic Study. In *Report to the Cook Inlet Risk Assesment Advisory Panel*. Pgs. 4,6,12.

Challinor, S. (September 24, 2007). TBT- Treatment and Disposal. In *Central Dredging Asociation*. from http://www.dredging.org/documents/ceda/downloads/ceda-uk-2007-09-24-_challinor.pdf. 11/13/13

Clean Water Act, Sec. 404. Id. § 46.03.715(e) (2001)

Cook Inlet, the. (n.d.). In *Alaska Climate Research Center*, from http://climate.gi.alaska.edu/history/Cook.html. 11/9/13

Data Sheet on Pesticides. (n.d.). In *IPCS Inchem Home*. Retrieved November 9, 2013, from http://www.inchem.org/documents/pds/pds/pest65_e.htm. 11/9/13

Davoren, M., Folley, B., Giltrap, M, et. al. (2008). A model compound study: The ecotoxicological evaluation of five organic contaminants employing a battery of marine bioassays. In *Dublin Institute of Technology*. Pgs. 3-5

Dubilier, N. (n.d.). Mussel Adaptations and Symbiosis. In *FLEXE Forum*. from http://www.flexe.psu.edu/Ecology_Unit/FORUM2/FORUM.cfm. 11/25/13

Duxbury, A. B., A. C., Duxbury, and K. A., Sverdrup. 2006. Fundamentals of Oceanography. New York, NY: McGraw Hill.

Ecological Coatings, LLC. (2013). In *Marine coating*. from http://www.ecologicalcoatings.com/marine.html 11/13/13

Eley, D. (2012). Report to Cook Inlet Risk Advisory Panel. In *Cook Inlet*. from http://www.cookinletriskassessment.com/documents/120206CIVTSvFINAL.pdf. 11/01/13

Environment Protection Authority, (2001). *Guidelines for dredging*. Best practice Environmental Management (Publication 691 ISBN 0 7306 7578 5). Pgs. 10-23, 73.

Floyd, E. (2011). *Division of environmental health*. from http://dec.alaska.gov/eh/index.htm. 11/9/13

Green, John. Hydrex US. 604 Druid Rd E Clearwater, FL 33756, USA. jgreen@hydrex.us. 1 727 443 3900. October 2013

Haeussler, P., Bruhn, R., and Pratt, T. (2000). Potential seismic hazards and tectonics of the upper Cook Inlet basin, Alaska, based on analysis of pliocene and younger deformation. In *The Geological Society of America*, *Bulletin*.

Helvoigt, T., T. Schwoerer, and D. Charlton. 2010. Economic Analysis of the Chiutna Watershed and Cook Inlet. Cook Inletkeeper. Pgs. 1-4.

Heylen, A., (2011). Port of Antwerp. In *Dredging in the Port of Antwerp: challenges and best pratice.*. Environment Authority: Antwerp Port Manager.

Hydrex. (2011). In *Hydrex*. from http://www.hydrex.be/ecospeed_hull_coating_system. 11/9/13

Joling, D. (2012). Survey spots fewer Cook Inlet belugas. In *Alaska Journal of Commerce*, from http://www.alaskajournal.com/Alaska-Journal-of-Commerce/AJOC-January-15-2012/Survey-spots-fewer-Cook-Inlet-belugas/. 11/13/13

Central Peninsula Borough, (2013). Central peninsula landfill *(cpl)*. In *Solid Waste Department.* from www.borough.kenai.ak.us/swd-waste/swd-locations/158-swd-centrallandfill. 11/13/13

CDLI. (2004). Food Chains and Food Webs. http://dev.cdli.ca/sci2200-04/unit01/section01/lesson04/3-lesson-c.htm#top 11/13/13

Life, E., (2004). European Commission. In *TBT Clean project summary of results*. Port of Antwerp: TBT Clean. Pgs. 2-7

Lydecker, R. (2012, February). Is Copper Bottom Paint Sinking. In *Boat Us Magazine*. from http://www.boatus.com/magazine/2012/february/copper.asp. 11/12/13

Mergel, M. (2011). Tributylin. In *Toxpedia.* from http://toxipedia.org/display/toxipedia/Tributyltin 11/02/13

Moltzen, K. (2010). Toxic and Obesogenic effects of Tributyltin Oxide. *Environmental Awareness.*

Moran, W. (2012, April 12). Why you should paint your boat yourself. *Sail Magazine*, from http://www.sailmagazine.com/projects/paint-your-boat

Nature of Conservancy, the. (2003). In *Cook Inlet Basin Ecoregional Assessment*. Pgs. 12-18

Nucella lima. (n.d.). In *Encyclopedia of Life*., from http://eol.org/pages/397203/details 11/9/13

Pensaert, S., De Becker, G., De Clercq, B, et al. (2003). Development of an integrated approach for the removal of tributyltin (TBT) from waterways and harbors: Prevention, treatment and reuse of TBT contaminated sediments task 3550 treatment of. *LIFE02 ENV/B/000341*. Pgs. 1-35

Port of Antwerp.(2013). In *Meditteranean Shipping Company*. from http://www.mscbelgium.com/our_services/ports_info.html. 11/13/13

Johnston, P., W. Langston, and D. Santillo (2000). Tributyltin (TBT) antifoulants: a tale of ships, snails and imposex. In *European Environment Agency*, *22*(13), 135-143.

Salazar, M.H. and S.M. Salazar. 1996. Chapter 15. Mussels as bioindicators: effects of TBT on survival, bioaccumulation and growth under natural conditions. In: M. A. Champ and P. F. Seligman (Eds.), Organotin: Environmental Fate and Effects. Chapman & Hall. pp. 305-330.

Savarse, J., & Showalter, S. (2005). Restrictions on the use of marine anitfoulaning paints containing tributyltin and copper. *California Sea Grant Extension Program*. Pgs. 2-4

Strategic Location. (2013) In *Port of Antwerp*. from http://www.portofantwerp.com/en/strategic-location-and-connections 11/25/13

Tallmon, D. (2012). Tributyltin contamination and imposex in alaska harbors. *Springer Science Business Media*, (88), 245-249.

TBT Sealer. (n.d.). TBT Sealer Primer: Underwater Primer. *Interlux*. http://www.yachtpaint.com/MPYACMDatasheets/TBT_Sealer+eng-usa+A4+Y+20100608.pdf

Tributyltin . (1993). Informally published manuscript, Extension Toxicology Network, Cornell University, Ithaca, NY, In *E X T O X N E T*. from http://pmep.cce.cornell.edu/profiles/extoxnet/pyrethrins-ziram/tributyltin-ext.html

US Environmental Protection Agency [Web Graphic]. (2012, November 15). from http://www.epa.gov/osw/wycd/catbook/what.htm. 11/25/13

US Department of Fish and Game, (2007). Harvesting kelp and other aquatic plants in Southcentral Alaska. In *Southcentral Alaska Recreational Fishing Series*. Pgs. 1-3

Verte, A. (2013, August). Technology at work. In *Green Machine*, 45. from http://canadiansailings.ca/documents/Green_Marine/Aug_2013/files/assets/basic-html/page45.html 11/19/13

World Watch Institute. (Composer). In *Sources and Effects of Marine Pollutions* [Print Graphic]. from http://www.gdrc.org/oceans/marine-pollution.html. 11/25/13