Environmental Hazard And Impact Identification



Nick Hales expands on his earlier article, published in the February 2024 Newsletter, which advocated the use of a modified Doughnut Economics ring using three rings to recognise the current situation of the global economy. Nick helps illustrate these concepts with a real-world example relating to the production of electric vehicle batteries, in particular, the mining of resources required for their manufacture.

The Chief Executive of the Royal Society for the Protection of Birds, Beccy Speight, recently wrote [1], *"Tackling the nature and climate crisis is not easy; we must be bold, innovative and think big."* This article is intended to address the challenge to be bold and innovative in engineering terms and examines how the 21 principles of the Doughnut Economy [2], given in Table 1, (covered in more detail later), could be used to provide categories of risk. In due course these or similar principles may be incorporated into a guidance document on, "A Systems Approach to Safety of the Environment". To achieve this intent, the article considers hypothetical aspects of a project conducted by an ethical corporation involved in electric vehicle car battery production. The company wishes to produce an environmental and socially focussed hazard analysis. The stage of development examined in this article is the hunt for resources for batteries for the car. A previous article [3], introduced the topic of Doughnut Economics.

The image of the 'doughnut' from the Doughnut Economics Action Lab (DEAL), website [4] given in the previous article is reproduced here (Figure 1). Just to recap, the safe space for humanity is in the 'bread' of the ring doughnut.



Figure 1

The SASEWG term for a modified Preliminary Hazard Analysis, (PHA), is a Preliminary Environmental Hazard and Impact Identification, (PEHII) analysis. This term will be used in the rest of this article. The factors which are outside the doughnut, are risks to the environment including those arising at any stage in the project lifecycle. They are beyond the ecological ceiling. Similarly the factors inside the hole in the middle of the doughnut, are the risks to people that push them below an acceptable social foundation.

The previous article [3] advocated the use of a modification of the Doughnut Economics ring with three rings to recognise the current situation of the global economy. The reason for this being that it would be unacceptable for many of those in the developed world to suddenly have all they had taken from them and replaced by a worldwide homogeneous wealth structure. The objective of the three rings is to haul the developing and underdeveloped economies up to developed status without dragging others down which may be a cause of umbrage, if it were to occur. The three rings doughnut helps in the planning of the project. Those using it should look for a net positive gain for the environment and a measurable lifting of those identified as lacking in some aspect that forms the minimum social foundation.

The three ring version as described in context in [3] is given in Figure 2. and ties responsibilities to earnings. The initial specification suggested was, though this is in no way definitive, that an under-developed salary may be under £1000 a year, developing countries salaries in the bracket £1000 to £10,000 per year and the developed world £10,000 and above.

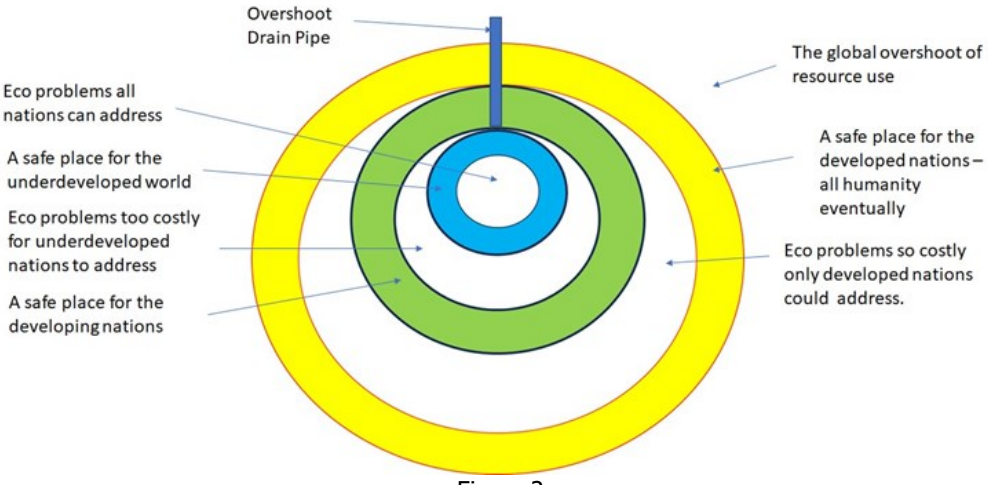


Figure 2

A company wishing to offset its overall environmental impact, in the first instance, should engage trained staff or employ an independent researcher to take deep dives into the social issues and current science around ecological matters associated with the raw materials sources they will use. These people will be the project- and resource-specific skilled members working on the PEHII. There will almost always be other science programmes looking at environmental issues that may be of use so thorough investigation is required.

Preliminary Environmental Hazard Impact Identification

Looking at how to assess what damage a project to create a manufacturing production line could do in a global sense rather than just by malfunction can seem a daunting task. The batteries alone require a good deal of raw materials from the environment in areas which are frequently sensitive and where the resource itself may be limited. Two entries for the PEHII are considered and the logic of why they are necessary is discussed. The evidence is not simplistic so sometimes needs intense consideration.

One other area examined is the problem of data veracity which is critical, as decisions will have long term effects on the planet. That does not mean that conventional tools, with a little tweaking, will not be adequate. A full Hazard Analysis may still be used for through-life control of potentially damaging substances. But issues around Dark Data[1] will certainly affect the PEHII because there are so many unknowns outside the normal concerns of a project when the through life effect on the environment is brought into consideration.

[1] In his book "Dark Data – why what you don't know matters" [6], David Hand introduces the concept and classifies types of "Dark Data" – this explores the many ways in which we can be blind to missing data and how that can lead to conclusions and actions that are mistaken, dangerous, or even disastrous.

A PEHII based on PHA tables assists with three tasks that most engineers will recognise. A good presentation on PHA can be found at [5]:

1. Identify all potential hazards and hazardous events that may lead to an accident
2. Rank the identified hazardous events according to their severity
3. Identify required hazard controls and follow-up actions

The conventional Hazard List for a PHA may consider the following, taken from [5]:

- Mechanical Hazards e.g. crushing hazard or inadequacy of mechanical strength
- Electrical Hazards e.g. contact with operator or electrostatic phenomena
- Thermal Hazards e.g. work environment too hot or scalds
- Thermodynamic Hazards e.g. over-pressure or under-temperature
- Noise Hazards e.g. acoustic signal interference or hearing loss
- Vibration Hazards e.g. poor design causing poor posture or neurovascular problems
- Radiation Hazards e.g. microwaves or gamma radiation
- Material or Substance Hazards e.g. harmful gases or microbiological

The Hazard List for the PEHII, by contrast, is provided by the doughnut economy in the default situation. Two lists are given, one for exceeding the ecological ceiling and one for leaving people beneath the social foundation. All the factors may be hazards in any particular project. These are the tabulated lists of the factors which carry humanity away from the 'dough' of the doughnut as shown in Table 1:

Table 1

Ecological ceiling	Social foundation
Ozone layer depletion	Gender equality
Climate change	Networks
Ocean acidification	Housing
Chemical pollution	Energy
Nitrogen and phosphorous loading	Water
Freshwater withdrawals	Fuel
Land conversion	Health
Biodiversity loss	Education
Air pollution	Income and work
	Peace and Justice
	Political Voice
	Social Equity

It should not be taken, however that this is the only doughnut picture. The doughnut is adaptable and the granularity can be adjusted for the setting, but for the initial PEHII, this is a very useful planning tool for those taking the systems approach to safety of the environment. The PEHII must be reviewed and updated as knowledge increases, especially in the case here of mineral resource supply.

Frequency, consequences and severity need to be considered but also the regulatory environment. Some nations may be less strict than others but lobbying for them to adopt regulations broadly accepted elsewhere is a useful activity as the consequences for the reputation of a company that is damaging the environment, even though legal in a country with a less developed approach to safety, could be dire.

Constituents Of The First Stages Of An Eco-Friendly Project

Three topics are dealt with in the rest of this article. An aspect of data safety is examined, as it is essential to have correct data in order to understand the potential consequences for the planned development and the environment. Two examples of issues for the battery development are given and after discussing the reasons for their entry, the possible appearance in a PEHII hazard list is demonstrated in the form of a table. The issues have been restricted to the following three simply due to space.

1. Deceptive or dark data
2. Deep sea mining
3. Sourcing minerals from plants

Deceptive Or Dark Data

Engineers need to be sure, in order not to breach the ecological ceiling or to prevent fellow citizens suffering by being buried below the social foundation, that the data they use to make decisions is correct. The environment must be described sufficiently too, thus ensuring the correct data applies to that environment, which may be new and unique.

In his book "Dark Data – why what you don't know matters" [6], David Hand describes a particular type of dark data addressed in this section, Type 13 "Intentionally darkened data", which he labelled as particularly troublesome. This is described in the Data Safety Guidance Annex K published by the Safety Critical Systems Club [7]. In a PEHII, bad data will always lead to false conclusions. An early victim of Dark Data was Lord Kelvin, one of the most celebrated mathematician/scientists of his day. He claimed Darwin's theory was impossible. He came to the conclusion that the sun could not have shone down on earth for as long as evolution would have taken because he was unaware of nuclear fusion. That was a case of 'Known Unknown' but that fact was ignored and Kelvin opposed without any real evidence.

In his book, The Skeptical Environmentalist, [8], Bjorn Lomborg highlights the gamble the economist Julian Simon offered all comers, that any given raw material would drop in price over a year or more later. Lomborg claimed Simon could not have lost, yet neither lithium nor lithium carbonate were in the extensive table of materials that Lomborg produced to illustrate his point.

UK inflation between 1997 and 2024, as calculated from the composite price index published by the Bank of England [9].

1. Lithium carbonate was around $2,100 per metric tonne in 1997
2. Lithium carbonate was $68,100 per metric tonne in 2022
3. By the Bank of England calculator, the price by 2022 should have been about $3,600

Lomborg was either ignorant, (which is not a crime), consciously biased or unconsciously biased. One hopes it was not consciously biased which would be Dark Data Type 13 in [7]. From the SASEWG position of protecting the environment and not crossing Doughnut Economy lines, Data errors could lead to destruction of any social foundation already established.

The lithium extraction process uses a lot of water – approximately 500,000 gallons (1.9 million litre) per metric ton of lithium. South America's Lithium Triangle, is one of the driest places on earth. Evaporation used in the extraction activities consumes 65% of the region's water, which is having a large impact on local farmers. Some communities have to get water elsewhere, pushing them below the acceptable social foundation[2].

PEHII Analyses

Two PEHII analyses follow, one for the Ecological Ceiling aspect and the other on the Social Foundation. As will be seen, very large amounts of research and explanation is needed to back up just single entries in the PEHII. Artificial Intelligence may assist with the process. How the entries in a PEHII might appear are given at the end of each of the two problem descriptions.

PHEII Risk – Breaching The Ecological Ceiling

If proof were ever needed that researchers aren't always manipulated to find results that agree with what their paymasters want to be the truth, then the most recent work of Andrew Sweetman, on sea bed mining provides it. This was reported in New Scientist [10]. In 2013 Sweetman found that oxygen was present but not declining when his team sealed off areas of the abyssal Pacific ocean. Something was maintaining the oxygen level. The oxygen source, whatever it is, is important for marine life at a depth where light does not penetrate to enable photosynthesis to supply the gas. The floor of the sea being investigated was rich in minerals needed for car batteries and much of the zone has already been licensed for exploitation. The minerals are found in potato sized nodules containing manganese, cobalt and nickel that litter the floor of the ocean. Those are exactly the elements that electric vehicle battery manufacturers require, so they are keen to mine these deep underwater plains. Sweetman ignored his result in 2013 because he thought the instruments used must be wrong. Then in 2021, he got the same result in a different area of the Pacific ocean using different instruments, so began to think his 2013 results may have been correct.



The initial theory Sweetman is now working on is that some forms of natural batteries are being created in the sea water, by the nodules, and splitting the water molecules to produce oxygen and hydrogen. It remains *"unclear under what conditions the reaction takes place and the contribution this dark oxygen makes in sustaining surrounding eco-systems"* [10].

How creatures and plants survive in the abysses without a ready supply of light for photosynthesis remains a mystery, but this could explain some of it. Mining of the ocean floor, that extracted all the sources of oxygen, would likely lead to extinction of the many tens of thousands of species we know so little about in the dark parts of the oceans. So again, the need to be extremely careful about where resources are sourced from arises.

[2] The acute dependency on water in the Lithium Triangle is illustrated by the storyline of the Bond film: "Quantum of Solace". In the film, the villain from Spectre, Dominic Green, blackmails corrupt military and politicians to control water in the Lithium Triangle.

In 2016, investigation of the seafloor in the Clarion-Clipperton Zone,(CCZ), was found to contain an abundance and diversity of life – more than half of the species collected were new to science. Estimates are that some 6,000 to 8,000 species could be waiting to be discovered in the CCZ alone, according to a June 2023 study published in the journal Current Biology [11], so concern for biodiversity there is high. Sweetman's original sponsors, The Metals Company, are trying to develop a rebuttal of Sweetman's findings because, if his results are correct, global mining of the ocean floor, such as the CCZ, will be paused and perhaps halted completely. The following table shows the PHEII hazard assessment entry:

Ref	EC1
Hazard	Potential for severe ecology disruption
Event/Error	Sea creatures dependent on abyssal plain minerals for oxygen go extinct due to bottom trawling
Cause	Deep water oxygen may be produced by metallic nodules of cobalt, nickel and manganese. Extracting nodules may cause hypoxia in life on the plains
Prevention	Halt bottom trawl for manganese-nickel-cobalt nodules until scientific research completed
Probability	High
Severity	Very High
Comment	Bottom trawl could become a crime, if science consensus reached

PEHII Risk - Dropping Below The Social Foundation

Taking, as an example, a nation in the developing bracket, a corporation could expand investment in projects that are showing promise. The science could be conducted in the field in a developing country with assistance from the parent companies research units in the developed world. Here, relatively small amounts would be invested and for a small amount extra, good relations with the people of the nation could be established with the construction of a technical college or some other environmental or social problem tackled to help the nation rise above the social foundation.

The complexity of the process involved in creating an unbiased, fair and accurate PEHII can hardly be overstated. For this example, which has just one single entry on the PEHII register, some quite remarkable science being conducted in Albania has been selected; this was reported in New Scientist [12]. The average salary in Albania is £750 per month, equivalent to £9000 per year, so the people fall into the category of a developing country, using the ratings in the original article [3], when earnings are between £1000 and £10,000 per year income. The development selected is an agricultural programme to reduce CO_2 emissions and provide a source of Nickel, which will be much needed in the near future for batteries for our electric cars, especially if bottom trawling is banned in many areas.

Albania has high nickel levels in its soil. Demand for nickel is expected to increase hugely with Brazilian mining company Vale estimating that 6.2 million tonnes would be needed by 2030 [13]. The plants native to that nation are resistant to the effects of metals in soils which are toxic to many other plants from elsewhere on the planet. A farm in Albania is growing plants that accumulate nickel. The programme is overseen by a University spin-off business called Econick. It operates several soil remediation operations using hyperaccumulator plants. The joint company with Aperam, a leading French steel producer, is called Botanickel and is engaged with local communities which helps raise them to a point above the social foundation and could transform them over the years into a fully developed nation with average salaries above the £10,000 threshold set. On their website [14], they declare they will "*develop opportunities in research, education, training, employment and energy production that are aligned with local priorities".*



The return may seem small at 2% of dry weights of the flowers of the plant Odontarrhena Decipiens but, in fact, hyperaccumulator plants growing in metalliferous soils safely accumulate extraordinarily high amounts of heavy metals, including cobalt, cadmium, manganese, zinc, and nickel. Aperam's website [4] states it is in fact a relatively good return, estimated at 400Kg per hectare.

The cleaning up of the soil enables the growing of normal crops that cannot tolerate these soils as they are, but could be grown once the heavy metals have been sucked out of the ground by farming Odontarrhena Decipiens. The following table shows the PHEII hazard assessment entry for this activity:

Ref	SF1
Hazard	Investment in poor soil harvesting proves ineffective.
Event/Error	Insufficient minerals obtained from the flowers for commercial success.
Cause	Market price of minerals reduces year on year
Prevention	Make sure stocks of the minerals are obtainable elsewhere
Probability	Med
Severity	Low
Comment	The science is good since the plants improve the soil

Conclusion

It is clear that increasingly corporations are recognising that some effort towards conserving the planet biodiversity and treating people decently has to be made in order to maintain reputation. The technique of using a PEHII in parallel to the more familiar PHA offers one opportunity to recognise formally the problems of factors outside the boundaries of the project. Other methods of creating such an analysis may arise and engineers should always be on the look out to source better resources, utilise better processes and, in due course, produce better products and outcomes. If data is not correct then an opportunity to protect the oceans and the thin layer of soil we live on, may be missed. Blasé attitudes such as those Lomborg appears retrospectively to have encouraged, can have terrible consequences such as the killing of two rangers in Mexico who were trying to protect the Monarch Butterfly wintering sites. Lomborg's book declares there was no threat to the butterflies, the rangers recognised there was and paid with their lives [15].

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