Submission relating to Draft Burrup Rock Art Strategy (ref: 62-03516)

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Introduction

I welcome this initiative by the Department of Water and Environmental Regulation and commend the current Western Australian Government for showing real concern about preservation of the priceless, irreplaceable and world significant petroglyphs on Murujuga (Burrup Peninsula).

I am particularly gratified by the stated recognition of the importance of, and need to apply, the *Precautionary Principle* and the *Principle of Intergenerational Equity* within the Environmental Protection Act, 1986.

Recognition of these principles within the Act places an immediate obligation on the Department to substantially reduce emissions from industry on Murujuga and from shipping associated with the various Dampier port terminals. Recognition of these principles should also ensure there is no further expansion of industrial activity on Murujuga.

Continuing industrialisation and permitted high levels of emissions on Murujuga have been based on research administered by Western Australian governments. However, the research conducted since 2004, which claimed there was no consistent effect of industrial emissions on rock art, has been completely discredited because of faulty methodology, analysis and interpretation[1,2,3]. Similarly, the conclusion made by Gillett (2008)[4], without measurement of buffering capacity of rocks, that the rocks on Murujuga would withstand the highest critical acid load of any environment in the world has been proven wrong by Professor Kuylenstierna at the recent Senate Inquiry[5].

This ongoing faulty research provided a 'cover' for increasing industrialisation on Murujuga, which has resulted in accelerated deterioration of the rock art.

Critically, this new research initiative should not be used by industry or government to allow continuing high levels of emissions '*because ongoing research is being conducted to determine the impact of emissions on rock art, so the status quo can continue until the research is completed*'.

Evidence for accelerated deterioration of Murujuga petroglyphs

There is now irrefutable evidence that acidity of the Murujuga rock surfaces has increased at least 1,000-fold from preindustrial times[6,3,7]. The pH of Murujuga rock surfaces pre-industrialisation was around neutral at 6.8±0.02, whereas the pH of rocks with petroglyphs measured by Dr MacLeod in June 2017 was as low as 3.81±0.15.

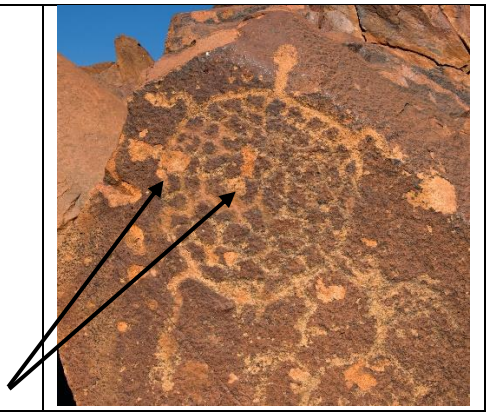
Electro-chemical principles show that the manganese and iron oxides and hydroxides essential for maintenance of the outer rock patina are dissolved at these higher acidity levels[8]. With increasing acidity, the patina becomes more porous, thinner, lighter in colour and flakes away. The flaking is caused by an increase in acid causing sulphur and nitrogen compounds weakening the chemical bond between the patina and underlying weathering zone. These acid-forming sulphate and nitrate compounds crystallise and expand when dry, causing the patina to flake away. The figure of a turtle adjacent to the Woodside company flares shows evidence of flaking patina. Clearly, once the patina has gone, the rock art is lost.

Emissions cause acid deposition - rain

Acid on rocks dissolves outer coating or patina

Increased porosity of the patina allows penetration of sulphates & nitrates that crystallise and expand when dry

This causes the patina to flake away
Lose the patina and the engraving is destroyed



The huge release of nitrogen compounds from industry and the 25 tonnes annually of ammonium nitrate dust particles from the new Yara Pilbara plant are also a major concern for the rock art. The Murujuga region, like much of the Australian environment, is deficient in nitrogen. Nitrogen, particularly the fertiliser ammonium nitrate, simulates growth of organisms within an environment. There is evidence of increased weed growth on Murujuga. However, more serious for preservation of the petroglyphs is the growth of adventitious microbes on rock surfaces. These microbes release organic acids that exacerbate the impact of high rock surface acidity. These organisms also cause black and dark stains on the rocks that can obliterate the rock art.

The figure below shows how acid rain with high nitrogen content has eroded the concrete paving at the Woodside visitors centre and cause a dark stain resulting from excessive microbial growth.

Woodside Visitors centre

Erosion of concrete paving stones where acid rain falls

The picture below shows evidence of black staining on a petroglyph, which most likely is the result of increased microbial growth caused by increased nitrogen in the atmosphere.

Dark staining most likely to result from excessive microbial growth caused by increased nitrogen in the environment

Dark staining affects visualisation of the petroglyphs

Immediate Government action

The theoretical evidence presented above suggests strongly that the petroglyphs are deteriorating because of the increase in acidity and microbial activity on Murujuga rock surfaces due to industrial emissions. However, no reliable scientific studies have been conducted to prove these changes are caused by industrial emissions and are not natural decay.

Nevertheless, the WA Government must immediately enact the *Precautionary Principle* and ensure all industry on Murujuga, including shipping, reduce SO_x, NO_x and ammonium nitrate particle emissions to near zero. Reductions of this magnitude can now be achieved with the modern scrubber and emission reduction technologies available through Yara International and other companies. Yara International are the world leaders in emissions reduction technology and claim to reduce SO_x emissions to 0 ppm[9] and NO_x emissions by 99%[10].

Monitoring and analysis

The draft strategy document lists several types of monitoring to be pursued. Although these are important for assisting understanding of the changes that are occurring, they are not the most important measurements to be made.

Effect of acidity and electric charge on the <u>rate</u> of dissolution of patina oxides and hydroxides

Electrochemical theory is clear that the manganese and iron oxides and hydroxides are dissolved by increasing acidity. However, the rate of dissolution from the patina will determine the life of petroglyphs on Murujuga. Knowing the rate of patina dissolution is crucial for implementation of policies that may save the petroglyphs for future generations.

I believe quantifying the rate of dissolution of mineral compounds within the patina of Murujuga rock types is the most important initial research project. The rate of dissolution may also depend on the age and other characteristics of the patina.

Careful thought is needed to develop the appropriate hypotheses to be tested, the methods to be used and the experimental designs.

Potentially, the CSIRO Extreme Weathering experiments[11] could have provided some of the required knowledge. However, the design and experimental methods used for that research were so poor, the outcomes are of no value for making informed decisions about the effect of acids and other compounds on dissolution of the patina of different rock types.

Restoration of patina stability

Since the acidity of many rock surfaces on Murujuga is already 1,000-fold greater than when the patina was formed under the natural, neutral to alkaline conditions existing pre-industrialisation and the patina is now dissolving, research is needed to determine whether the acidity can be reversed and the stability of the patina returned.

There needs to be a detailed review of possible hypotheses and of methods to test the hypotheses. However, questions to be answered include whether Murujuga rock type patina would be restored in the typical Murujuga dry-maritime environment if industrial emissions were eliminated. Another question to be answered would be whether treatment of rock surfaces with buffering chemicals or other techniques would reverse dissolution of minerals from the patina and restore stability. However, disturbing further the natural condition of patina formation would need to be examined carefully, particularly if the patina forming microbes are adversely affected.

Monitoring colour and mineralogy changes

Continuing the colour and mineralogy monitoring on the rocks previously studied by CSIRO should provide further information about changes over time that may affect the petroglyphs. Unfortunately, the CSIRO methodology was poor and results previously obtained need to be analysed carefully for their suitability for quantifying changes.

Methods should be explored for retrieving value from the previous CSIRO measurements, particularly understanding results from comparisons made between the BYK and KM instruments and the use of colour standards. However, it is difficult to visualise how the CSIRO ASD instrument values can be of value for assessing colour or mineralogy change since 2004, because the instrument was placed at only one position annually for each spot on a rock. The consequent high variation in annual measurements, depending on the exact position the instrument was located, means determining trends over time will be unreliable.

There are more suitable, but more costly, instruments available for making the colour and mineralogy measurements under field conditions existing on Murujuga. The use of these for the future should be explored.

Microbiology

Understanding and identifying the species and environment of the microbes thought to form the patina at the rate of <1 to 10 microns in 1000 years is important for developing any long-term solution to patina loss. In addition, changes in microbial species and populations in relation to changes in nitrogen content and acidity of rock surfaces will assist understanding the impact of industry on patina dissolution from enhanced microbial growth.

Rock surface pH dissolved minerals

Continuing measurements of rock surface pH and dissolved minerals is essential for identifying changes to patina.

Air quality and particle deposition

There have been no publicly available detailed air quality measurements since 2008[4]. Industry appears unwilling to release continuous air quality data. Currently, industry provides some measurements that are unrealistic, such as a negative 90,000 micrograms of dust particles in the air[12].

An essential component of any research must be to have continuous measurement of air components at a range of sites around Murujuga. These continuous measurement values should be displayed in

real-time on a public website. Real-time measurement is essential to identify the impacts on air quality of industrial plant startup, shut down and upset conditions.

Furthermore, measurements are required at least twice weekly of all industrial emission deposition rates. The technology is widely available and will allow comparisons with cities in Australia and southeast Asia.

Changes in vegetation type and growth patterns

Changes in the type and growth of vegetation can have a substantial effect on the petroglyphs. It can be observed that there is no patina where the rocks are in close proximity to vegetation at the bottom of hills. One reason is thought to be the impact of fire, which flakes away the patina. An increase in nitrogen in the environment will change plant growth patterns and most likely lead to more intense fires.

Research funding and management

The Department is aware of the ***Murujuga (Burrup) Rock Art Conservation Project*** being undertaken by the Murujuga Aboriginal Corporation, the UWA Centre for Rock Art Research + Management and Friends of Australian Rock Art. The project is supported by the Conservation Council of Western Australia, the Western Australian Museum and several philanthropic individuals and organisations. The project is being run through the University of Western Australia and has many national and international rock art and other specialists committed to the research. The project is planned to run for five years from 1 July 2018.

The project has, at 1 November 2017, raised or been promised $395,000. Fund raising is continuing. A Commonwealth Government Linkage grant is to be applied for by late January 2018.

The project was established to be independent from industry or government influence. However, the objectives are similar to those proposed by the Department and described above, except for the addition of a mechanistic simulation model. The model is important for predicting into the future likely changes to petroglyphs and possible mechanisms for reducing the damage.

There appears to be little logic in running two similar, but independent projects with the same goals.

Management of the Murujuga Rock Art Conservation Project believe it would be sensible for funds available from industry sources, but managed through the WA government, to be funnelled through the independent project. This would strengthen the Linkage grant application and enhance the funds available for the research.

We believe approximately $500,000 is required each year to undertake the research required to fully understand emissions, their effects on the petroglyphs and methods to restore damage that has occurred.

Amalgamation of the government and independent research program would require careful management. Industry will clearly have interest in the objectives of the research, but it is critically important industry has no influence over the design, analysis or interpretation of the science.

This could be achieved by having two management groups:

- An industry, government and other groups advisory committee for setting and discussing general research objectives; and
- A scientific committee that oversees the actual scientific method, design, methodology, analysis and interpretation.

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