University of Canterbury

The Hidden Environmental Impacts of Copper in the Christchurch Rebuild

Darlene Adrian, Alice Butler, Natsumi Imao, James Marwick, Sarah Pienisch
10/14/2015

Table of Contents

1 Executive Summary

1.1 Research Question

What adverse effects does runoff from copper cladding have on the Avon River in Christchurch, and how can these be mitigated?

1.2 Research context

The topic of stormwater contamination caused by copper cladding was brought to our attention by our community partner, Di Lucas from Peterborough Village. The Christchurch rebuild currently taking place incorporates copper into the designs of many buildings. She believes that research should be carried out to determine the effects copper-cladded buildings are having on the Avon River. The research group was asked to determine if the adverse effects outweigh the use of the fashionable material.

1.3 Aims and Objectives

- To determine the level of copper concentration present in the Avon River in Christchurch.
- To define adverse effects of copper cladding from runoff on the Avon River.
- To improve awareness and knowledge associated with the negative effect of copper cladding of architects working in Christchurch.
- To suggest mitigation solutions to reduce the amount of copper entering the Avon River.

1.4 Summary of Methods

1.4.1 Quantitative method

20 water samples were collected during two different rain events at two different sites, Knox Presbyterian Church and the Christchurch Courthouse. New and old copper claddings were included.

1.4.2 Qualitative method

An online survey was sent out to 222 architects in Christchurch to identify mitigation practices and raise awareness about this issue.

1.5 Key Findings

1.5.1 Water samples

High copper concentrations were found in the majority of samples at both sampling sites.

1.5.2 Surveys

It was found that there is little knowledge about the actual effects of the heavy metal on the environment. Furthermore, participants in the survey suggested mitigation solutions such as maintenance and restrictions to copper use.

1.6 Limitations

- Budget - limited number and types of samples collected and analysed, and limited survey questions.
- Time - short period (3 months), therefore only allowing two sampling events.
- Weather - sampling was dependent on rain events.
- Unknown cladding parameters on buildings

1.7 Future Research

- Inclusion of more samples for more representative data for the Avon River.
- Inclusion of dissolved copper water samples, as it is known to be more bioavailable.
- Inclusion of other heavy metals such as zinc and lead, as they are also contributors to toxicity in water.

2 Introduction

2.1 Purpose

This report investigates the negative impacts of copper cladding runoff on the Avon River and recommends ways to combat the issue. It discusses copper concentrations found in the Avon River and compares these to Australian and New Zealand Environment and Conservation Council (ANZECC) trigger values in order to establish and understand the adverse impacts on the aquatic ecosystem. Furthermore, Christchurch architects' knowledge about the issue and existing policies in Christchurch are evaluated to determine mitigation solutions.

2.2 Background

Copper has been embraced in the design of buildings for centuries. Its versatility, durability and aesthetic qualities make copper a highly valued material (West, 1982). The 2010/2011 Christchurch earthquake sequence damaged infrastructure located in the Central Business District (CBD) and in the city's suburbs. As a result, many buildings were deemed structurally unsafe and were subsequently demolished or rebuilt. This led to opportunities for developers and architects to implement alternative materials such as copper into the design of new buildings. Hence, its implementation has recently become a trend within the Christchurch rebuild. However, despite its popularity, copper is a heavy metal that can become bioavailable and harm aquatic ecosystems when it occurs in high concentrations (Sneddon & Treblay, 2011)

2.3 Scope

Research shows that many heavy metals can be toxic to ecosystems when present in high concentrations (Sneddon & Treblay, 2011). The aim of this study is to determine the effects of copper cladding runoff in the Avon River and obtain the copper concentrations therein, and following this provide mitigation solutions concluded from a survey with Christchurch architects.

3 Literary Review

3.1 Sources of copper

It is suggested that there are other sources that contribute copper into waterways including roads, carparks, air conditioning, brake linings and fertilisers (Arnold, 2005; Charters et al., 2014; O'Sullivan et al., 2012). Therefore the results of this research cannot conclude with certainty that the copper measured was solely due to copper cladding runoff.

3.2 Mobilization of copper

The dry periods between rainfall events exposes the copper to corrosion (Hedberg, et al. 2014). This means that the amount of corroded copper available to be transported by rainfall is determined by the time and intensity of environmental conditions acting upon it.

Copper (Cu) has an adverse effect on stormwater runoff due to the interaction of the cladding with the atmosphere (corrosion) resulting in the formation of patina layer, a thin green layer made of copper sulfate. Further patina products form due to exposure depends on the environment and pollutants that are present in air readily interact with the copper surface producing different copper constituents of different chemical composition (Leygraf & Wallinder, 2001). These can be broken into four main categories: copper oxides and sulfides, inorganic salts, organic copper salts and other components (Franey, Graedel & Nassau, 1987).

The time scales for corrosion rate that eventually lead to the formation of patina would vary substantially with geographic location (Franey, Graedel & Nassau, 1987). Leygraf and Wallinder (2001) emphasised that a full risk assessment of environmental adverse effects of copper needs to be taken into the consideration of chemical speciation along with surface characteristics, precipitation condition and pollutants present when determining the contribution of copper in runoff and eventually further in the river.

3.3 Sampling and Testing Copper

Water sampling techniques were investigated. This was important as results are heavily dependent on water samples as well as proper methodology. The literature review helped to determine the steps and precautions to take. The samples were collected during a storm flow event. However, it was taken into consideration that copper concentration levels will be higher than in a base-flow event, due to the behaviour of copper in conditions of lower turbidity (O'Sullivan et al., 2011). A report carried out by Mohuiddin et al. (2011) highlighted the importance of a successful collection process.

Michels et al. (2002) stated that it is essential to collect samples one hour after the rain has begun, in order to eliminate the first-flush. The first-flush gives abnormally high concentrations before decreasing to a constant rate (Michels et al., 2002). To avoid this, it was decided to collect samples at a steady state. This allowed for constant copper concentration at steady state condition from the time of precipitation (He, Wallinder & Leygraf, 2000). As a result of these sampling and testing methods from previous research, it was decided to explain the purpose of taking five water samples from each sampling site per event and to do so at least one hour after rainfall first commences.

3.4 Copper in freshwater ecosystems

Sneddon and Treblay (2011) outlined that excess copper concentrations in ecosystems can have adverse effects on aquatic organisms. The high copper concentration is toxic to some species causing a decline in their population (Sneddon & Treblay, 2011). This was an important finding because it gave the research a purpose. Previous research shows that high copper concentrations do in fact have adverse effects. However, as Arnold (2005) suggests, the concentration of copper in stormwater can decrease its bioavailability as it travels from source to waterway. Furthermore, the surface of which the water travels across changes the chemical composition of the water (Göbel et al., 2007). Because of these findings, observations were made at the sampling sites to understand the contact the stormwater has with different surfaces.

4 Methodology

4.1 Quantitative Sampling

20 water samples were collected from two sites, Knox Presbyterian Church and Christchurch Courthouse, representing different ages at two rain events.

4.1.1 Sampling sites

The sampling sites were chosen based on both recommendations by our community partner and professionals interested in the project and the characteristics of the cladding of the buildings such as age.

The chosen sampling sites in Christchurch included the Courthouse (CH) on Durham Street North constructed in 1989, and Knox Presbyterian Church (KPC) on Bealey Avenue, rebuilt in 2014 (Rice, 2014; Knox Church, 2014). Each sampling site included five sampling points; downspout (A), drainage point (B), in stream (C), upstream (D) and downstream (E). These were chosen to determine the mobilization of copper level concentration from the source to the Avon River due to their accessibility and proximity.

Figure 1. Sampling points at KPC

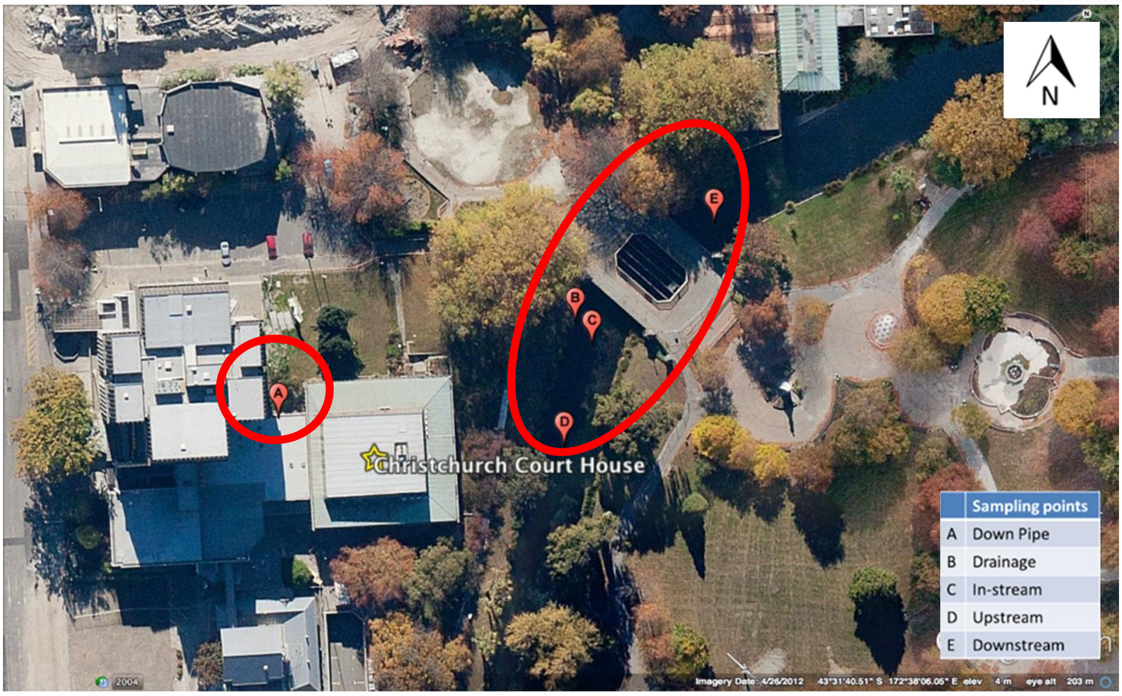


Figure 2. Sampling points at CH

4.1.2 Sampling Events

The sample collection occurred during two separate rain events which allowed for comparison of the copper concentration levels between light to moderate and heavy rain events. The sampling collection event dates were determined by constant inspection on local meteorological websites; *www.metservice.com* and *www.accuweather.com.* Sampling occurred on August 15, 2015 and September 1, 2015, where samples were collected for Total Metals (TM) from the mentioned sampling points. TM collection was chosen as an initial investigation of water samples which accounts for the dissolved form of heavy metals and particulates present. The two separate events allowed for sample repetition resulting in a good estimate of accuracy and unbiased results. Secondary data was used to compare analysed values (Rice, 2003).

4.1.3 Sampling Preparation

For TM collection a total of 20 plastic containers with an approximate volume of 75ml per bottle were prepared with 2-3 drops of 70% concentrated Nitric Acid (HNO_3). This gave a pH value <2 to dissolve the metals, prevent metals sticking to the sides of the container and to preserve the water samples (He, Wallinder & Leygraf, 2000). The samples were labelled to be identifiable in the field and translated into approved chemistry codes for analysis in the Chemistry lab (Appendix 1).

4.1.4 Sample collection

Samples were collected to determine copper concentration levels; from point A to E. Different empty containers were used to collect the samples. The samples were then transferred to the acidified containers, filled to the brim of the container to avoid interaction with air that would produce air bubbles in the sample which could lead to the samples being impure and therefore not true representations of the concentration present.

The group was provided with waders for instream sampling collection from B to E and equipped with Nitrile gloves for protection as well as minimising any contaminants that may contribute to the samples. Instream samples were collected in the main flow of the river at 15cm depth to avoid organic matter, eddies or rubbish that could contaminate the samples. After each sample collection, samples were kept chilled until the environmental laboratory was available to prepare for analysis.

4.1.5 Analytical Preparation

The samples were brought to the laboratory and prepared for chemical analysis. The process involved the samples to be acid digested in a heating block and analysed through induced coupled plasma mass spectrometry (ICP-MS). Precise 25ml of samples using an Eppendorf pipette were transferred into a 50ml centrifuge tube and 5ml of 70% concentrated HNO_3 acid was added. Tubes were then placed in a heating block at 120°C for one hour. After the samples cooled down, approximately 8-10ml of the sample were filtered through a 25ml syringe with a 0.45µm pore size filter and transferred into labelled ICP-MS tubes. The samples were prepared for analysis through ICP-MS, measured in the Chemistry Department. Each event contained 12 samples to be analysed which included a blank and a duplicate for quality control purposes.

4.2 Qualitative Sampling

4.2.1 Participants

Christchurch architects were chosen as the target population after the following three assumptions were made:

- Architects make design decisions on a project
- Architects ensure that aesthetic aspects are met
- Only Christchurch architects are involved in the Christchurch rebuild

During the site location process, it was realised that the architects of Knox Presbyterian Church in Christchurch, from Wilkie and Bruce Architects, won a prize for their work on the church. Thus, the importance of raising awareness and understanding architects' knowledge about the environmental impacts of copper was recognized.

4.2.2 Materials

The survey was created on the online platform *www.surveymonkey.com*. The survey comprises an information sheet, eight closed-questions, one open-ended question and one comment segment (Appendix 2). Every question was set to require an answer to avoid skipping questions by the participants. Moreover, an optional comment box was included for the first nine questions of the survey to allow for additional notes.

4.2.3 Procedures

The survey was distributed to 222 identified personal email addresses of Christchurch architects. 49 architects participated in the survey within the given timeframe September 1, 2015 midday until September 18, 2015 midnight, giving a response rate of 22.1%.

5 Results and Discussions for water samples

5.1 Tracing copper from roof to stream

Concentrations of total copper on two different rain events are summarised in Table 1. For four samples, in stream and upstream samples from both KPC and CH on September 1, 2015, copper concentrations were under the detection limit of 5µg/l. However, the remaining samples were all above the 'save' value (Figure 3). Through dilution with rainwater and stream water, copper concentrations in stormwater decreased significantly from downspout to in stream water (Appendix 3 and Appendix 4). In addition, the amount of copper present in the runoff can also be reduced by contacting sediment, as heavy metals tend to bind to concrete and soil (Arnold, 2005). An unusual trend was observed in samples taken on September 1, 2015, namely, higher copper concentrations were found in downstream samples than those of in stream samples (Appendix 3 and Appendix 4). These unexpected results suggest a presence of other copper sources running into the Avon River.

Table 1. Concentrations (in micrograms per litre) of total Cu in water samples. 4 out of 20 samples are below the level of detection (BDL) of 5µg/l. (Relative percent difference = 6.47% between duplicates, 12.47% between two different rain events)

Location	**Sampling point**	**Cu concentration (µg/l)**	
		15/08/2015	**01/09/2015**
KPC	Downspout	88.80	109.73
	Drainage point	11.18	35.44
	In Stream	8.80	BDL
	Downstream	8.16	9.00
	Upstream	12.44	BDL
CH	Downspout	105.95	86.82
	Drainage point	30.18	69.99
	In Stream	7.72	BDL
	Downstream	6.14	18.85
	Upstream	6.45	BDL

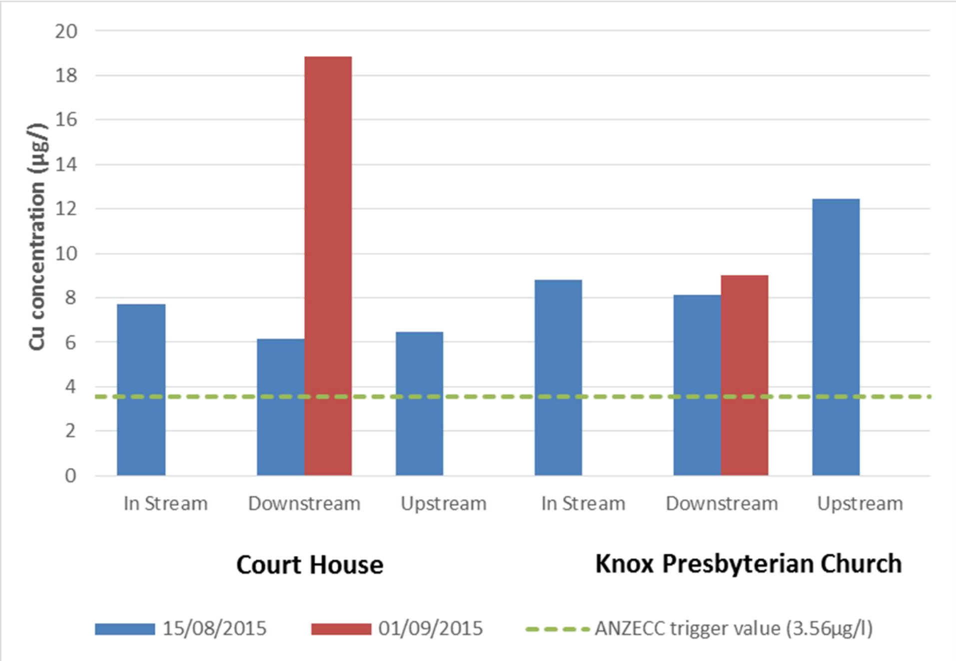


Figure 3. Copper concentrations in the Avon River compared to the ANZECC trigger (save) value.

5.2 Difference in weather (precipitation) events

Overall, copper concentrations of samples taken on September 1, 2015 (light rain) are higher than those taken on August 15, 2015 (heavy rain) (Appendix 5). This could have resulted from the slow flow of rainwater, allowing water to interact with copper roof surface for longer time, which in turn possibly caused increased copper corrosion. Furthermore, less dilution of copper with rainwater should be expected since the total amount of rainfall is significantly lower (Appendix 5). Assuming that stream water mixing is not as fast as it is during heavy rain, some copper might have been attached to the sediment. This could support the low copper concentration levels found in upstream and downstream samples (Table 1).

5.3 Age of copper roof

According to Leygraf and Wallinder (2001), aged copper surfaces would develop defects and cracks, where pollutants react with copper surface which tends to be concentrated in between the cracks contributing to high copper concentration in runoff which is inevitable in the river. An increase of copper corrosion with the age of roofing caused by the degradation of the copper surface was observed during the research. CH samples generally had greater copper concentration than KPC.

However, the opposite was observed in Auckland by Pennington and Webster-Brown (2008), where buildings with newer copper cladding had higher concentration compared to older copper cladded buildings (Appendix 6). Significantly high copper concentrations (Appendix 6) observed in Auckland could be the future image of Christchurch city, considering that Auckland is the largest city in New Zealand and Christchurch is still at the starting point of the rebuild.

5.4 The effects of corrosion rate and patina formation

Copper surfaces exposed to atmosphere, humidity and environment will undergo corrosion. The corrosion rate is determined by environmental factors such as surface characteristics of copper including age, thickness and inclination precipitation events versus dry periods, pollutants present in air and urban environment including other sources of copper, precipitation pH and intensity (Leygraf & Wallinder, 2001). These factors affect the rate of runoff which could potentially lead to increased impact of copper concentration in the river.

The patina layer visually changes from metallic; dull brownish to black and finally to green blue tinge. With the appearance of patina formation comes the chemical speciation of copper. Initial products formed by the patina are commonly found as cuprite and then as a non-crystalline water soluble cupric sulfate in the early stages of copper surface development (He, Wallinder & Leygraf, 2000). The water soluble cupric sulfate, is the most toxic form of copper and would further increase with organics, inorganics and be made bioavailable in aquatic life (Legraf & Wallinder, 2001).

5.5 Other sources of copper

Other sources of copper including brake linings and fertilisers could explain the unusual high concentrations of copper observed in upstream samples (Table 1). Between KPC and CH, there are several possible copper containing sites, such as Hagley Park, Christchurch Botanic Gardens, severely damaged Christchurch Cathedral with copper roofing, and busy traffic roads that could add to the copper content in the Avon River. This could also explain the sudden increase of copper found in Mona Vale by Interim Global Stormwater Consent (IGSC) (Figure 4), as it also has a garden along the river. Schools, commercial buildings, museums, hospitals, hotels and other buildings could also introduce copper if they use air conditioning with copper pipes. Considering the fact that Christchurch CBD area will be more populated and trafficked as the rebuild activities progress, concentration of copper in

Avon River could increase through these factors. O’Sullivan et al. (2012) further suggested that a continuous input of copper from other sources would have an impact in the long run unless maintain.

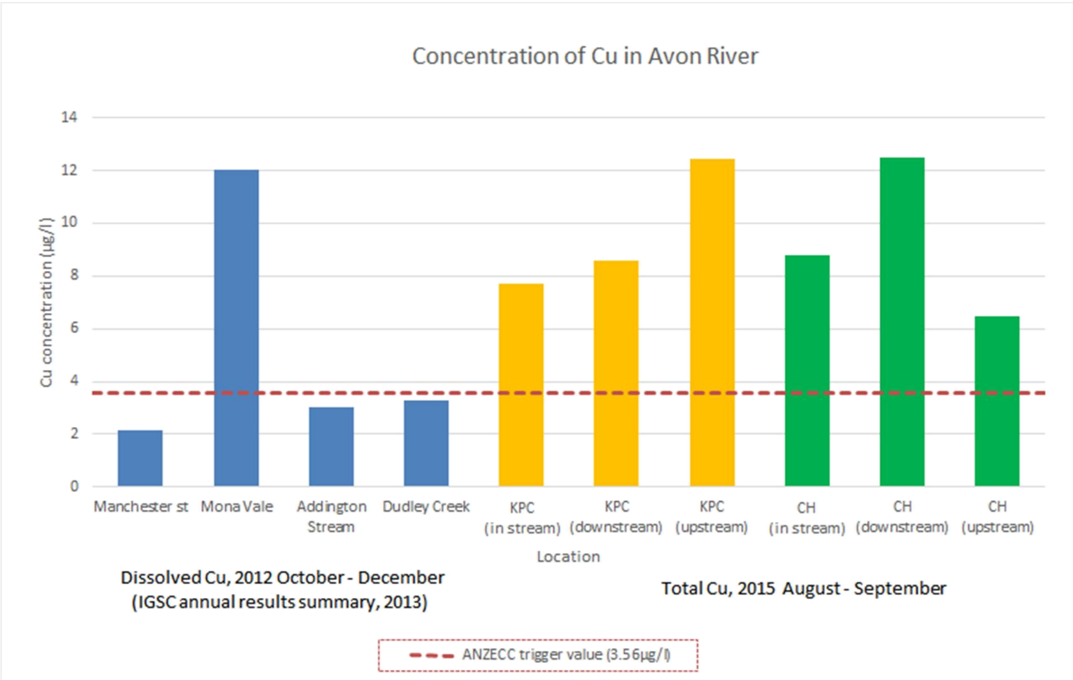


Figure 4. Comparison of copper concentration from a previous study with this study including the ANZECC trigger vale.

5.6 Ecotoxicology

The ANZECC guidelines are a tool used to determine the sustainability of waterways (ANZECC, 2000). In this case, the guidelines are used to understand consequences of excess copper on the ecosystem in the Avon River. In 2006, an ANZECC trigger value of 1.4µg/l was used as the Avon River was categorised as a slightly to moderately disturbed system. This trigger value means 95% of species are expected to be protected at 1.4 micrograms of copper per litre.

In a 2013 investigation of the water quality of the Avon River, a trigger value of 1.8µg/l. meaning 90% of species are expected to be protected at this concentration. The reasoning for the change is in accordance with the 2011 Environment Canterbury (ECAN) Natural resource regional plan (NRRP) guidelines for ANZECC trigger values for spring-fed rivers (ECAN, 2011) (Appendix 7).

All observed values in water samples exceed the 90% ANZECC trigger value of 1.8µg/l (Figure 3). Therefore, as directed in ANZECC a 90% hardness modified trigger value (HMTV) of 3.56µg/l was employed for further investigation (Figure 4). This is the value modified based on the concentration of $CaCO_3$ present in Avon River, which indicates more site specific potential risk (ANZECC,2000). As most samples exceed the 90% HMTV of 3.56µg/l, this suggests that 10% of aquatic life present in Avon River could negatively affected by high concentration of copper.

One of the project aims was to determine the adverse effects copper has when it enters the Avon River. Copper is an essential element to the survival to most organisms when it is bioavailable in low concentrations (USEPA, 2007). However, it becomes toxic to species when the concentration of copper in the water is too high. If copper is able to be transferred from the water to biochemical receptors in or on an organism, it becomes bioavailable. The ability of copper to become bioavailable varies between species (USEPA, 2007).

The industrialisation of Christchurch has changed the ecology of the Avon River in the city centre (CCDU, 2013). The decline in water quality is proven by the disappearance of clean water invertebrate taxa in the Avon River which only thrive in good quality water (CCDU, 2013). High copper concentrations in water can harm species living there in a number of ways. Sneddon and Tremblay (2011) discussed that different aquatic species react and are affected differently by the contamination. For instance, larger organisms are more robust and able to regulate and therefore control excess metal concentration amount within their body, while smaller organism are more vulnerable and sensitive to contamination (Michels, Boulanger & Nikolandis, 2002).

Sneddon and Tremblay (2011) added that, if the environmental levels of copper exceed an organism requirement, the metals begin to interfere and compete for enzyme or membrane protein sites resulting increasing in toxicity. Once the copper disrupts the metabolism, it reduces growth rate; causes weight loss; sensory responses dysfunction and they become more prone to disease. A study in the U.S. found that when rainbow trout fry are exposed to 14µg of copper per litre, there was a 50% mortality rate within 14 days shown in Figure 4 (Marr et. al., 1998)

As shown in Figure 5, 14µg of copper per litre can kill 50% of rainbow trout fry within 14 days. Trout Spawn in the Avon River and are therefore exposed to the copper entering the river from the stormwater systems. This study is therefore applicable to the survival of young trout in the Avon River by indicating a copper concentration threshold for trout fry. When compared to the water sample results of this study, some in stream copper concentrations from water samples were above the value of 14µg/l. Therefore, the Avon River may potentially cause a higher rate of mortality for trout fry due to the high levels of copper concentrations entering the water from stormwater runoff.

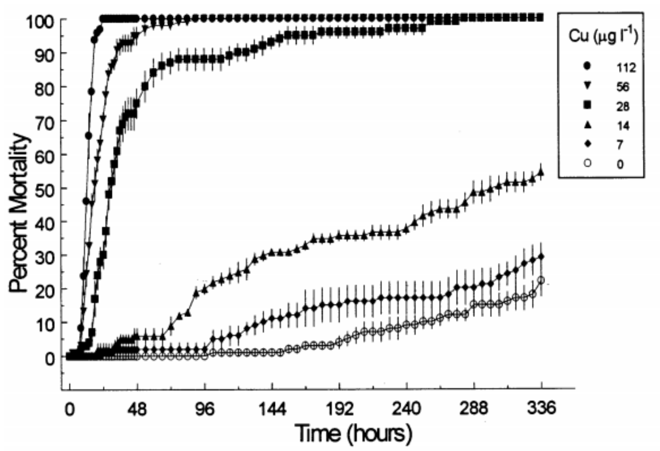


Figure 5. Shows after 14 days, 50% of rainbow trout fry have deceased when exposed to 14µg copper per litre (Marr et. al., 1998).

6 Results and Discussion for Surveys

6.1 Results

The survey was conducted to answer the subsequent part of the research question, namely, to identify mitigation solutions about the environmental impacts of runoff from copper cladding on the Avon River and as a part of it improve awareness and knowledge associated with the negative effect of copper cladding of architects working in Christchurch.

The first question in the survey was asked to understand architects' knowledge about the effect of copper cladding runoff on the environment. Results show an almost 50/50 distribution between yes and no/I don't know (Appendix 8). The fact that almost 50 % of the respondents were unaware consequently raised awareness of the issue. When architects were asked whether the heavy metal degrades over time, it became apparent that many architects know about the degradation of copper over time but they do not know about the increasing adverse effects the aging of copper causes to the environment (Appendix 9). 10 out of 49 participants stated that copper degrades very slowly over time; nevertheless, they use the heavy metal as it is the best choice with regards to building maintenance, environmental and economic sustainability.

The majority of participants agreed to substitute copper for other alternatives. However, they suggested predominantly lead and zinc which are heavy metals known to be just as harmful to the ecosystems as copper (Appendix 10). Such heavy metals are also known to be toxic to aquatic organisms, adversely affecting their fertility, growth, respiration, physical structure and behaviour when evident in high concentrations (Margetts & Marshall, 2014). Many architects claimed to include environmental effects when making design decisions, nonetheless, most participants would also use more copper if it was less expensive (Appendix 11). This shows that architects rather respond to market prices than including environmental factors in their design decisions.

6.2 Discussion

6.2.1 Mitigation solutions

The above results were helpful to understand architects' knowledge and awareness about the issue. It underlines the need of identifying mitigation solutions that address all professionals involved in a project. Therefore three different mitigation approaches are suggested.

6.2.1.1 Direct Mitigation approach

Incorporating current methods of stormwater management need to be implemented in order to prevent copper concentrations from entering the water. The majority of survey respondents claimed both that they include long-term environmental effects in their design choices and that they would use more copper if it was less expensive. Therefore, to protect the Avon River ecosystem in the long-term given the evidence of excessive amounts of copper already entering the Avon River (Figure 3) and how the participants responded to the survey, a direct approach to reducing copper entering the Avon River should be implemented.

A small minority of respondents raised issues regarding their support for protecting New Zealand waterways and ecosystems, and moving towards more sustainable options. The research conducted by Charters et al. (2014) provides a diverse range of mitigation options that aim to directly prevent stormwater contaminants such as copper entering neighbouring streams. Solutions provided by Charters et al. (2014) that should be applied to reducing runoff from copper cladding include *inter alia* rain gardens, roof maintenance, and wet ponds (Appendix 12 – Appendix 14).

The Christchurch City Council (CCC) plans to spend approximately $51,000 on stormwater system management in 2015, with the money going towards replacements, improvements and meeting growing demand of stormwater management (CCC, 2015). Plans are underway to filter stormwater through rain gardens to prevent direct discharge into the stormwater system (CCDU, 2013). This will mitigate the adverse effects of excess copper in stormwater which causes environmental degradation and reduces water quality (CCC, 2015). This funding has been planned to continue through to 2025 (CCC, 2015).

6.2.1.2 Restriction to copper use

In 2014, the CCC introduced a bylaw for Water Supply, Wastewater and Stormwater. Sections of this bylaw are targeted at treating receiving waters to meet the US Environmental Protection Agency (USEPA) water quality standards for copper (CCC, 2014). The bylaw requires polluted stormwater discharge to run into a separate part of the stormwater system (CCC, 2014). This is to improve the water quality of the Avon River in the central city. Additionally, water quality monitoring within Christchurch takes place monthly at 40 sites involving identifying dissolved copper concentration in the water (CCC, 2015).

Christchurch plans to establish stormwater treatments so that receiving waters in urban areas at least meet USEPA water quality standards for copper (CCC, 2009). The Biotic Ligand Model (BLM), used by USEPA, gives "guidance on the concentrations of copper that will be protective of aquatic life" (USEPA, 2009, pg.1). Despite the fact that such bylaws are in place, water samples showed high copper concentrations in the Avon River. This urges for policies restricting the use of copper cladding in Christchurch to avoid further rises in concentration.

The contradiction between inclusion of environmental effects and copper pricing underlines that many architects are driven by market prices as well as product quality rather than environmental awareness (Appendix 11). Although, prices of copper are a natural restriction to the use of the heavy metal this does not stop architects from using it as they are also bound to their clients' wishes and project specification. Maintenance, cost and longevity characteristics are sought to be optimised in design for their clients. Therefore, a policy restricting copper use is seen as more effective than only focussing on direct prevent methods.

Limiting the use of copper through enforcing restrictions on its use is not a favoured action by architects (Appendix 15). The low proportion of the survey population in support of restrictions is a clear indicator that copper is a building material of high value to architects and their businesses. The high value it has amongst architects is also reflected in the support of maintenance options of copper (Appendix 16). This shows that a higher proportion of architects would be in favour of simply introducing maintenance requirements rather than restricting its use. It was found that most participants do not agree to the introduction of restriction to the use of copper unless further proof of the issue was provided. However, the quality of the environment should be regarded more important than architects' wishes and needs.

6.2.1.3 Education Mitigation approach

The need for more education surrounding the effects and chemical reaction of heavy metals in general with the environment is emphasised in Appendix 8 and 9. Participants refer to the benefits of the aging process of copper cladding including good appearance, the impression of quality and durability. However, they do not understand the process itself as well as the increasing concentration the patina layer can add to receiving waters. Furthermore it is apparent that only 55% of the participants are aware that copper cladding runoff can have adverse effects on the environment.

This is the reason for the third mitigation approach. Ideally the New Zealand tertiary education system will be targeted with the ultimate goal of educating and raising awareness among students completing their tertiary studies in the field of architecture. The main education institutions that provide tertiary qualifications within architecture in New Zealand are CPIT (Christchurch), Victoria University (Wellington) and in Auckland, the University of Auckland and Unitec. It is suggested that the tertiary providers listed introduce compulsory courses which target the environmental impacts and chemical reactions of materials used in architecture. As all of these tertiary institutions curriculums do not offer courses relating to this area (Appendix 17 – Appendix 20). This is out of the scope of this study but has the potential to be implemented in the long-run with further research in this area.

7 Conclusion

The objective of this report was to determine copper concentration levels in the Avon River and generate an understanding of the impacts of runoff from copper cladding into the Avon River in Christchurch. Furthermore, we aimed to provide forms of mitigation by improving Christchurch awareness and knowledge about the issue that could potentially reduce the amount of copper entering the Avon River.

The quantitative data collected through the water samples confirmed that the copper concentration present in the Avon River was above the safe level for aquatic ecosystem as determined by the ANZECC. Further investigation into preventing copper entering the Avon River was therefore necessary. Due to copper having been implemented into many new buildings in Christchurch's CBD, an online survey was designed that targeted architects as their opinion was regarded as the most important when it came to building design. The survey provided a qualitative approach to collecting data that was used to raise awareness amongst architects of the adverse environmental effects of copper. It also had the purpose of providing a better understanding into how much architect's valued copper and thereafter options for mitigation were suggested.

Overall, as high copper concentrations were found and the first step of raising awareness among professional architects in Christchurch has been accomplished, this research suggests an implementation of all three suggested mitigation solutions together in order to achieve a positive outcome for the aquatic ecosystem in the Avon River.

The opportunity for future research in this area is important if the aquatic life of the Avon River is to survive. This research could include the extension of data points collected to encapsulate more of the site, or conducting research on metals such as lead or zinc, which were also present in high concentrations in this study.

8 Acknowledgements

This research was supported by Di Lucas and Dr Kelly Dombroski. We thank you, Di and Kelly, for your continuous support, your insight and expertise that greatly assisted the research.

We thank Justin Harrison for his assistance with equipment, Frances Charters for her guidance and help with sample preparation, Peter McGuigan for making the lab available for us, and Dr Sally Gaw for helping us with the water sample analysis and sample numbers.

We would also like to show our gratitude to Shelley McMurtrie, Robert Watts, Belinda Margetts and Professor Jenny Webster-Brown for sharing their pearls of wisdom with us during the course of this research.

9 References

Arnold, R. (2005). Estimations of Copper Roof Runoff Rates in the United States. *Integrated Environmental Assessment and Management*, *1* (4), 333-342.

Australian and New Zealand Environment and Conservation Council – ANZECC. (2000) *Australian and New Zealand guidelines for fresh and marine water quality*.

Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, 1-103.

Charters, F. J., Cochrane, T., & O'Sullivan, D. A. (2014). Modelling storm water management options in established urban areas. Retrieved August 25, 2015 from http://ir.canterbury.ac.nz/bitstream/10092/9913/1/12649785_F.%20Charters.pdf

Christchurch Central Development Unit – CCDU. (19 November 2013) *The ecology of Te Papa Ōtākaro/Avon River Precinct* [video file]. Retrieved September 15, 2015, from https://www.youtube.com/watch?v=dqM_QBb704g

Christchurch City Council – CCC. (2009) *Surface Water Strategy 2009 - 2039*.Retrieved September 23, 2015, from: http://www.ccc.govt.nz/assets/Documents/The-Council/Plans-Strategies-Policies-Bylaws/Strategies/SurfaceWaterStrategy2009.pdf

Christchurch City Council – CCC. (2014) *Water Supply, Wastewater and Stormwater Bylaw - Part 31: Design and other requirements*. Christchurch City Council, Christchurch. Retrieved from: http://www.ccc.govt.nz/assets/Documents/The-Council/Plans-Strategies-Policies-Bylaws/Bylaws/ChristchurchCityCouncilWatersupplyWastewaterandStormwaterBylaw2014.pdf. Accessed: 23/9/2015

Christchurch City Council – CCC. (2015). *Long Term Plan 2015 – 25*. Retrieved September, 23, 2015 from: http://www.ccc.govt.nz/the-council/plans-strategies-policies-and-bylaws/plans/long-term-plan/long-term-plan-2015-25/

Christchurch City Council – CCC. (2015). *Monitoring.* Retrieved September 23, 2015, from: http://www.ccc.govt.nz/environment/water/waterways/monitoring/

Environment Canterbury – ECAN. (2007). *Avon and Heathcote Rivers: Analysis of water quality data from 1992-2006.* Retrieved September 23, 2015, from: http://www.cleanwaterways.org.nz/pdf/AvonOtakaroandHeathcoteOpawahoRiversanalysisofwaterqualitydatafrom19922006.pdf

Environment Canterbury – ECAN. (2011). *Canterbury Natural Resource Regional Plan (NRRP).* Retrieved September 23, 2015, from: http://ecan.govt.nz/our-responsibilities/regional-plans/nrrp/Pages/read-plan.aspx

Franey, J. P., Graedel, T. E. & Nassau, K. (1987). Copper Patinas Formed in the Atmosphere - I. Introduction. *Corrosion Science, 27* (7), pp. 639 - 657.

Göbel, P., Dierkes, C. & Coldewey, W. G. (2007). Storm water runoff concentration matrix for urban areas. *Journal of Contaminant Hydrology, 91*, 26-42.

He, W. (2002). *Atmospheric Corrosion and Runoff Processes on Copper and Zinc as Roofing Materials*. Royal Institute of Technology. Stockholm, Sweden. Retrieved September 24, 2015 from: http://www.diva-portal.org/smash/get/diva2:9230/FULLTEXT01.pdf

He, W., Wallinder, O, I. & Leygraf, C. (2000*).* A laboratory study of copper and zinc runoff during first flush and steady-state conditions. *Corrosion Science, 43* (2001)*,* 127-146.

Hedberg, Y. S., Hedberg, J. F., Herting, G., Goidanich, S., & Odnevall Wallinder, I. (2014). Critical review: copper runoff from outdoor copper surfaces at atmospheric conditions. *Environmental science & technology, 48* (3), 1372-1381.

Knox Presbyterian Church (2014). *Rebuild Information.* Retrieved October, 12. 2015, from: http://www.knoxchurch.co.nz/rebuild.html

Leygraf, C. & Wallinder, I, O. (2001). Seasonal variations in corrosion rate and runoff rate of copper roofs in an urban and a rural atmospheric environment. *Corrosion Science, 43* (2001), 2379 - 2396.

Marr, J. C. A., Hansen, J. A., Meyer, J. S., Cacela, D., Podrabsky, T., Lipton, J., & Bergman, H. L. (1998). Toxicity of cobalt and copper to rainbow trout: application of a mechanistic model for predicting survival. *Aquatic toxicology, 43* (4), 225-238.

Michels, H. T., Boulanger, B., & Nikolaidis, N. P. (2002, January). Copper Roof Storm Water Runoff: Corrosion and the Environment. In *CORROSION 2002*. NACE International.

Mohiuddin, K. M., Ogawa, Y., Zakir, H. M., Otomo, K., & Shikazono, N. (2011). Heavy metals contamination in water and sediments of an urban river in a developing country. *International Journal of Environmental Science & Technology, 8* (4), 723-736.

O'Sullivan, A., Wicked, D., & Cochrane, T. (2012). Heavy metal contamination in an urban stream fed by contaminated air-conditioning and stormwater discharges. *Environmental Science and Pollution Research, 19* (3), 903-911.

Reuther, W. (1957). Copper and soil fertility. *Soil—US Dep. Agriculture Yearbook*, 128-135

Rice, G. (2014). Victoria square: *Cradle of Christchurch*. Christchurch, New Zealand: Canterbury University Press.

Rice, S. (2003). Chapter 15: Sampling in Geography. In Clifford, N. J., & Valentine, G., *Key methods in geography* (pp. 223 – 248). Thousand Oaks, Calif; London;: SAGE.

Sneddon, R., & Trembly, L. (2011). *The New Zealand King Salmon Company Limited: Assessment of Environmental Effects – Copper and Zinc.* Prepared for The New Zealand King Salmon Company Ltd. Cawthron Report No. 1984. 53p.

Syed, S. (2006). Atmospheric Corrosion of Materials. *Emirates Journal for Engineering Research, 11* (1), 1-24.

United States Environmental Protection Agency - USEPA. (2007). *Aquatic Life Ambient Freshwater Quality Criteria - Copper.* Washington, D.C.: U.S. Environmental Protection Agency, Office of Water.

United States Environmental Protection Agency - USEPA. (2009). *National recommended water quality criteria*. Washington, D.C.: U.S. Environmental Protection Agency, Office of Water.

West, E. G. (1982). *Copper and its alloys*. Chichester: E. Horwood.

10 Appendices

Appendix 1

Table 2. Table presents Chemical labelling code for sample collection and analysis.

		EVENT 1		EVENT 2	
NOTES:		Heavy Rain (Continuous), fast flow rate & high volume of water in the river		Drizzle (light rain; irregular interval), low flow rate & low volume of water in the river	
		Date: 15/08/2015	**Time: 12.00pm**	**Date: 1/09/2015**	**Time: 1.00pm**
Location	**Sampling site**	**Sampling Container**	**ICP-MS tubes**	**Sampling Container**	**ICP-MS tubes**
Knox Presbyterian Church	Downpipe	KPTM1	AB1	KPTM2	AB1
	Discharge point	KDTM1	AB2	KDTM2	AB2
	In Stream	KITM1	AB3	KITM2	AB3
	Downstream	KSTM1	AB4	KSTM2	AB4
	Upstream	KUTM1	AB5	KUTM2	AB5
Courthouse	Downpipe	TPTM1	AB6	TPTM2	AB6
	Discharge point	TDTM1	AB7	TDTM2	AB7
	In Stream	TITM1	AB8	TITM2	AB8
	Downstream	TSTM1	AB9	TSTM2	AB9
	Upstream	TUTM1	AB10	TUTM2	AB10
Blank	Distilled water		AB11		AB11
Duplicate			AB10D1		AB5D1

KEY

Knox Street	K	Downpipe	P	Total Metal	TM	Sampling event	1
Town Courthouse	T	Discharge point	D				2
		In Stream	I				
		Downstream	S				
		Upstream	U				

Appendix 2

Use of Copper in the Christchurch rebuild

Welcome

31/08/15
University of Canterbury, Christchurch, New Zealand

You are invited to participate in the research project:
The effect of copper cladding on Christchurch's receiving waters

The aim of this project is to investigate the extent of adverse effects of copper cladding on receiving waters. We are interested in any changes in copper concentrations in waters due to newly added copper cladding in the Christchurch rebuild. Additionally we would like to find out why copper is used in the rebuild and whether professionals would be willing to change towards a more environmental friendly alternative. We are a group of five 300 level students working in conjunction with Di Lucas who has raised the concern that additional copper cladding might raise copper concentrations in receiving waters.

Your involvement in this project is voluntary. We would be grateful if you could complete a questionnaire, which will about 2-5 minutes.

The results of the project will be aggregated for our final report, but you may be assured of the complete confidentiality of data gathered: the identity of participants will not be made public.

This student project is being carried out as part of the undergraduate degree in Geography. The work is supervised by Dr. Kelly Dombroski who can be contacted on Kelly.dombroski@canterbury.ac.nz or by phone at +64 3 364 2987 ext. 7936. Dr. Kelly Dombroski would be pleased to discuss any concerns you may have about participation in the project. For general questions contact Sarah Pienisch on spi40@uclive.ac.nz , one of the five students conducting the research.

The project has been reviewed and approved by the Department of Geography at the University of Canterbury.

Thank you.

Figure 6. Survey template which was created on www.surveymonkey.com (Pg. 1).

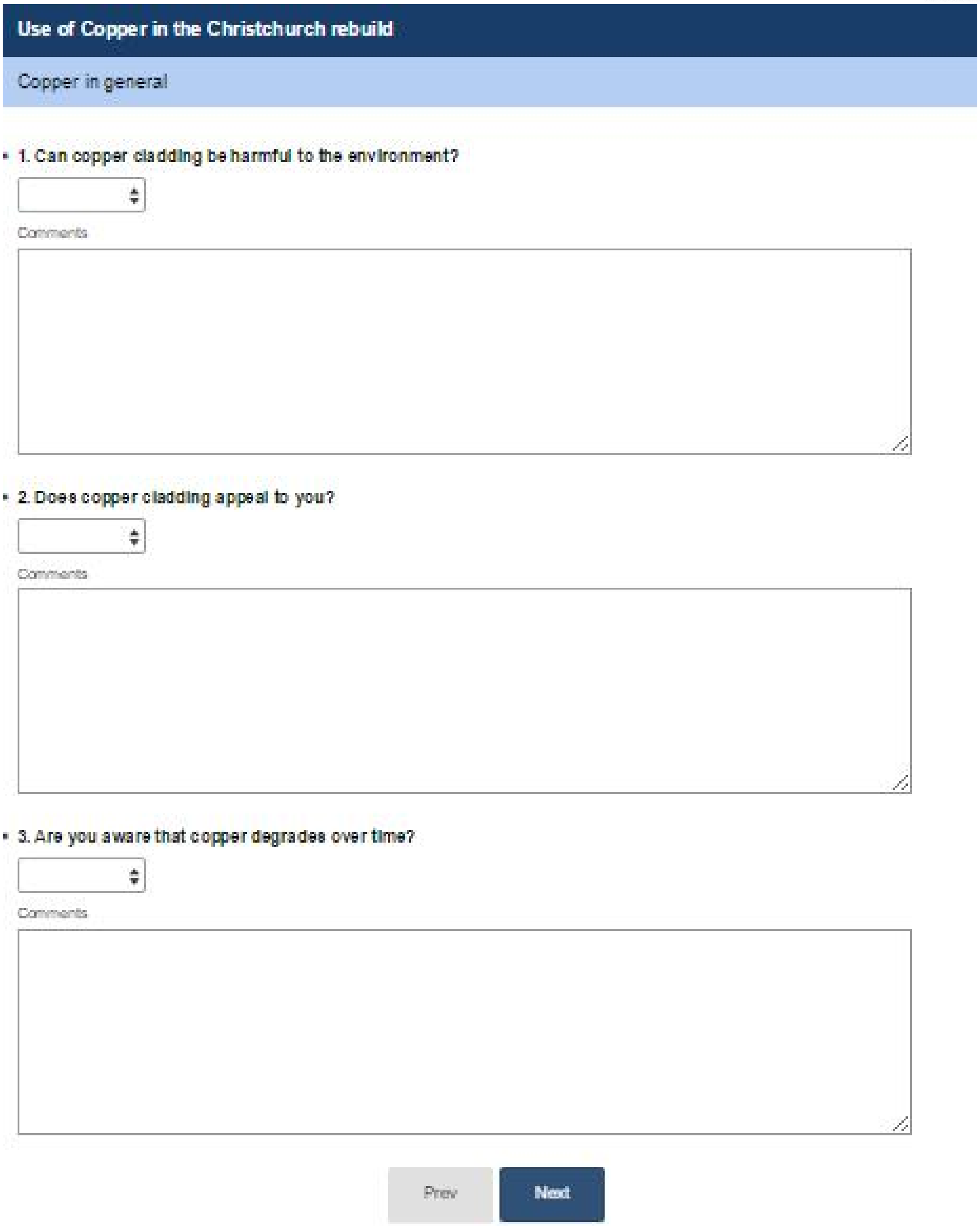
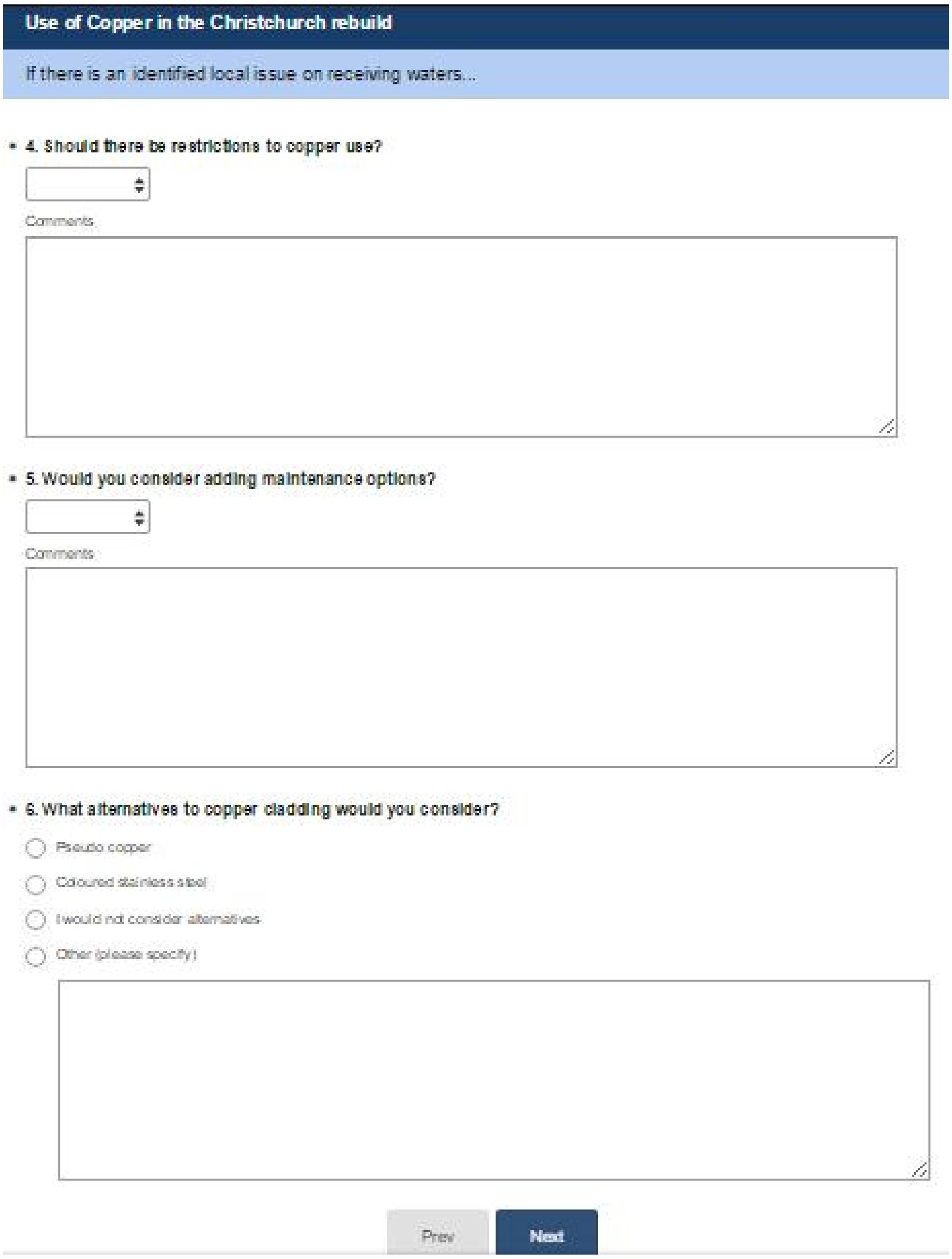


Figure 7. Survey template which was created on www.surveymonkey.com (Pg. 2).



Use of Copper in the Christchurch rebuild

If there is an identified local issue on receiving waters...

* 4. Should there be restrictions to copper use?

Comments

* 5. Would you consider adding maintenance options?

Comments

* 6. What alternatives to copper cladding would you consider?

- Pseudo copper
- Coloured stainless steel
- I would not consider alternatives
- Other (please specify)

Prev Next

Figure 8. Survey template which was created on www.surveymonkey.com (Pg. 3).

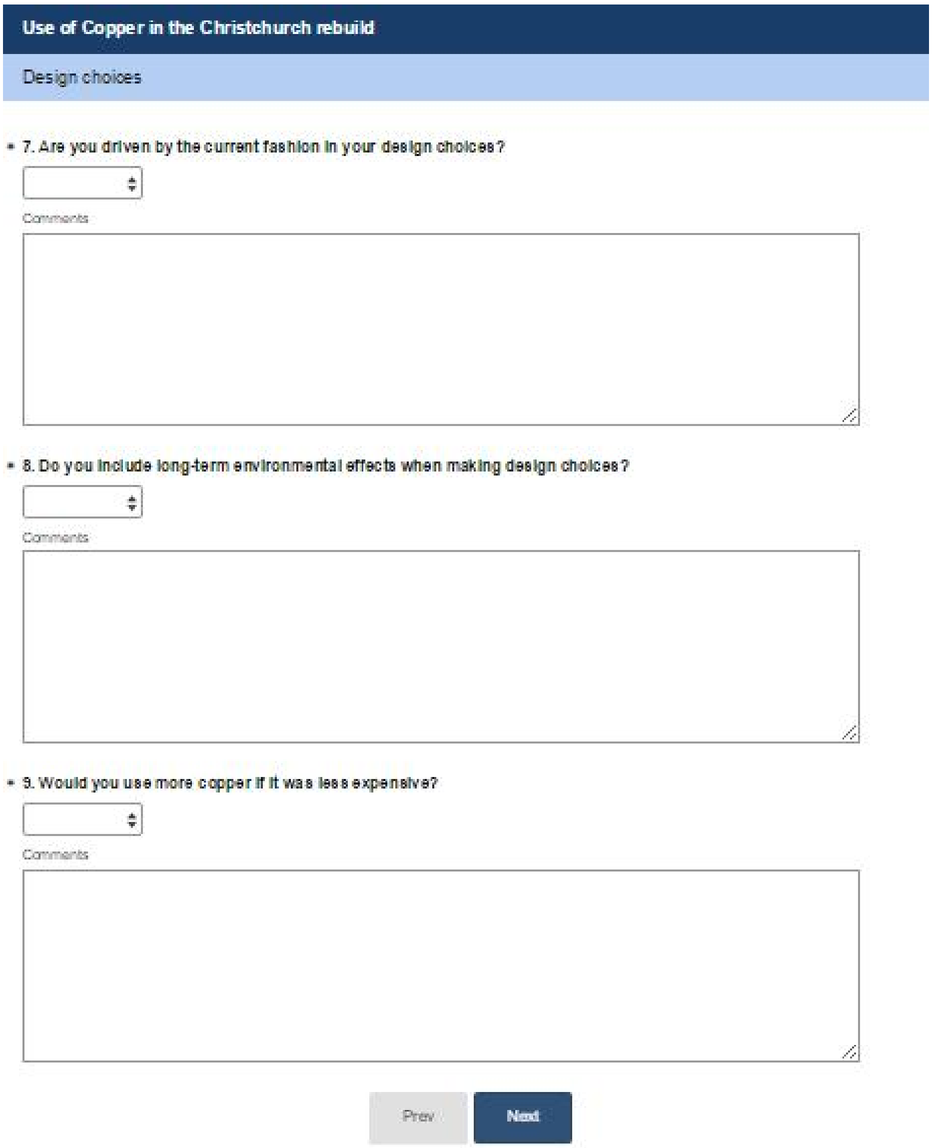


Figure 9. Survey template which was created on www.surveymonkey.com (Pg. 4).

Figure 10. Survey template which was created on www.surveymonkey.com (Pg. 5).

Appendix 3

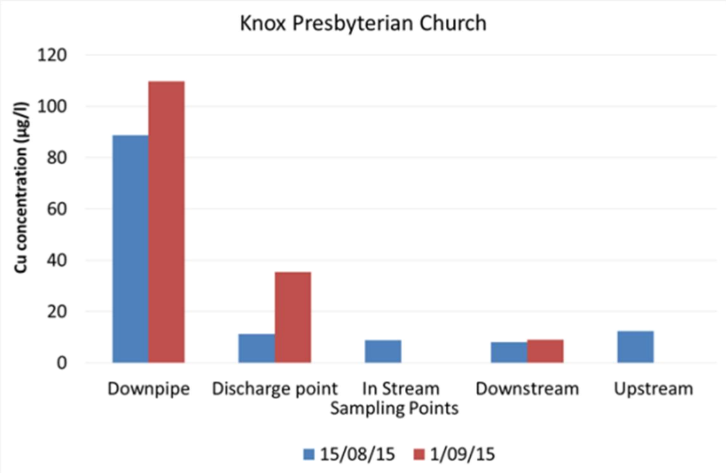


Figure 11. Decreasing copper concentration from downspout to the in stream- KPC.

Appendix 4

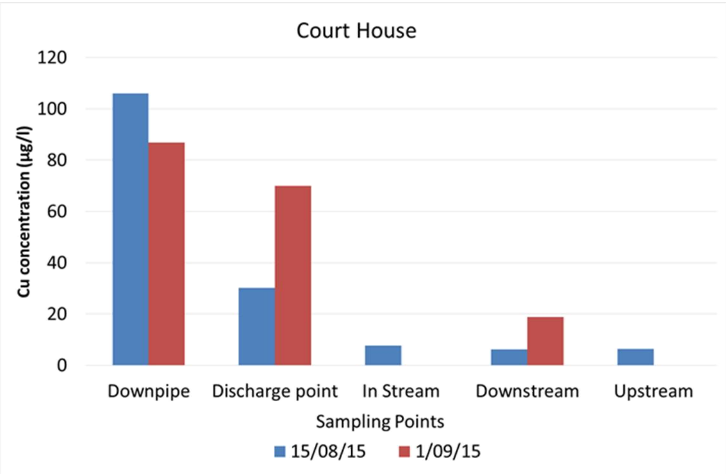


Figure 12. Decreasing copper concentration from downspout to the in stream- CH.

Appendix 5

Sources: http://weather.crowe.co.nz/Rainfall/Month/?Date=2015-08-01, http://weather.crowe.co.nz/Rainfall/Month/?Date=2015-09-01

Table 3. The table shows the weather conditions for the two sampling events with regards to rainfall in mm per day.

Date	Time	Rainfall	
15/08/2015	11:30 - 13:00	Heavy rain	10.00mm/day
01/09/2015	13:30 - 14:45	Drizzle	1.58mm/day

Appendix 6

Source: Pennington & Webster-Brown (2008).

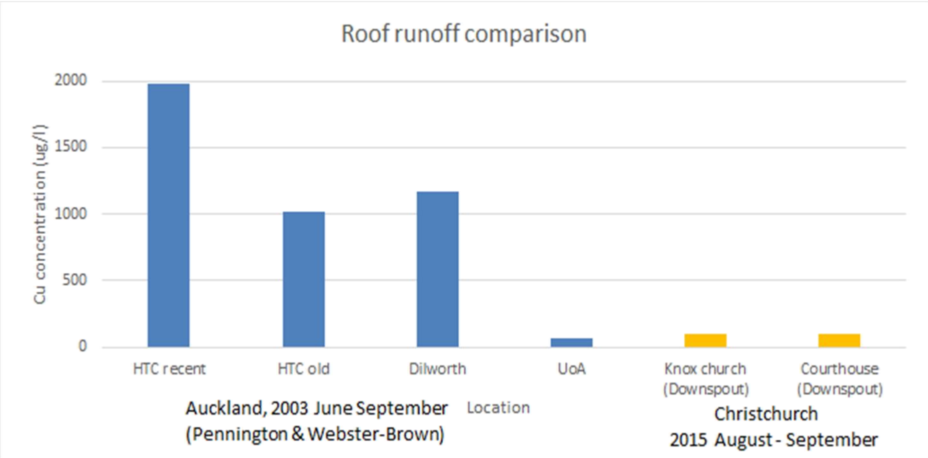


Figure 13. Average concentration of total Cu in roof runoff in Auckland and Christchurch. Auckland data taken from HTC: Holy Trinity Cathedral (recent = 8 years old, old = 37 years old), Dilworth: Dilworth School Hall (45 years old), UoA: University of Auckland

Appendix 7

Source: ANZECC (2010).

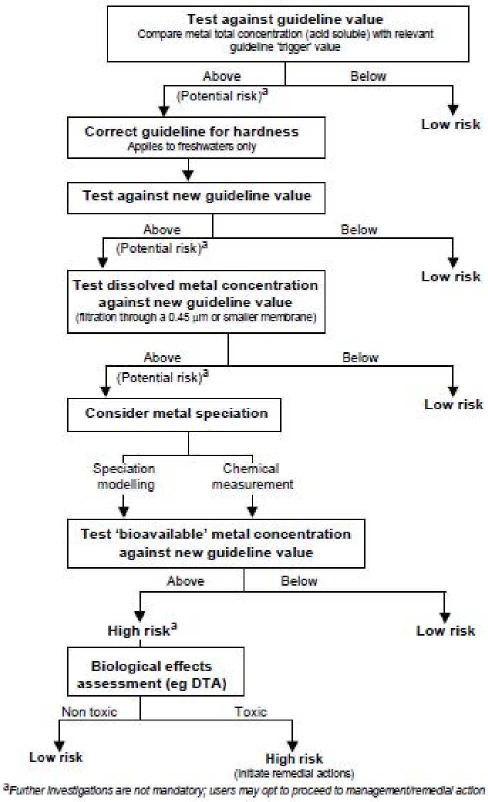


Figure 14. Decision tree to determine the potential toxicity.

Appendix 8

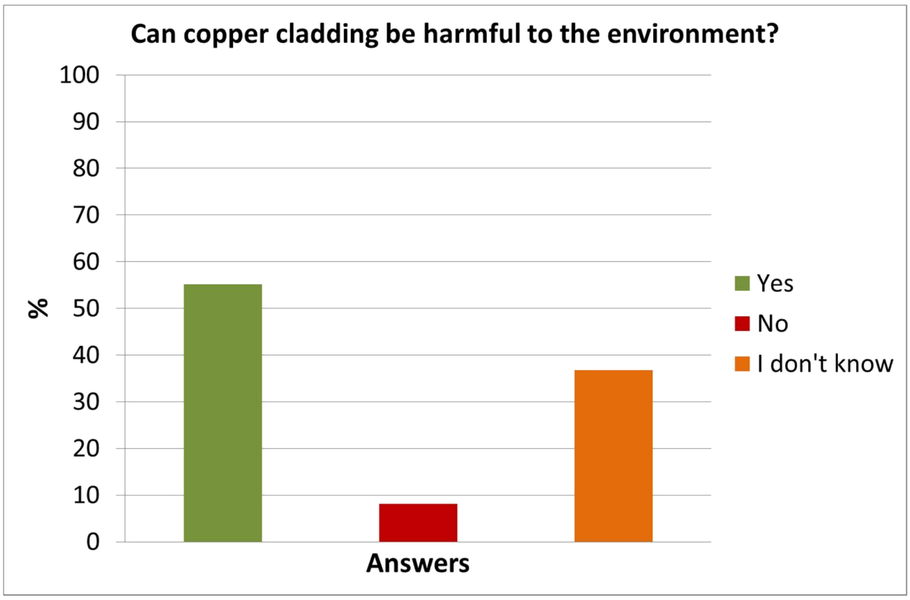


Figure 15. Graph showing survey answers for architects' awareness about adverse effects of runoff from copper cladding on the environment.

Appendix 9

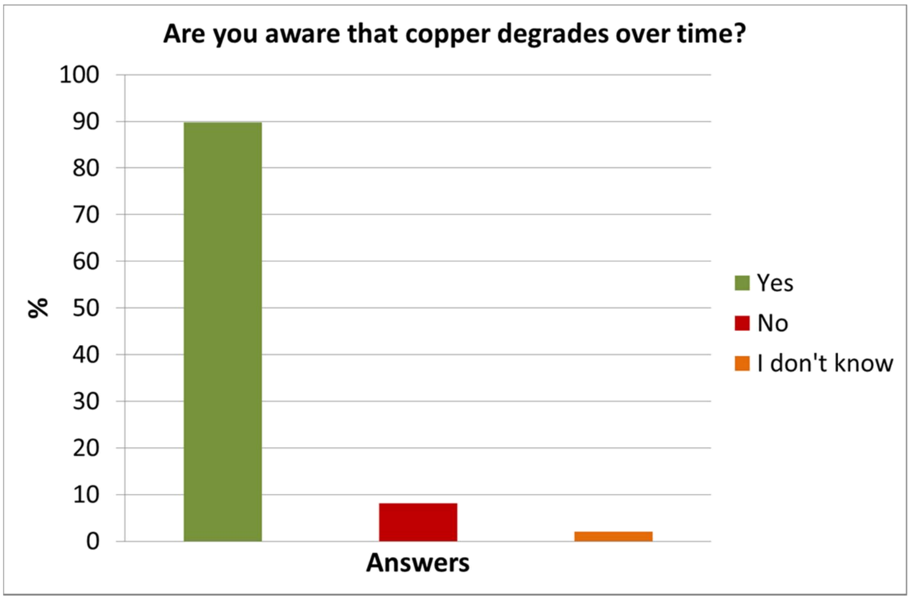


Figure 16. . Graph showing survey answers for architects' awareness about degradation of copper over time.

Appendix 10

Table 4. The table below summarises other metals present in high concentration in the samples collected. Further analysis resulted in other metals (Lead (Pb), Zinc (Zn), and Cadmium (Cd)) present in high concentration were noted in the collected water.

		Pb		Zn		Cd	
Trigger Value		5.6ug/L		15ug/L		0.4ug/L	
Date		15/08/2015	1/09/2015	15/08/2015	1/09/2015	15/08/2105	1/09/2015
KPC	downspout	1.76	3.02	160.33	219.66	77.92	BDL
	drainage	12.29	12.44	228.32	591.82	70.27	BDL
	in stream	19.94	0.20	111.10	11.01	121.92	1.35
	downstream	18.11	2.59	102.48	60.19	110.46	7.16
	upstream	12.86	0.11	125.66	BDL	38.98	1.65
CH	downspout	5.89	9.81	239.39	323.04	47.97	BDL
	drainage	89.75	6.52	167.62	184.45	51.94	80.81
	in stream	16.20	0.62	106.02	BDL	35.41	0.75
	downstream	10.57	0.50	101.21	2.46	51.65	599.69
	upstream	10.41	0.06	108.70	BDL	43.78	0.05

- BDL = below detection level (>0)
- 13 out of20 sample collected in Pb exceeded ANZECC (2000) trigger value
- 15 out of 20 samples collected in Zn exceeded ANZECC (2000) trigger values
- 17 out 20 samples collected in Cd exceeded ANZECC (2000) trigger values

Table 5. The table below summarises Antimony (Sb) present in high concentration.

		Sb (ug/L)	
	Date	15/08/2015	1/09/2015
KPC	downspipe	0.08	42.172
	drainage	69.85	45.428
	in stream	121.51	44.407
	downstream	110.05	55.003
	upstream	38.57	46.138
Ch	downspipe	47.56	39.694
	drainage	51.53	42.679
	in stream	35.00	53.744
	downstream	51.24	37.720
	upstream	43.36	43.991

Appendix 11

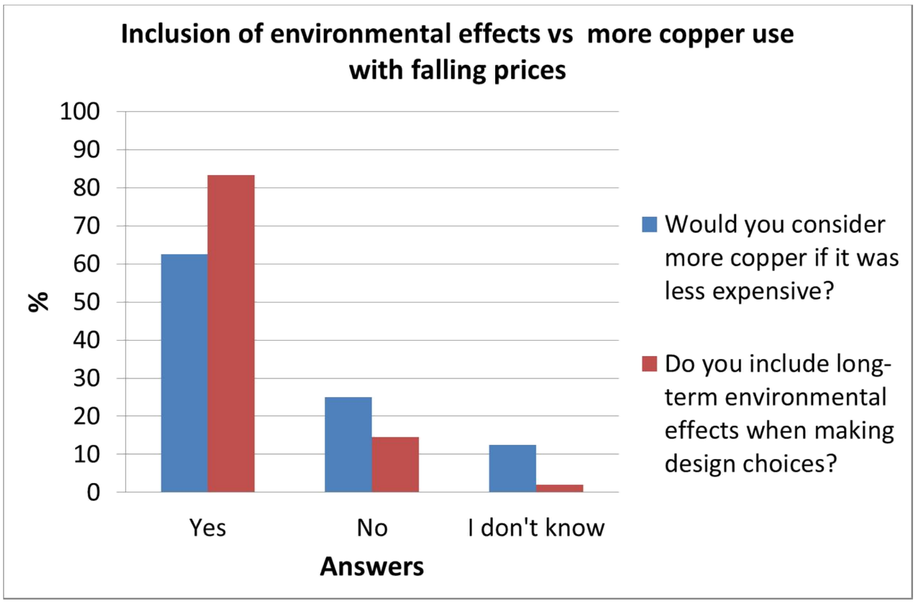


Figure 17. Graph opposing architects' inclusion of long-term environmental effects in design decisions and their responsiveness to prices.

Appendix 12

Source: http://www.mineo.co/rain-garden-design/

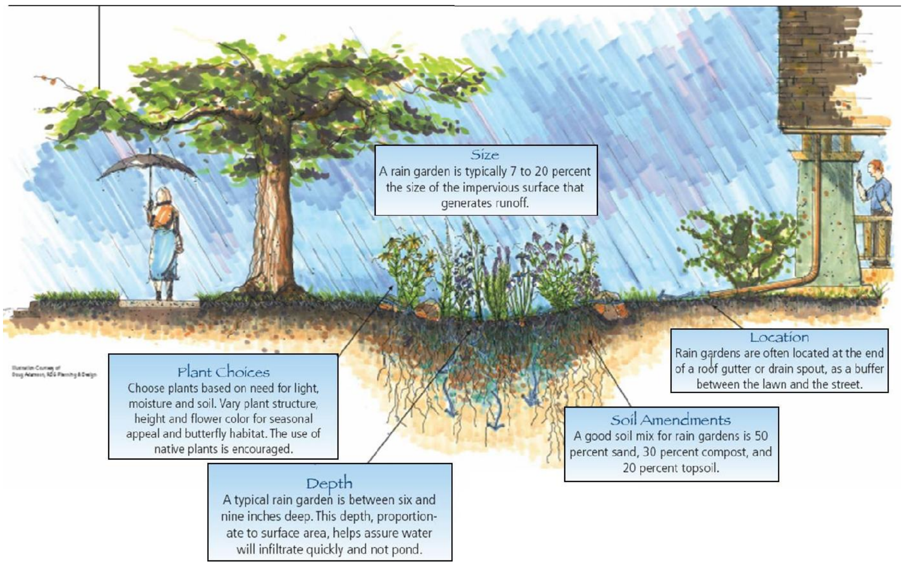


Figure 18. Rain gardens as copper catchment. Ideally with soil that is high in organic, matter, weathered and high in sand content as this types of soil is known to be deficient in copper (Reuther, 1957).

Appendix 13

Source: http://inspectapedia.com/roof/Copper_Roofs.htm

Figure 19. The picture shows a maintained roof and an unmaintained roof with copper cladding. Maintenance would slow the patina layer formation down leading to lower copper concentrations in receiving waters.

Appendix 14

Source: http://www.ccc.govt.nz/assets/Documents/Environment/Water/waterways-guide/WaterwayswetlandsandDrainageGuideWWDGchapter6StormwatertreatmentsystemsMay2012.pdf

Figure 20. The picture shows a manmade wet pond which was installed in Auckland. This allows water quality and quantity management with regards to stormwater runoff (CCC, 2012).

Appendix 15

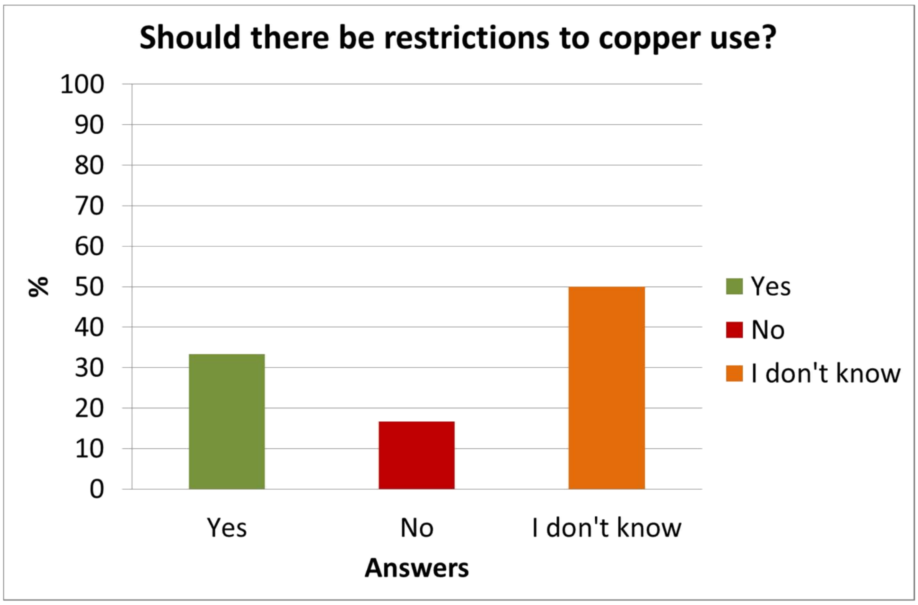


Figure 10. Graph showing architects' opinion about restriction to copper use.

Appendix 16

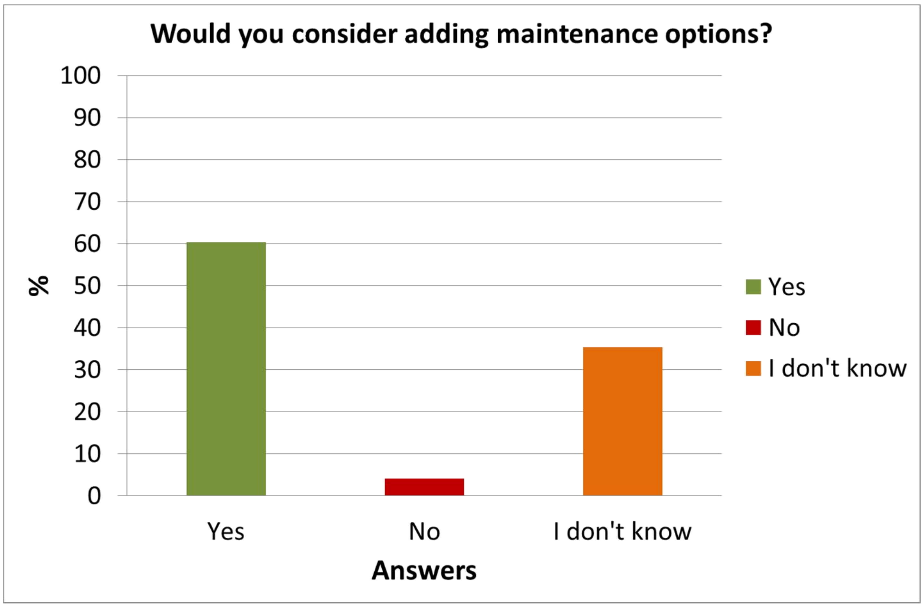


Figure 11. Graph showing architects' opinion about introducing maintenance to copper cladding.

Appendix 17

Source: http://www.cpit.ac.nz/__data/assets/pdf_file/0006/169260/Science_Architecture_Engineering-brochure.pdf

Bachelor of Architectural Studies (Architectural Technology)

If you are creative and technically minded, architectural studies could be the perfect channel for your talents. Our degree will give you the skills and knowledge to pursue a career in architectural design.

Content

The foundation year of this programme includes studies in architectural design, drawing, computer aided design and building construction and science as they apply to architecture.

Our Bachelor of Architectural Studies involves working in collaborative studios with a range of specialist electives including an Internship in Year 3.

Career opportunities

As a graduate of this programme you will be qualified to begin work as an architectural designer in an established architectural practice. With the right experience and determination you could establish your own company.

Study pathways

This degree can prepare you to go on to more advanced study and professional development such as a Master's degree in Architecture.

The next step

To apply for this programme please complete an Admission and Enrolment form available at www.cpit.ac.nz/enrolment and send it back to us.

Portfolio requirements - all applicants must provide a portfolio demonstrating design, graphic and/or art skills equivalent to NCEA Level 3. Contact us for details of the portfolio requirements.

Why not also consider: **Page/Brochure**

- Diploma in Computer Aided Design 32
- National Diploma in Architectural Technology 26
- Bachelor of Design (Visual Communication) .... see Creative

For more information: **www.cpit.ac.nz/architectural-technology**

Bachelor of Architectural Studies (Architectural Technology)

PROGRAMME CODE:	CH3900
LEVEL:	7
CREDITS:	360
DURATION:	Full time - 3 years
COMMENCES:	February
APPLICATIONS DUE:	Received all year
FEES PER YEAR:	$7,000 - $7,500
INTERNATIONAL FEES:	$19,850
ADDITIONAL COSTS:	$1,000
LOCATION:	Madras St Campus

Summary of entry requirements*

- NCEA Level 3 (60 credits at Level 3 and 20 credits at Level 2 or higher) which must include 14 credits in each of the three approved subjects at Level 3
- Literacy - 10 credits at Level 2 or above, made up of 5 credits in reading, 5 credits in writing AND
- Numeracy - 10 credits at Level 1 or above (specified achievement standards, or unit standards 26623, 26626, 26627) OR relevant experience
- IELTS 6.5 Academic (no lower than 6.0 in any subtest)
- Portfolio

Application checklist

- Admission and Enrolment form
- Portfolio

Recommended subjects

- Art
- Graphics
- Design
- Photography
- Painting
- English
- Maths
- Physics

***For full entry requirements see the pages at the back of this brochure.**

If you don't meet the criteria above, please talk to us about other ways we can support you with entry into this programme.

27

Figure 23. Study information for a Bachelor of Architectural Studies study at CPIT in Christchurch, New Zealand excluding subjects about environmental effects and chemical reaction of materials used.

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Appendix 18

Source: http://www.victoria.ac.nz/architecture/study/subjects/arci

Architecture

Please note: Information on this page relates to the 2016 academic year unless otherwise specified.

On this page:

- Overview
- Undergraduate information
- Postgraduate information
- Professional accreditation
- How to find out more
- Related subjects and careers
- List of courses

This subject is taught by the School of Architecture.

Overview

Architects imagine, create, design and build awesome public places, homes, workplaces and spaces of cultural and spiritual significance. They take our breath away with magnificent enclosures and design and build cities of the future.

Architecture is both the process and product of designing and constructing buildings and other physical structures that we inhabit. It considers the construction and design of the space and how it addresses functional, social and aesthetic needs of existing or new environments.

As creators of the built environment, architects need to apply the fundamental concepts of construction, consider historical and environmental issues and solve problems using the latest materials, technologies and design systems.

Architecture at Victoria will give you a thorough grounding in architectural design together with the ability to address and integrate a broad range of related areas. In Victoria's Architecture programme you will explore:

- history and contemporary theory of the built environment which we inhabit
- sustainable design solutions within the built environment
- architectural structural systems, materials and construction techniques
- the impact humans and buildings have on the environment and learn how this can affect comfort, efficiency, mood and meaning.

Victoria's Architecture students are taught in one of the best facilities in Australasia. We have state of the art equipment, world-class lecture theatres, workshops, computer labs and design studios. Our students graduate with strong design, construction and professional skills, ready to continue with postgraduate study or pursue a technical career.

Architecture is a specialisation in the Bachelor of Architectural Studies (BAS) degree. This undergraduate programme leads into the two-year Master of Architecture (Professional) degree for those seeking a professional qualification in Architecture.

For more detailed information on the School of Architecture and its programmes, see School of Architecture.

Figure 24. Study information for a Bachelor of Architectural Studies study at Victoria University of Wellington in Wellington, New Zealand excluding subjects about environmental effects and chemical reaction of materials used.

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Appendix 19

Source: http://www.unitec.ac.nz/sites/default/files/public/BAS.pdf

Table 6. Study information for a Bachelor of Architectural Studies study at the Auckland Unitec in Auckland, New Zealand excluding subjects about environmental effects and chemical reaction of materials used.

Level	Course No.	Course Name	Credits	Pre-requisites	Restrictions
Level 5					
5	ARCH 5011	Architecture & Context	15		
5	ARCH 5112	Design Studio 1	45		ARCH 5111
5	ARCH 5213	Architectural Representation 1	15		ARCH 5211
5	ARCH 5214	Design Communication	15		
5	ARCH 5311	Critical Studies 1	15		
Level 6					
6	ARCH 6112	Design Studio 2	45	ARCH 5111 or ARCH 5112	ARCH 6111
6	ARCH6113	Technical Studio	15	ARCH6411 & ARCH7112	
6	ARCH 6213	Architectural Representation 2	15		ARCH 6211
6	ARCH 6311	Critical Studies 2	15	ARCH 5311	
6	ARCH 6312	Critical Studies 3	15	ARCH 6311	
6	ARCH 6411	Architectural	15		

Bachelor Of Architectural Studies ■ Page 2

Level	Course No.	Course Name	Credits	Pre-requisites	Restrictions
		Technology 1			
6	ARCH 6412	Architectural Technology 2	15	ARCH 6411	
6	ARCH 6413	Architectural Technology 3	15	ARCH 6411	
6	ARCH 6123	Design Studio 2B	30	ARCH6121	
6	ARCH 6611	Negotiated Study 6611	15		
6	ARCH 6612	Architectural Drafting	15		
6	ARCH 6613	NZ Architecture	15		
6	ARCH 6614	Contemporary NZ Architects	15		
6	ARCH 6615	Brazilian Modernism	15		
6	ARCH 6616	Autodesk Revit®: Fundamentals and Application	15		
6	ARCH 6617	Life Drawing	15		
6	ARCH 6618	Design Process	15		
6	ARCH 6619	Sense of Place	15		
6	ARCH 6620	Special Topic 1	15		
6	ARCH 6621	Special Topic 2	15		
6	ARCH 6622	Sustainable Communities	15		
6	ARCH 6623	Essentials of Energy Efficient Housing Design	15		ARCH 6620
6	ARCH 6624	Pacific Island Architecture 1	15		
6	ARCH 6625	Pacific Island Architecture 2	15		
6	ARCH 6626	Special Topic 5	15		
6	ARCH 6627	Special Topic 6	15		
6	ARCH 6628	Architectural Photography – Mediating Architecture through the Lens of a Camera	15		
Level 7					
7	ARCH 7111	Design Studio 3	30	ARCH 6111 or ARCH 6112	
7	ARCH7311	Critical Studies 4	15	ARCH6311 and ARCH6313	
7	ARCH 7411	Architectural Technology 4	15	ARCH 6412	
7	ARCH 7511	Professional Studies	15		
7	ARCH 7611	Negotiated Study 7611	15		
7	ARCH 7612	iArchi[tech]ture	15	ARCH 6212 or ARCH 6112	
7	ARCH 7613	Animation using Film Techniques	15	ARCH 6212 or ARCH 6112	
7	ARCH 7614	Revit: Beauty + the BIM	15	ARCH 6212 or ARCH 6112	
7	ARCH 7615	Traditional Architectural Rendering	15	ARCH 6212	
7	ARCH 7616	Urban Cultures	15	ARCH 6313	
7	ARCH 7617	Urban Housing_H1	15	ARCH 6111 or ARCH 6112	
7	ARCH 7618	Site Analysis & Design	15	ARCH 6111	

Bachelor Of Architectural Studies ■ Page 3

Level	Course No.	Course Name	Credits	Pre-requisites	Restrictions
7	ARCH 7619	Climate Responsive Architecture	15	ARCH 7411	
7	ARCH 7620	High Performance Cladding	15	ARCH 7411	
7	ARCH 7621	Digital Fabrication	15	ARCH 6412	
7	ARCH 7622	Japanese Architecture	15		
7	ARCH 7624	Special Topic 3	15		
7	ARCH 7625	Special Topic 4	15		
7	ARCH 7626	New Zealand Architectural History	15	ARCH 5311 and ARCH 6311	ARCH 6613
7	ARCH 7627	Generative Design	15	ARCH 6212 or ARCH 6112	
7	ARCH 7628	Drawing Architecture, Landscape and the Human Form	15	ARCH 6212 or ARCH 6112	
7	ARCH 7630	Design Elective	15	ARCH6111 or ARCH6112	
7	ARCH 7631	Negotiated Study – Professional Studies	15		
7	ARCH 7632	Negotiated Study – Light Timber Frame Construction	15		
7	ARCH 7633	Negotiated Study – Seismic Design	15		
7	ARCH 7634	Negotiated Study – New Zealand Architectural Theory and Culture	15		

The student may include courses from other programmes at Unitec in their elective mix, subject to approval by the Programme Committee.

Appendix 20

Source: https://cdn.auckland.ac.nz/assets/creative/for/current-students/course-planning-enrolment/Planning%20and%20enrolment%20assets/14%2008%2013_BAS_Planner_2015.pdf

Bachelor of Architectural Studies (BAS) Degree Planner

For NEW STUDENTS from 2015.

	Semester One	Semester Two
Year One 120 points	ARCHDES 100 – Design 1 (20 points) ARCHDRC 102 – Architectural Media I (10 points) ARCHTECH 106 – Architecture and Sustainablility (15 points) General Education course (15 points)	ARCHDES 101 – Design 2 (20 points) ARCHHTC 102 – Modern Architecture and Urbanism (15 points) ARCHTECH 107 – Design Technology I (10 points) General Education course (15 points)
	Semester One	**Semester Two**
Year Two 120 points	ARCHDES 200 – Design 3 (30 points) ARCHDRC 202 – Architectural Media II (10 points) ARCHHTC 235 – Contemporary Architecture and Urbanism (10 points) ARCHTECH 207 – Design Technology II (15 points)	ARCHDES 201 – Design 4 (30 points) ARCHHTC 236 – Introduction to Architectural Theory (10 points) ARCHTECH 208 – Environmental Design I (15 points)
	Semester One	**Semester Two**
Year Three 120 points	ARCHDES 300 – Design 5 (30 points) ARCHHTC 340 – Oceanic Architecture and Urbanism (10 points) ARCHTECH 307 – Environmental Design II (10 points) **And** One elective taken from ARCHDRC 300 - 304, 370 - 373 (10 points)	ARCHDES 301 – Design 6 (30 points) ARCHHTC 339 – Pre-modern Architecture and Urbanism (10 points) ARCHTECH 312 – Design Technology III (10 points) ARCHGEN 300 – Design as Research (10 points)

- 30 points must come from courses offered in the General Education Open Schedule or the General Education Faculty Schedule approved for this degree, or from a combination of these schedules. BAS students cannot take ARCHHTC 102G for General Education.
- As part of completing the requirements for General Education students must also pass the Academic Integrity course as specified in the Enrolment and Programme Regulations, Academic Integrity, of the *University Calendar*.
- BAS is the first part of a two-tiered programme and is a prerequisite degree for your entry into the Master of Architecture (Professional), the qualification required to register as a professional architect.

The information included in this form is correct at the time of going to print, however no responsibility will be accepted for any errors, omissions or subsequent changes to timetabling or courses offered.

See the School of Architecture and Planning or NICAI Student Centre for advice
www.creative.auckland.ac.nz | info-creative@auckland.ac.nz | 0800 61 62 63

THE UNIVERSITY OF AUCKLAND
NATIONAL INSTITUTE OF CREATIVE ARTS AND INDUSTRIES

Figure 25. Study information for a Bachelor of Architectural Studies study at the University of Auckland in Auckland, New Zealand excluding subjects about environmental effects and chemical reaction of materials used