assessing microbial health risks associated with the Burwood Beach Treatment Plant

march 2010
SUMMARY

Hunter Water is a State-owned Corporation providing water and wastewater services for more than half a million people in the lower Hunter region.

Our area of operation covers 5,366km² with a population of 517,273 in the local government areas of Cessnock, Lake Macquarie, Maitland, Newcastle, Port Stephens, Dungog and small parts of Singleton.

We collect, treat and then deliver drinking water to our customers and then transport, treat and dispose of the region’s wastewater.

Hunter Water consistently meets the most recent guidelines for drinking water set by the National Health and Medical Research Council (NHMRC).

Wastewater is collected and treated to a very high standard and clear effluent is discharged to waterways or reused where it is economically and environmentally beneficial.

GLOSSARY

**Dose–response:** The quantitative relationship between the dose of an agent and an effect caused by the agent.

**Indicator micro-organisms:** Bacteria (generally faecal coliforms and/or enterococci) that indicate the presence and level of faecal contamination in waterways. Indicator organisms are generally used in the monitoring of recreational water quality, because searching for specific micro-organisms that cause disease, such as viruses, is both difficult and costly.

**Micro-organisms:** Organisms too small to be visible to the naked eye such as bacteria, viruses, protozoa and some fungi and algae.

**NHMRC:** The National Health and Medical Research Council. An independent Federal organisation that oversees public health and medical issues on a national scale. On the basis of current research, this organisation produces exposure guidelines intended to protect public health.

**Pathogens:** Micro-organisms that can cause diseases in plants and animals.

**Quantitative microbial risk assessment:** A form of risk assessment that aims to indirectly estimate the risk to human health by predicting infection or illness rates for given densities of particular pathogens, assumed rates of ingestion and appropriate dose–response models for the exposed population.

**Secondary sewage treatment:** the degradation of the biological content of the wastewater by chemical and/or biological processes. Secondary treatment follows primary treatment which is the removal of materials that can be easily collected from the raw wastewater via physical means and disposed of.
EXECUTIVE SUMMARY

Hunter Water has commissioned a Quantitative Microbial Risk Assessment (the study) of the discharge of treated effluent and biosolids from the Burwood Beach Wastewater Treatment Plant (the plant) following discussions with the Community Reference Group (CRG) during the community consultation process for the upgrade of the plant.

The study was designed and carried out by the University of New South Wales’ Water Research Centre with extensive liaison with NSW Health, the Department of Environment, Climate Change and Water (DECCW) and the CRG.

The study involved a detailed analysis including the measurement of the numbers of virus, protozoa and indicator organisms (Enterococci) in the treated effluent and biosolids discharges and experimental work to quantify the inactivation via sunlight of the treated effluent and biosolids discharges when diluted in seawater.

The study was the first of its kind in Australia with hydraulic modelling used to estimate the movement of the pathogen, as particles, from the outfall. This was combined with pathogen die off results from the experimental work and statistical analyses undertaken to estimate the concentration of pathogens in bathing areas. Illness risks were then estimated based on dose-response relationships for bacterial indicators and pathogens on occasions when the plume came back towards the beaches.

The hydraulic modelling found that most of the time the effluent was dispersed out to sea but there were occasions when the currents and winds allowed the plume to surface and then move back to the beaches, albeit in a highly diluted form.

An acceptable level of risk of contracting Gastro intestinal illness was defined as 1%. This was based on the National Health and Medical Research Council’s Guidelines for Managing Risks in Recreational Water (2008) (the Guidelines) which are the Guidelines used by Beachwatch for their monitoring and beach classification program in NSW.

Results are consistent with ongoing and reliable Beachwatch data which for more than a decade has shown that Burwood, Bar, Merewether and Dudley Beaches are among the cleanest in NSW. These beaches have very good water quality overall with all local beaches meeting the highest microbial water quality rating.

The study shows that biosolids (sludge) pose a negligible health risk due to the small volume discharged and subsequent dilution.

This new modelling suggests that effluent discharge from the plant could present a slight elevation in health risk to bathers at these beaches around 5% of the time and this is in line with Beachwatch data which suggests an elevated risk around 3% of the time. The majority of the time these beaches have a Category A water quality rating.

There is a conservative assumption that surfers swallow 200mls of seawater per swim, compared to 30mls for bathers, therefore the modelling estimates a slightly elevated health risk for surfers could occur up to 25% of the time, even though water quality for bathers and surfers both meet the highest standard.

While our beaches have Category A water quality overall, infrequent periods of poorer water quality could occur when impacted by a combination of unpredictable environmental factors such as water temperature, winds, currents and sunlight levels. All beaches, including Category A beaches, will still experience periods of poorer water quality when affected by a range of both artificial and naturally occurring pollutant sources, such as stormwater.

A summary of the modelling results is shown in the table below.

<table>
<thead>
<tr>
<th>User group</th>
<th>Beach</th>
<th>Effluent discharge</th>
<th>Biosolids discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bather</td>
<td>Merewether</td>
<td>5%</td>
<td>&lt;1%</td>
</tr>
<tr>
<td></td>
<td>Dudley</td>
<td>&lt;1%</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>Burwood</td>
<td>1.5%</td>
<td>NA</td>
</tr>
<tr>
<td>Surfer</td>
<td>Merewether</td>
<td>25%</td>
<td>6%</td>
</tr>
<tr>
<td></td>
<td>Dudley</td>
<td>15%</td>
<td>6%</td>
</tr>
<tr>
<td></td>
<td>Burwood</td>
<td>15%</td>
<td>6%</td>
</tr>
</tbody>
</table>

Notes:
1. Where multiple scenarios were assessed for varying sunlight conditions, the (moderate) 15 MJ/m2 inactivation scenario (i.e. typical sunny day) is reported.
2. Where multiple scenarios were assessed for Winter and Summer conditions, the higher risk is reported.
3. Where multiple scenarios were assessed for 2007 and 2030 conditions, the higher risk is reported.
4. N/A = Not Applicable

Table 1 Percentage of time the outfall presents an elevated illness risk to beach users
While the health risk is small and periodic in nature, Hunter Water has commenced work on providing ultraviolet (UV) disinfection of the treated effluent at the plant. The disinfection plant will be commissioned following the completion of the current Stage 2 upgrade of the plant. Local beach monitoring will also be doubled during the bathing season with results reported on the Beachwatch and Hunter Water websites. This will provide more information to the public about local beach water quality.

The health risk study has been useful for Hunter Water and our stakeholders. While by its nature the study is theoretical and explores hazardous events (worst case scenario situations) it assists in understanding and contextualising risks.

The key findings to emerge from this work:

- Our beaches remain have high quality in line with ongoing actual Beachwatch monitoring data.
- There is a slight elevation in risk. The consequence of exposure to contaminated water is typically a mild case of gastro intestinal illness.
- Surfers appear to be a higher risk group as they notionally use the beach more often, for longer periods and were modelled to ingest more seawater.
- Risk management focus on the effluent discharge – there appears to be no immediate heath risk imperative arising from discharge of the biosolids stream.

There are still some challenges ahead for organisations using Quantitative Microbial Risk Assessment tools. These include:

- Refining and improving assumptions that feed into the model
- Developing approaches to be able to effectively calibrate and validate QMRA findings
- The lack of any epidemiological data to support and calibrate model predictions.

The Hunter has great beaches and Hunter Water is committed to working with stakeholders to ensure we continue to remain clean and safe. It is intended to continue to use and refine the model as we work with the community on developing the preferred long term strategy for the plant.

1 INTRODUCTION

1.1 Background

Hunter Water is upgrading the Burwood Beach wastewater treatment plant (the plant) to improve plant reliability and to ensure the plant operates sustainably into the future. The upgrade is being undertaken in consultation with the local community. In 2007 Hunter Water set up an independently chaired Community Reference Group (CRG) set up to provide guidance on community issues has been meeting on a regular basis.

As a result of discussions with the CRG, a Quantitative Microbial Risk Assessment (QMRA) relating to the pathogen health risk posed by the plant’s discharge on local beach users was commissioned. The QMRA was undertaken by the University of New South Wales’ Water Research Centre (UNSW) (Roser et al, 2010).

This report summarises the work and findings of the QMRA as well as the risk management approach adopted in response to the findings.

A copy of the QMRA report as well as more information on upgrading the Burwood Beach treatment plant and other studies undertaken in relation to the plant can be found at www.burwoodupgradeproject.com.au.

1.2 The plant

The Burwood Beach plant is the largest wastewater facility operated by Hunter Water. The plant serves the Newcastle City area and suburbs to Dudley in the south, Wallsend in the west and Mayfield in the north. This represents an equivalent population of around 180,000.

Wastewater arrives at the plant where it is micro-screened and de-gritted and then put through a process that uses bacteria to break down and treat the waste. It then flows through clarifiers that separate the biosolids and the clear effluent.

While other wastewater treatment plants around Australia have ocean and estuary outfalls, the plant is unique in that it is the only plant in Australia that discharges treated effluent as well as biosolids generated at the plant, to ocean. As part of a staged upgrade process for the plant, the practice of discharging biosolids to ocean is being examined.

Biosolids from the plant are very different from those present in raw water.
sewage. The biosolids discharged to ocean have been well screened and are predominantly the bacterial solids from the secondary biological process.

The plant discharges on average around 44 million litres of treated effluent and 2 million litres of biosolids each day. The treated effluent and biosolids are discharged to ocean via an ocean outfall and dispersed via a diffuser system at a depth of 22 metres under the sea about 1.5 km offshore.

The plant’s operation and the discharge of treated effluent and biosolids to ocean is licensed by the Department of Environment, Climate Change and Water (DECCW).

1.3 Why was the study done?

The study was commissioned as a result of discussions with the CRG regarding the pathogen health risk to local beach users presented by the discharge of effluent and biosolids from the Burwood Beach outfall.

Discussions focussed on the following points:

1. The ability of regular monitoring undertaken for the Beachwatch program to characterise the health risk from the discharge, particularly with respect to the biosolids discharge
2. The ability of regular monitoring undertaken for the Beachwatch program to characterise the health risk from longer living viral pathogens
3. The health risk posed by short duration, high impact hazardous events

Historically, the human health risk presented by the plant’s discharge has been assessed using the Beachwatch program, which uses the indicator organism enterococci, to assess health risk. The Beachwatch program is run by the DECCW in collaboration with local councils and water utilities. The Beachwatch program shows that all of the beaches in the vicinity of the Burwood Beach discharge are consistently among the cleanest through the Hunter, Sydney and Illawarra. A summary of Beachwatch results is contained in Appendix A.

The use of indicator organisms, particularly enterococci, is largely justified based on epidemiological studies which correlate the concentration of the indicator to the incidence of disease. The disposal of biosolids to ocean is not commonly practiced and there is no evidence that the use of enterococci as an indicator adequately characterises the health risk from such a practice.

Human health is a key concern for Hunter Water and the community. The only meaningful way to address the issue was seen to be to undertake a detailed quantitative microbial risk assessment of the risk presented by viral, bacterial and protozoan pathogens potentially present in both the effluent and biosolids discharges.

This approach is in line with the new Guidelines for Managing Risks in Recreational Water” (the Guidelines) released by the National Health and Medical Research Council (NHMRC) in 2008.

1.4 Assessing health risks

To determine whether water quality is safe for swimming, the study uses new national recreational water guidelines (NHMRC, 2008).

The primary aim of the Guidelines is to protect the health of humans from threats posed by the recreational use of coastal, estuarine and fresh waters so that as many people as possible can benefit from using the waters. Threats may include natural hazards such as surf, rip currents and aquatic organisms, and those with an artificial aspect, such as discharges of wastewater.

Under the Guidelines, there are major changes to the way recreational waters are assessed for suitability for swimming. Recreational water quality at swimming sites is no longer reported as percent compliance based on microbial data. Instead, beaches are given a “suitability for swimming” grading using a combination of a sanitary inspection category with a microbial water quality assessment category. This approach provides information on possible sources of pollution and numerical data on the likely level of faecal contamination.

The Guidelines represent microbial water quality in four categories (A to D) based on the level of illness risk associated with the level of microbial contamination of recreational water. A description of the microbial beach classification framework and microbial categories adopted in the Guidelines is contained in Appendix B. The Guidelines represent a major revision of the previous documents by advocating a preventative approach to the management of recreational water,
focussing on assessing and managing hazards within a risk management framework. This represents the varying nature of potential risks to recreational beach users.

By its nature, and in line with the Guidelines, the study focuses on an examination of hazardous events and tests worst case scenarios.

The study has been conducted in accordance with the health risk assessment framework contained in Enhealth (2002). Health risk assessments should include the following steps:

1. Identify issues
2. Identify hazards
3. Assess exposure
4. Assess dose response
5. Characterise risk
6. Undertake uncertainty assessment

The process is shown in the figure below.

2 THE STUDY

2.1 Overview

The study assessed the risk of local beach users contracting gastrointestinal illness as a result of discharges from the plant outfall under a range of scenarios and was undertaken in the form of a quantitative microbial risk assessment (QMRA).

For the purposes of the study an acceptable level of risk of contracting Gastro intestinal illness was defined as 1% in excess of other health risks (Category A microbial water quality). Based on Beachwatch data, Newcastle beaches typically satisfy Category A microbial water quality.

The study focussed on hazardous conditions in line with the Guidelines. The study assessed the health risk presented to bathers at the shoreline as well as surfers who use the beach more frequently and for longer periods.

The study did not assess wet weather impacts such as stormwater overflows or other hazards such as bather shedding.

The scope, methodology and assumptions used in the assessment have been developed in collaboration with NSW Health, DECCW and were presented to the CRG before commencing the study.

2.2 Methodology

In accordance with the EnHealth (2002) health risk assessment guidelines the study looked at hazard assessment, exposure pathway and dose response assessment, in the following steps:

- Estimation of the inputs to the treatment plant (the community’s wastewater) of biological agents which cause disease – both pathogens and bacterial indicator organisms
- Estimation of the effect of the treatment plant in moderating these pathogens and indicator organisms
- Estimation of the effect of the coastal waters (dilution and sunlight) on the concentrations of pathogens and indicator organisms – from both treated effluent and biosolids
- Estimation of the probability density function (a dataset showing variability) of the concentrations of pathogens and indicator organisms to which bathers (in the surf zone) and surfers (200 metres from the shoreline) are exposed at four different locations
- Estimation of the intake of pathogen and indicator organisms per bather (or surfer) for each event.

To illustrate, the figure to the right shows a schematic of the system examined in the study, including the microbial pathogen source and exposure pathways.

The pathogens selected for analysis (referred to as index pathogens) were those considered common, which represent major pathogen groups (i.e. bacteria, virus and protozoa) and for which testing processes were well established.

*Giardia Lamblia* and *Cryptosporidium* were selected because they are easily analysed and are the most common source of disease from protozoan pathogens. The bacteria *Campylobacter* and bacterial indicator Enterococci were also selected, along with the virus Adenovirus.

The assessment team examined the pathogen loads in both the raw sewage input to the plant, and the material discharged via the ocean outfall – both treated effluent and biosolids. Variables such as time of day, dry and wet weather conditions and varying flow rates were considered. This process delivered data on concentrations of pathogens in both streams.

Complex hydraulic and hydrodynamic computer models for the coastal waters off Newcastle were developed and verified by dye tracer studies. The hydrodynamic modelling found that most of the time the discharge was dispersed out to sea but there were occasions when the currents and winds allowed the plume to surface and then move back towards the beaches, albeit in a highly diluted form (see figures on following page).

The model was applied separately to both treated effluent and biosolids stream to show how microbial particles moved in the ocean and were inactivated by sunlight under a variety of weather conditions and different seasons. This was done for both current demand, and that projected for the plant in 2030.

Tests were carried out to confirm estimates of inactivation as a result of ultraviolet radiation of microbial particles from both the treated effluent and biosolids streams in seawater. The tests found that the inactivation rates for treated effluent and biosolids diluted with seawater were comparable to each other and also comparable to literature values obtained from other studies in marine waters. The results were used to enhance the hydrodynamic modelling.

Four sites were selected to estimate the probabilities of the concentrations of pathogens to which bathers (at the shoreline) and surfers (200 metres from the shoreline) would be exposed:

- Bar beach
- Merewether beach
- Burwood beach
- Dudley beach

Different estimates were made of the intake of pathogen for a bather and a surfer for each exposure – 30mLs for swimmers and 200mLs for surfers. This enabled the formulation of dose response curves for the various locations.
2.3 Key findings

The results of the risk assessment are specific to the input assumptions used to construct the scenarios. It is emphasised that the risks are modelled ones developed to support decision making by project stakeholders. They should not be confused with actual risks of disease calculated via epidemiological studies.

In interpreting the findings of the study it is important to consider:

1. There is no local epidemiological data to suggest recreational water use is linked to increased illness rates.

2. There has been no change to date, or planned for the future, in plant operating conditions or environmental conditions which could impact health risks. The study provides an estimate of health risk for existing conditions.

3. The consequences of exposure are low. Infections and illness due to recreational water contact are usually mild and are therefore difficult to detect through routine surveillance.

The key findings of the study are:

- The solids in the biosolids do not significantly inhibit pathogens from the main mechanism of inactivation (sunlight) when discharged and dispersed to the ocean. On this issue, the use of indicator bacteria was found to adequately characterise the health risk from the biosolids discharge.

- The indicator bacteria dose-response curve appears to provide a conservative estimate of total gastrointestinal illness compared to...
• to illness risks estimated for individual pathogens, even allowing for pathogen assay limits. This included the index virus chosen Adenovirus. On this issue, the use of indicator bacteria was found to adequately characterise the health risk from the biosolids discharge.
• The biosolids discharge presents a much lower overall health risk compared to effluent discharge, because of its smaller discharge volume.
• The modelling suggests that for the majority of the time the outfall presents a negligible health risk to beach users. This was consistent with Beachwatch data which indicates the beaches typically achieve Category A water quality status.
• Episodic, short lived periods of increased health risk do appear to occur. These periods were found to be closely associated with a combination of de-stratification of the water column, on-shore currents, strong or extended duration on-shore winds and low sunlight levels. These periods are infrequent and are largely unpredictable.
• For shoreline bathers a slight elevation to the health risk could occur around 5% of the time.
• Surfers appear to be a higher risk group as they notionally use the beach more often, for longer periods and were modelled to ingest more seawater compared to bathers – 200mLs per exposure compared to 30mLs. Based on this assumption the modelling estimates a slightly elevated health risk for surfers could occur up to 25% of the time, even though water quality for bathers and surfers both meet the highest standard.

The different beaches and swimming locations did not appear to differ greatly from one another in the levels of pathogens seen.
• The impact of the upgrade and larger discharge volumes predicted over time seem very small compared to other sources of health risk variability and uncertainty in the QMRA method.
• The estimated illness risks presented here were based on QMRA methods. The assessment explores a number of scenarios but the estimates are still model outputs. Key sources of uncertainty include the amount of seawater consumed by beach users, the long term variability in pathogen discharge loads and environmental conditions as well as inherent errors in measurement and modelling.

3 OUTCOMES

3.1 Beach Classification

Under the Guidelines, beaches are rated for their suitability for recreational use based on a combination of a microbial water-quality assessment category (i.e. regular beach monitoring) and a Sanitary Inspection Category (see appendix A). All local beaches have Category A microbial water quality based on Beachwatch data.

A Sanitary Inspection of each beach is undertaken each year and considers all potential sources of pollution. The results of health studies associated with recreational water such as this study are considered as part of the annual sanitary inspection.

Sanitary Inspections for Newcastle beaches have reported that the Burwood Beach WWTW outfall has been given a Moderate likelihood of susceptibility of faecal contamination. The rating is in response to the findings of the study. When the microbial water quality results are combined with the results of the Sanitary inspection Bar, Merewether and Burwood beaches have a “Good” beach suitability grade.

Nobbys, Newcastle and Dudley beaches were not assessed to be at risk from wastewater discharges and have a “Very Good” beach suitability grade.

<table>
<thead>
<tr>
<th>Beach</th>
<th>Microbial Assessment Category</th>
<th>Sanitary Inspection Category</th>
<th>Beach Suitability Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nobbys</td>
<td>Category A</td>
<td>Low</td>
<td>Very Good</td>
</tr>
<tr>
<td>Newcastle</td>
<td>Category A</td>
<td>Low</td>
<td>Very Good</td>
</tr>
<tr>
<td>Bar</td>
<td>Category A</td>
<td>Moderate</td>
<td>Good</td>
</tr>
<tr>
<td>Merewether</td>
<td>Category A</td>
<td>Moderate</td>
<td>Good</td>
</tr>
<tr>
<td>Burwood</td>
<td>Category A</td>
<td>Moderate</td>
<td>Good</td>
</tr>
<tr>
<td>Dudley</td>
<td>Category A</td>
<td>Low</td>
<td>Very Good</td>
</tr>
<tr>
<td>Redhead</td>
<td>Category A</td>
<td>Low</td>
<td>Very Good</td>
</tr>
</tbody>
</table>

Table 2 Beach suitability grades
3.2 Risk Management

This study is the first of its kind for an ocean outfall plant in Australia and Hunter Water has consulted extensively with NSW Health and DECCW about the results and outcomes of the study to come up with risk management that will be cost effective and provide immediate and long term benefits to customers.

Hunter Water is proactively moving forward with plans to provide ultraviolet (UV) disinfection of treated effluent at a cost of $15 million. The UV disinfection plant will provide an additional treatment barrier and significantly reduce the risk. UV disinfection is similar to the natural disinfection process through sunlight; however it is concentrated and able to be undertaken throughout the night.

Construction works are currently underway with a $43 million plant upgrade to improve effluent quality and plant reliability. The completion of the current upgrade works will then enable implementation of disinfection at the Burwood Beach plant.

A preliminary concept design has been prepared for the UV disinfection plant. Further testing of the effluent stream following the upgrade is required to determine the level of disinfection required.

Hunter Water will also double beach monitoring at beaches around the outfall – from every 6 days to every 3 days during the bathing season. Results of the monitoring will be reported on the Beachwatch and Hunter Water websites.

Hunter Water will also continue consultation on this issue with local surf groups, the CRG, NSW Health and DECCW.

In addition to these Burwood Beach specific works, Hunter Water is also improving stormwater management and sewer overflows near beaches by investing $100 million over the next 10 years on wet weather system upgrades.

4 CONCLUSION

The health risk study has been useful for Hunter Water and our stakeholders. While by its nature the study is theoretical and explores hazardous events (worst case scenario situations) it assists in understanding and contextualising risks.

The key findings to emerge from this work:

- Our beaches continue to have high quality in line with ongoing actual Beachwatch monitoring data.
- Surfers appear to be a higher risk group as they notionally use the beach more often, for longer periods and were modelled to ingest more seawater
- In managing health risk the focus is better targets on the effluent – there appears to be no immediate health risk imperative arising from discharge of the biosolids stream

The $43 million plant upgrade currently underway will improve effluent quality and is expected to reduce the occurrences of elevated risk.

Hunter Water will invest a further $15 million to provide UV disinfection at the plant. UV disinfection will provide an additional treatment barrier which will allow for further and significant reductions in the risk.

Hunter Water will undertake further investigations and consult extensively with the community to guide the preferred long-term biosolids management strategy through the Stage 3 upgrade.

There are still some challenges ahead for organisations using QMRA tools. These include:

- Refining and improving assumptions that feed into the model
- Developing approaches to be able to effectively validate QMRA findings

The Hunter has great beaches and Hunter Water is committed to working with stakeholders to ensure we continue to have great beaches for all users. It is intended to continue to use and refine the model as we work with the community on developing the preferred long term strategy for the Burwood Beach WWTW.
REFERENCES


