21 July 2015

Brendon Love
Bay of Plenty Regional Council
sent via email

Our ref:
Your ref:

Dear Brendon

Independent – Comments on bioremediation studies

As requested, I have reviewed a series of documents related to myco and phytoremediation studies of Kopeopeo sediments. The studies have progressed over the past couple of years and have included ascertaining the most appropriate strain of fungi species to use for mycoremediation. The studies have largely been conducted on a small scale and have identified some of the rate determining factors that will influence successful bioremediation. Recent comments by the researchers have indicated that there is a good potential to degrade dioxins in the Kopeopeo canal sediments.

It is recognised that a lot of thought and effort has gone into these studies and there is evidence that myco and phytoremeduation (or a combination of both) can degrade dioxins. The comments presented in the attached table do not cast doubt on the bioremediation approach, rather they are provided to assist in highlighting the potential limitations and/or constraints to implementing bioremediation of this type on a large scale, especially given that field conditions may differ significantly from those established in the laboratory.

The draft CRC CARE *Application Guide for Bioremediation* recommends that where there is uncertainty as to whether bioremediation will achieve the required outcome, up to three stages of treatability studies may need to be conducted. Research to date is consistent with the first stage in which the ability of bioremediation techniques to meet the remediation objectives is assessed.

The second more detailed stage is to evaluate the application of the method under the specific site conditions. The laboratory trials have shown that biological degradation can occur, but it is necessary to demonstrate that the processes can occur under the site conditions that will be present in the proposed containment cells. Field trials will have to also take into account the proposed method by which the sediments will be placed into the containment area (in geobags) – as commentary on the application of the fungal strains and soil conditioning (e.g. adding lime to the soil) has been based on placing the sediments over a large area. If necessary, the third stage would assist in developing specific operating requirements and performance criteria to enable development of an RAP.

The Kopeopeo sediment research has indicated that that a number of physical and chemical conditions have to be achieved (and maintained) for bioremediation to be successful. These include moisture content, presence of oxygen (via aeration), pH conditioning, nitrogen, magnesium and potassium content, temperature and duration of biological activity. This is a complex recipe and given the volume of material that is to be treated, it is essential that the ideal operational conditions and amounts of the ingredients (and how they can be applied) are appropriately defined before bioremediation is implemented. Comments by the researchers to date that amendments could be applied during the

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remediation are potentially underestimating the level of effort and constraints involved in scaling these laboratory scale processes to full scale under the likely field conditions.

To gain the necessary confidence in documenting that the bioremediation can be implemented on a large scale, it will be necessary to conduct field trials that replicate actual conditions, including how soils once in the geobags can be monitored and ameliorants added. The scope and duration of such trials will need to be endorsed by both the PSG and the community. I look forward to meeting you and the PSG next week to discuss these comments.

Sincerely
GHD Pty Ltd

Andrew Kohlrusch

Table A Independent Monitor comments

Comments	Data gaps or uncertainties
Te Runanga O Ngati Awa - Report from Te Ohu mo Papatuanuku Bioremediation Trials Kopeopeo Canal Trials Project Team 26 April 2011, summarised and supported with subsequent data in: **Te Ohu Mo Papatuanuku Scientific Project Documents (Assessment of fungal and plant-based remediation of PCDD/PCDF-contaminated sediment from the Kopeopeo Canal)** June 2012 Outlines set up of myco and phytoremediation trials that were conducted from February 2010 to May 2011. Aeration and heating of the mycoremediation treatment was conducted from February to August 2010. Inoculum was setup and mixed in 3.5 and 7 percent concentrations. Aim of trial was to monitor percent reduction, not absolute reduction. Phytoremediation trials were based on using a combination of plants, fertiliser and microbes. The mycoremediation trial showed that PCDD/PCDF concentrations could reduce and that pH and moisture content control before inoculation could enhance the process. Only one of the mycoremediation treatments in the May 2011 results recorded lower concentrations when compared to those recorded in February 2010. A nominal reduction in TEQ was observed in the phytoremediation trials. A beneficial effect of combining myco with phytoremediation was observed. The recommendations include adding lime to the soil to adjust pH (to be completed before remediation) fertilising with Mg and K and adjusting moisture content and that for large scale mycoremediation, a simple system for aeration and heating would be required.	*pH and sulfate were deemed to affect the degradation rate associated with phytoremediation and may also affect the performance of fungi species in the mycoremediation. How these effects would be managed in large scale remediation needs to be established. The pH was adjusted at the beginning of the trials from 2.65 to 4.5 to 4.8 (adding 9 g to 50 g of sediment). This ratio could have significant cost and logistical affects for large scale remediation.* *There was an increase in many of the TEQ measurements for many of the mycoremediation treatments. No explanation was presented for this result.* *For the phytoremediation trials, biological activity at the end of the trial was dramatically lower than at the beginning. The reason for this is not clear, but maybe due to the soil drying out, or possibly due to toxicity of any breakdown products of degraded PCDD/PCDF congeners. This could affect large scale remediation.* *The recommendations for soil amendments/conditioning as part of a large scale remediation project could necessitate a staged process being implemented. This could add time and costs to full scale implementation, particularly regarding aeriation and/or heating the sediments.*
RAP Appendix M_Bioremediation Methodology (The bioremediation of contaminated sediment dredged from the Kopeopeo Canal) 8 October 2012 The report describes the methods to be used to bioremediate approximately 40,000 m^3,	*It is not clear what impacts there would be on large scale mycoremediation if the passive and low-maintenance phytoremediation and monitor cell design was implemented*

Comments	Data gaps or uncertainties
using a combination of myco and phytoremediation. The testing was presented in the Scientific Project Document (SPD). Additional information supplied in the document compared to the SPD included that the mycoremediation system relied on forced heating and aeration which would not be suited to larger scale projects. A remediation timeframe of 15 years was nominated. Three areas were defined for the establishment of containment cells. Sediment is to be placed into the cells, mixed with agricultural lime and wood chips and covered with a geotextile. Further testing was recommended to establish the appropriate liming rate. Addition of 5 percent of woodchips to the sediment was also recommended as well as N, Mg and K – for which further testing was recommended. The bacterial slurry is to be injected through the geotextile liner into the sediment. The injection system was not defined.	*on full scale remediation.* *A waiting period of six months for dewatering (MC not defined) before inoculation can take place will require additional contractor mobilisation and will present difficulties in working across the cells.* *The recommended dosing rate of lime was one truck of lime to 10 trucks of sediment and that the material could be added periodically across a series of sediment horizons. This means of adding lime might have some logistical constraints given the soft nature of the sediment.* *No information was given as to how the wood chips would be mixed with the sediment, nor on the amount of (or how) N, Mg and K would be added.* *It is not clear how the inoculum will be added to the wood chips if they have already been mixed with the sediment.* *Optimal temperature for mycoremediation is stated to be 30 degrees. Monitoring temperature is appropriate, but there is no contingency in how to adjust temperatures if the desired temperature (and biological activity) cannot be sustained. Similarly, no statement has been made in relation to pH control.* *High moisture content is deemed to inhibit bioremediation, but no contingency has been defined to amend moisture content should it not reduce.* *The statement that the Regional Council may remove the sediment before the end of 15 years if bioremediation is showing little effect presents a high risk to the project.*

Comments	Data gaps or uncertainties
Bioremediation response to Section 92 Description of scientific and technical validity of bioremediation. Information referenced international examples of bioremediation of similar compounds as well as responses to potential scenarios associated with the proposed remediation of the Kopeopeo sediments. Elevated groundwater levels are not considered to be relevant as bioremediation will occur in both aerobic and anaerobic conditions. Moisture content is regarded as a key parameter that will affect pH and ORP. There are no means of controlling temperature at large scale, but the report states there is no reason to believe that the temperature range will be critical. No risk is deemed to be present by progressing from small scale to large scale bioremediation without an intermediate trial.	*Only one of the examples presented was related to bioremediation of dioxins. The final report information was not available for the CHH project (and it is acknowledged that privately funded remediation outcomes may not be available) but T&T job description suggests that the majority of the material was landfilled.* *No statement made regarding the volume of lime that will need to be added to achieve pH of 5.5.* *Research prepared to date by Waikato University to date appears to have focused on aerobic rather than anaerobic biodegradation.* *Previous comments stated that optimum biological activity occurs at about 30 degrees. It would be beneficial to understand the annual range of soil temperatures in Whakatane area.* *Somewhat optimistic in assuming there is no risk and that modifications to the process could be implemented during full scale bioremediation. A number of factors would need to be monitored and controlled for full scale remediation such as pH, temperature, sulfate and its affect on biodegradation, long term biological activity and that research to date has focused on aerobic biodegradation rather than anaerobic mechanisms. It is not clear how modifications could be implemented with the proposed geobag containment system.*
Removal, Remediation and Disposal of Canal Sediments Bay Of Plenty Regional Council - Kopeopeo Canal Removal AEE (Pg 449 Monitoring Plan incl Bioremediation) SKM 18 October 2013 The plan outlines the monitoring activities that will be conducted as part of the removal and	*The monitoring program is appropriate, but the corrective action of excavating and removing to a licenced landfill (if there is one nearby and has the capacity to accept such a large volume of material) is a significant project risk.*

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transport of the sediments to the containment areas and the subsequent bioremediation. The rationale, methods and locations of monitoring are detailed along with the validation and reporting requirements. The plan was based on the trucking of the sediments from the canal to the containment area – an action that may be reconsidered. Bioremediation monitoring will include regular measurement of moisture content, pH and EC using probes. Soil monitoring (of dioxin concentrations, ORP, pH and biological activity) will be conducted as well. The plan states that bioremediation will not commence until the pH of the soil is 5.5 and water content must be less than field capacity. Corrective actions are listed that include reanalysis of samples and excavation and disposal to a licenced landfill. A validation sampling program of the canal following removal of the contaminated sediments was proposed along with a program to monitor dioxin concentrations in eels.	
Consent Application 67173 Section 92 Response 18 October 2013 Contains additional data, especially in relation to the physical conditions of the sediments and the proposed containment areas. Includes Bioremediation response to Section 92 prepared by Chris Anderson and Joanne Kelly.	*Comments raised previously apply.*
Hearing Evidence files (Kopeopeo Canal) (Page 141 Bioremediation evidence) – December 2014 Transcript of evidence presented to the hearing in relation to the consent including information on: • the expertise of the researchers involved in the treatability trials; • international (and local) experience in bioremediation of dioxin and dioxin related substances; • the studies completed by Massey and Waikato Universities and how large scale remediation would be implemented	*Most of the information was presented in greater detail in other documents reviewed by the independent monitor. Comments in relation to the documents referenced in this letter apply.*

Comments	Data gaps or uncertainties
Bioremediation Science Package for peer review Kopeopeo – tabled at SG meeting 9 September 2014 This letter summarises the history of the research that has been conducted to date in relation to bioremediation of the Kopeopeo sediments. The report states that a good understanding of the key parameters affecting bioremediation has been gained and that an *integrated myco and phytoremediation* approach has a good potential to degrade dioxins. A bioremediation plan was prepared based on advancing the bioremediation to large scale along with a plan to monitor the effectiveness of the bioremediation.	*Comments in relation to the documents referenced in this letter apply.*
Kopeopeo Canal Contamination Remediation Project: R&D Package May 2015 Details the outcome of Steps 1 and 2 of the package; Step 1 being the establishment of a laboratory at Waikato University and method development with Step 2 resulting in the modelling (using bioreactors) of the processes that will occur at full scale bioremediation. Two fungal strains (*T. versicolor* and *Pleurotus sp.*) were used for the bioreactor trials. Wood slithers were inoculated with the fungal strains and combined with sediments (and 1.8% lime) from the Kopeopeo canal. Samples of the sediment collected and tested for dioxins after 70 days showed decreases in TEQ by up to 74%. Standard operating procedures for contractors to achieve the appropriate mixing of the inoculated slithers into the sediment were prepared.	*The amount/volume of the fungal strains added to the sediments was not stated. The purpose of air drying (Appendix 4) was not mentioned – if the samples need to be dry to obtain effective TEQ reduction, how will this apply to the Kopeopeo sediments? Is there an optimum moisture content for bioremediation?* *Air exchange is mentioned in the method (Appendix 4). Will this be necessary for large scale bioremediation?* *The control sample – no treatment (Table 6) shows the same decrease as many of the samples treated with fungi.* *The research did not provide a conclusive answer on the time frame of bioremediation. A 15 year duration has been nominated, but no statement has been made regarding the basis of this schedule.* *It is not clear how the mixing of the inoculated wood slithers will be achieved with the geo bags. Given that the sensitivity of the inoculation, it may not be appropriate for the contractors to assume responsibility of mixing the slithers into*

Comments	Data gaps or uncertainties
	the bags. The procedures if adopted by the contractors will have to be subject to monitoring. *Which samples were not tested owing to visual contamination by mould fungi (page 42)?*
What happens to dioxin during bioremediation? A critical review of dehalogentation and metabolism. Tracey Godfrey 2015 The report comprises a review relevant literature to the bioremediation of dioxins. The research confirmed that the *methods to remediate the Kopeopeo Canal contaminated sediment are considered generally suitable*, but that the fate of dioxin subject to microbiological metabolism is less well understood than that of dioxin subjected to dehalogenation. Further laboratory testing was recommended.	*The concerns that the biodegradation could generate metabolites with greater toxicity and/or mobility may not be acceptable to the community or consistent with project objectives.* *The statement that the addition of N, P, K fertiliser may inhibit bioremediation is a potential significant constraint to use of white rot fungi for the purposes of dioxin remediation.*
Biochar in Co-Contaminated Soil Manipulates Arsenic Solubility and Microbiological Community Structure, and Promotes Organochlorine Degradation PLOS ONE Gregory et al 2015 Presents the findings of a study into use of biochar (made from willow feedstock) to enhance biodegradation of organochlorine pesticides (OCPs) in sheep dip soil. The study recorded significant decreases in OCPs in the soils (pumice collected from a sheep dip in New Zealand) and the researchers deemed that the addition of biochar increased microbial activity.	*Soils used in the research have different properties that the sediments in Kopeopeo. One of the key chemical properties was pH (5.6) which is significantly higher than that of Kopeopeo sediments (less than 3).* *Further work was recommended to replicate field conditions.*