

WHAT IS THE OVERALL GLOBAL LIFE CYCLE COST OF A PROJECT IN TERMS OF SHE?

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This paper discusses the decision making processes for Safety, Health and Environment (SHE) for the design and/or the purchase of new chemicals, plant/equipment to final abandonment. It argues that the criteria used 10 to 20 years ago are not appropriate today particularly where there is a greater tendency to source equipment and materials from beyond the national shores. The decision has to be based on the total, global life cycle cost of Safety, Health and Environment (SHE). This will require a more critical analysis of the true costs and a new set of criteria for decision making based on global criteria. This, in turn, will almost certainly mean that criteria which are applicable to Europe and North America will have to be codified and used as part of the purchasing contract. The impact of these decisions may not be felt locally for some years but if they are not implemented "Industry" will have contributed to pollution and injury by its own default.

The Challenge tce November 2008 page 3 Quote by David Brown IChemE CEO

> "*It is good to set challenging targets for CO_2 because many have so far failed to appreciate the urgency with which we need to achieve cuts. The real challenge however will be to see how these cuts can be achieved in practice. Government must now provide the incentives, the tax breaks and the intelligent regulatory framework that will ensure industry can deliver these targets while remaining competitive and profitable. It will do no good to wreck industry in the UK to see it replaced by dirtier industry elsewhere*."

The paper outlines a methodology for the assessment of the life cycle risk to life and pollutants during fabrication, operation and demolition of any production plant (or manufacture of any bulk chemical) and challenges the impact of the production of pollutants elsewhere in the world.

Possibly of more concern is the increasing evidence of sub standard materials and manufacture from beyond the national shores. It also emphasises the need for the strict adherence and assurance of the best internationally accepted standards for materials and function.

KEYWORDS: safety, health, environment, life cycle, costs

INTRODUCTION

The life cycle of any project involves many studies such as concept selection and of course design reviews such as HAZOP. This paper does not involve these which are part of the overall project decision process. However, there is a modern tendency to source, beyond the national shores, the product which satisfies the requirements of cost, performance and delivery. This is because there are many potential suppliers of that item in the "global market". However, are these the only criteria for the choice and are there other factors which must be taken into account? These include not only the risk to humans during manufacture, use and demolition of process plant (or other equipment) but also the risk to the environment during both the manufacture, demolition and the life of that item. They must also include the strict adherence to the best quality control which must be proven and of international standards as equipment failure, be it from poor materials or fabrication is one of the causes of SHE risks. This may seem a complex concept but it is not when analysed in a little more detail. There are many news reports of pollution for example the spill of 100 tonne of Benzene in the outskirts of Harbin in China [1] and at the time of writing the loss of 500 tonne of oil from a Russian Tanker bunkering a Russian Naval Vessel off Ireland. Industry can not turn a blind eye to such events and continue to purchase from an *Environmental Polluter* or one which has *Safety Standards* that are inferior to those else where in the world just because the cost is perceived to be lowest. The bid assessment should also include an assessment of the likely global pollution and also an assessment of the impact on the health and safety of those who will be manufacturing the equipment. The COMAH Regulations part 2 para 4 [2] states this succinctly. "Every Operator shall take all measures to prevent accidents and limit their consequences to persons and the environment." This will apply to not only the operation but the fabrication/construction.

As yet the values for life are clearly un-defined in most of the world. It seems strange and illogical to discuss ***A****s* ***L****ow* ***a****s is* ***R****easonably* ***P****racticable* (ALARP) in the UK while ignoring it else where in the world! Likewise it is illogical to worry about the UK commitment to the Kyoto Agreement and allow greater pollution elsewhere in the world where there may be a global net loss of environmental quality. In other words to use those hackneyed words:

"*There should be a level playing field*"

In simple terms there should be an assessment of the life cycle costs (impact) on Safety, Health and the Environment for every feedstock and piece of equipment that is purchased. The only credible mechanism for comparing such disparate concepts is to reduce each to an annualised financial value. This paper will attempt to put all of this into perspective.

There is one other moral issue. Should the bid assessments ignore the benefits to another nation and the ability to rise up the technology and health scales even if, for a short time, there are negative factors? This is not for the author to decide but that is what happened in Britain some two centuries ago.

For historic reasons the operational phase will be treated first as, overall, it creates the greatest risk to SHE.

RISKS OR SAFETY (PRODUCTION PHASE)

The safe operation of a process plant depends upon the safety built into the design. The concept of inherently safer design is well established but it is not always easy to prove that the design chosen was the safest. This dilemma was highlighted in the Oil and Gas Industry by an Audit carried out on all of the *BP* Operated Facilities in the UKCS following the Piper Alpha Disaster in July 1988. The process for the production of oil and gas from a reservoir to export to a user is very simple and both the feed stock and product specifications are the same, within reasonable bounds, across the whole of the UKCS. However, the actual designs of the Facilities visited during the audit differed significantly, some of this was the result of improving technology and understanding of the risk concept but this would not explain the different forms of lay out or architecture. Clearly there was a degree of opinion engineering with the intent of providing a safer Facility but this could only be proven after it had been built and then it would be too late or too expensive to change the design.

Initial attempts to develop a risk ranking tools were based on subjective credit/debit factors. These resulted in a risk ranking for any particular design or development concept but it could not be done in absolute terms. The next step was to examine each element of the design (vessels, heat exchangers and others including the drilling program, which can be one of the more complex issues to be analysed) to determine if they could be characterised in a consistent manner. This involved assessing the average number of fittings, flanges, valves, instruments and other potential sources of leakage. With knowledge of the fittings and the use of accident databases it was easy to develop a leak profile of size and frequency per year for each unit and pressure regime. Fortunately the offshore oil and gas process has some fairly fixed operating pressures so it was possible to produce an un-ignited and ignited leak spectrum for each item of equipment. This characterised the process in a consistent manner. All of the computation, including outflows, ignition frequencies and probability of fatality for a person in the area was standardised [3]. This has been called *pre-processed data* as the leak spectrum of the equipment was produced as a look-up table.

The next step was to examine the escalating or mitigating factors inherent in the architecture or lay out. Some of these were based on research of the literature and others on reasoned subjectivity, as is normal with many Quantitative Risk Assessments. A similar approach has been proposed for the Chemical Industry. [4]

Further accident rates for slips, trips and falls, shipping impact, helicopter travel and other incidents, such as structural failure and the effects of seismic action was derived from various documents in the literature. More particularly the likelihood of shipping impact is dependent on the proximity of the installation and the Shipping Highways. This was reduced to a typical set of values based on the area of the North Sea and not the exact location. The location is, by definition, fixed by the reservoir and not the shipping highways.

RISKS DURING CONSTRUCTION AND DEMOLITION/ABANDONMENT

What is probably of more importance is the true impact of SHE as it is evident that different safety standards are used in different nations in the world. Risks during construction are definitely a function of the *safety culture* and *regulatory regime*. Within Europe the risk to life varies by a factor of about 5 between the most and least dangerous regimes. Even the risks in USA are a factor of over 2 higher than that in Britain, which has, fortunately, the best performance in the EU as a whole [5]. Clearly, a moral approach has to be adopted and the *Safe Working Practices* that would be adopted in the country purchasing the item must be adhered to and assured by the country manufacturing that item. If this is not so there is a dual standard being applied. As an example it should be noted that the number of miners killed in China in 2008 was 3,200 and nearer 3,750 in 2007 [6]. Is it appropriate to condone this in order to satisfy the financial needs of a project?

Following decommissioning it is self evident that the main part of the size reduction of an offshore facility must be carried out on land. The risks associated with helicopter transport are one of the major contributions to the risk incurred by the worker. The objective should be to fill the materials with an inert blanket, close all of the ends with blanks and then to transport large units to a place on shore where it can be cleaned and reduced in size. It will also allow a more structured approach to sorting the materials for re-cycling. In the case of the offshore industry apart from the risk associated with demolition the major feature is helicopter travel where the risk is 2×10^{-7} per trip plus 4×10^{-6} per hour in the air. [CAA data inside [3].) At the time of writing this statistic was highlighted by the loss of 16 souls following the crash of a helicopter off

Peterhead on 1st April. The human risks as well as the lower environmental impact of offshore construction/demolition show that, without any further thought, the work onshore should be maximised. The demolition of on-shore plants has similar problems but the cleaning may be more local. This is a topic in itself and will not be expanded upon in this paper.

The final size reduction for both on and off shore equipment will require a detailed plan or approach. The means of purging the equipment and the disposal of the residues is a case specific issue which is outside the scope of this paper. The order in which equipment is removed may depend on not only the location but also what it is supporting. While the general approach might be "outside to inside" and "top to bottom" this may not always be possible. For example it might be necessary to remove the underhung piping from a compressor before the compressor itself. In addition it is possible that one piece of equipment supports another.

ENVIRONMENTAL IMPACT DURING OPERATION

Most, if not all of the processes, will produce pollutants. These will vary between process and process but there are three common features, CO_2, NO_x and Pm_{10}s (and to a lesser level SO_x) will have its own particular bi-products which must be treated on a case specific basis. In particular the offshore oil industry has three particular pollutants: oil VOCs and chemicals in the produced water. The valuation of these will be given under a specific heading. No attempt has been made to assess the production of SO_x for no other reason than that it is fuel dependant and without the prior knowledge it is not possible to carry out a meaningful assessment.

The energy load for compressors can be assessed by means of simplified or *pre-processed data*.

Taking the offshore environment in particular it is to be found that the value of $\{(\gamma - 1)\ TZ/\gamma M\}$, (a constant in the power equation), tends to a constant of 2.66 K kg $kmol^{-1}$.

Where, in consistent units: γ is the ratio of specific heats at constant pressure and volume; T is the suction temperature; Z is the compressibility; M is the molecular weight.

In practical terms the compression ratio tends to be a constant due to the limits of the stage discharge temperature. This allows the simplification of the energy demand on a compressor. A typical hydraulic efficiency of 75% can be used such that the final power load is a constant $\times$ throughput. Refrigeration units can be treated in a slightly modified manner.

The same argument can now be applied to pumps. Power can be assessed readily using pre-processed calculation for pumps. The impact in so far as carbon dioxide is concerned can be assessed, for say a pump by a simple approach of a constant times throughput, times the specific gravity and the pressure head (all in consistent units). A typical hydraulic efficiency of 75% can be used. If appropriate furnaces can also be included with a modification for heat or energy recovery.

In the offshore environment drilling has a fairly constant power consumption which can be included on a well basis.

It is clear that the final summation will probably miss some of the smaller unit loads but by applying a global 30% for the offshore oil and gas Industry in particular to the assessment of the loads for major power consumers (or a value appropriate to another industry) the final carbon dioxide load can be assessed. It is of note that the final load can be assessed with a high degree of accuracy before the full electrical list is produced so allowing the earlier purchase of a power plant.

POWER PRODUCTION

In the same manner it is possible to assess the carbon dioxide load from the electrical load. There is a trend towards the use of gas turbines followed by a secondary heat recovery using steam and steam turbines. The conversion of power to carbon dioxide is fuel dependent and also dependent on the efficiency of the generation. There is, unfortunately, a range of efficiencies for gas turbines. At the 5 MW level this can range from 25% to 40%. To the first approximation a value of 35% has been used. It might be appropriate to include this impact in the bid assessments for such units, as; in real terms it may be better to spend more for the more efficient unit. In the case of an offshore platform this will extend the self sufficiency which will reduce the end of field life ***Op***erating ***Ex***penditure (OPEX) for an offshore installation.

If the power is generated as part of a Combined Heat and Power unit (CHP) suitable allowances can be incorporated into the *pre-processed data*.

The following table gives the CO_2 formation for different fuels.

Associated with power generation are traces of unburned hydrocarbons which are trivial in real terms but there is also the production of NO_x and particulates (Pm_{10}). Both of these have a health impact. Of course the classic *smogs* of yesteryear were the result of SO_x produced from Sulphur in the fuels which resulted in thousands of premature deaths and also the Clean Air Act (see later). Attempts have been made to put a value on these pollutants based on medical data but they always appear to be less that the trading value of CO_2. This was illogical and some allowance has now been made for the persistence of the pollutant and the equilibrium value, not the averaged value.

Each pollutant can be given a value based on the health of the public at large or the damage to the environment.

FUGITIVE EMISSIONS

Fugitive emissions and other losses can be assessed for each piece of equipment from data bases and rather surprising it is of note that the fugitive emission losses are far higher than

Table 1. Carbon Dioxide formation for 1 MW · hr

Fuel	CO_2 Production kg/hr for 1 MW.hr
Gas	520
Diesel Oil	630
Coal (taken as carbon)	1,175

the leaks. Fugitive emissions last for 8760 hours per year at a low rate but true leaks last only a few minutes during shut-down cycle but are of course at a higher peak rate. Many years ago [7] the material losses across an Olefin Plant were investigated in some detail. The results were also based on the monitoring of leaks from flanges, valve glands and other sources of fugitive losses. It was possible to measure the losses and then, as a result of the higher diffusivity of hydrogen, to verify the accuracy by measuring the hydrogen to ethylene ratio changes through the plant. The theory and practice of this study did show that mass losses due to fugitive emissions of about 1% were credible.

ENVIRONMENTAL IMPACT DURING CONSTRUCTION AND DEMOLITION/ ABANDONMENT

The impact on SHE during the operational phase of the life of an installation is predictable with a high degree of accuracy (+/− 20%). The impact during the first and last phases of its life is less certain but could be of equal importance. It is more than likely that equipment will be sourced beyond the national shores on another continent and that the ores for the raw materials may be mined in yet another continent. This will involve transport on land and sea. There is an impact during the construction itself and the release of pollutants from steel works and also fabrication processes. (In particular, electric arc welding produces NO_x). Finally there is the pollution which results from the cleaning of the equipment and making it safe for recycle as well as the recycle or destruction of waste chemicals or dumping of materials that can not be recycled. Many abandonment projects have targets for recycle which may be over 95% but it is the sweetening process or making the equipment safe for size reduction that is the main source of pollution. This is exemplified by the re-use of Brent Spar as a quay in Norway where the impact of making new steel was balanced against the cost of the recovery and reuse of the old Brent Spar structure. In reality the health aspects of the re-use option were higher due to the chemicals used in the clean up process. As a result the health implications more than offset any pollution savings.

Data for the amount of pollutants produced are available for transport by bulk ore carriers and extraction equipment such as drag lines and trucks. The problem lies in the assessment of the environmental and safety impact during the extraction and refining processes, the safety and environmental standards will vary around the world. Taken globally the environmental impact for the production of steel is fairly constant wherever it is produces. It does not matter where the ores are sourced and where they are refined the basic environmental impact of CO_2, NO_x and Pm_{10} is virtually the same from removing the ore from the ground through the refining process to its final use. What is less certain is the deviation from accepted norms due to poor maintenance on diesel drivers and poor (higher sulphur) diesel fuels and the pollution generated during the refining process due to higher sulphur bearing coals and other emissions. This is not readily assessed but is likely to be significant.

The following table illustrates the formation of different pollutants for the production of 1000 tonnes of steel in the UK. All values are in tonne. (Source – Confidential). The ore is taken to come from Australia but coal and limestone is taken to be sourced in the UK.

Pollutants for demolition can be assessed in a similar manner. (Source – Confidential).

In the case of the offshore industry there is a further CO_2 load of 0.75 kg per passenger km for transport by helicopter.

HEALTH OF EMPLOYEES

There are questions which now need to be answered. If it is necessary to have a plan for construction in the UK it would also be appropriate to have an assessment of the risks created by the construction of fabrication elsewhere in the world. If it is necessary to carry out a risk assessment to satisfy the requirements of the HASAW etc. Act in the UK why should this not be appropriate elsewhere in the world?

IMPACT OF TOXIC POLLUTANTS ON THE HEALTH OF THE POPULATION AT LARGE

One of the dilemmas will always be the global impact on the health of those manufacturing at large. This will include not only the hardware but also the products if they are chemical in nature. Serious attempts have been made by researchers to assess the likely *premature fatalities* from pollutants. The concept of *premature fatalities* leads to a bit of confusion. Was the person just clinging to life and the pollution

Table 2. Pollutants produced for the production of 1,000 tonne steel

Phase	CO_2	NO_x	Pm_{10}
Extraction	44	0.3	0.2
Transport to jetty	48	0.3	0.2
Transport by sea	1,400	4	2
Transport from jetty	48	0.3	0.2
Steel Manufacture	1500	2.5	1.2***
Fabrication	370	1	0.1
Transport to site	55	0.3	0.2
Total	3,465	6.7	4.1

***This value is site specific.

Table 3. Pollutants produced for the abandonment of 1,000 tonne steel

Pollutant	Tonne produced
CO_2	330
NO_x	7
Pm_{10}	0.5
SO_x	1.5***

***This value is site and fuel specific.

Table 4. Typical premature fatalities per 10^3 taken from [8]

Nation	Average Pm10 $\mu g/m^3$	Premature deaths per 10^3
Canada	21	0.127
China	80	0.212
Egypt	137	0.21
Eritrea	107	0.05
Russia	25	0.258
UK	60	0.21
USA	72	0.14

Table 5. Values for the pollutants and life in the SHE life cycle analysis

Life	£5M
CO_2	£12/tonne
NO_x	£150/tonne
Pm_{10}	£150/tonne
SO_x	£250/tonne
VOC	£100/tonne
Methane	£250/tonne
Oil	£7,500/tonne
Benzene	£750/tonne

precipitated the death a few days early than expected? Or, was the health so impaired that the pollution precipitated the death a few years early? There is a further difficulty in that the impact is probably multi-variable with both Pm_{10}s, NO_x and SO_x. Data from WHO [8] seems to show a poor correlation of premature fatalities from Pm_{10} with a range 0.1 to 0.3 per thousand of population. Typical values taken at random are:

This is contrary to expectation as other work would suggest that the incremental rise of pollutant can be correlated against premature fatalities [9 & 10]. Part of the difficulty may be that there is persistence within the atmosphere of the earth and that some stable concentration is finally reached which is in equilibrium between that produced and emitted into and removed from the atmosphere. The impact is proportional to the production rate and is most likely to be more local to the source of the pollutant. The evidence also suggests that there is a threshold value for pollutants which has limited effect on health but it is the peaks which cause the fatalities. The extremes, which create the health hazards, may be created by local short lived meteorological conditions which result is trapping or poor dispersion. [9] indicates that an increment of 10 $\mu g/m^3$ in Pm_{10} might result in an extra 1% premature fatality. [9 & 10] indicate that the background concentrations of Pm_{10} and NO_x are roughly the same in the range 40 to 60 $\mu g/m^3$ and 50 to 100 ppb v/v. The production rate from Britain is about 263,000 and 2,219,000 tonne respectively. Most of the Pm_{10} (70%) originates from diesel power units (and also aero engines) and 15% from power stations. Surprisingly NO_x is produced by humans, as Nitric Oxide [10], in the lungs and respiratory tract but the main contribution comes from power stations (50%) and vehicles (24%). [10] suggests that the threshold for NO_x affecting asthmatics is about 200 ppb v/v. This is again support for the concept that the back ground concentrations are tolerable but it is the peaks which should give cause for concerns. Using the toxicological data on the *average concentrations* of the two main pollutants indicated that there should be no premature fatalities but WHO [8] indicated that there are a significant number of fatalities which can not be dismissed. However, if the peak values are examined, particularly in the UK it is evident that excursions beyond the threshold do exist for some days per year and as was the experience of *smogs*. These were caused by extremes of meteorological activity and of course result in the major crops of fatalities. The premature fatalities quoted by WHO [8] do, therefore, have credibility.

Previous attempts to quantify the impact of pollutants as a value per tonne [12] produced very low values of about that of the value of CO_2. This was illogical so this has been re-visited. Taking the average production of Pm10 and NO_x across the UK it is evident that either the pollutants do not disperse vertically, which defies the dispersion theory, or that they have a *persistence*. That is, there is equilibrium developed and it will take some years for the concentrations to fall significantly even if no further pollutants are added to the atmosphere. The same is true for CO_2. The best estimate for the *negative cost* of the two main pollutants, Pm_{10} and NO_x, in terms of health are £150/tonne. It has not been possible to separate the two but as the concentrations of both seem to track each other it might be appropriate to treat each as the same. The atmospheric concentration of SO_x has fallen steadily over the years [11] but it also seems to catalyse the impact of the other two pollutants [11] it would be necessary to give it a higher value of £250/tonne. These values have some caveats. The value of a life which has been seriously impaired by other effects can not be the same as that for a healthy person and the effect of *persistence* of the pollutant has been taken into account. (All values based on 2009 assessments.)

These values are much higher than previously proposed [4] and are more in harmony with a logical analysis. However the cost to the project is likely to be second order to the implied cost of CO_2.

The assessment of the true life impact cost of the release of carcinogens is equally difficult. A value of £750 per tonne has been proposed for one of the more common materials, namely Benzene. This is still believed to be accurate and is also in harmony with the toxics quoted above. Benzene is a known cause of leukaemia and other Carcinomas, the difficulty is that the known cases for leukaemia are available but it is difficult if not impossible to ascribe the correct allocation to Benzene.

It is significant that the break-up and disposal of materials for the French Aircraft Carrier *Champlain* was awarded, not on cost but on health grounds because of the proven skills and the ability to control losses of Asbestos. It might have been broken up more cheaply in another country but what might have been the impact on life in that area?

IMPACT OF NON TOXIC POLLUTANTS ON THE ENVIRONMENT

The implied value of Carbon Dioxide can only be set against *carbon trading*. This is at present about £15 to £25 per tonne. Further there is an implied value through the UK Carbon Reduction Commitment for a trading value of £12 per tonne [13]. There is no scientific justification for these values; they are based on judgement and a perspective of greenness or being seen to be taking global warming seriously. There is a danger that a company may find that if it values CO_2 at too high a value it might suffer a loss of sales due to high product costs.

The cost of a 1 MW wind turbine located off shore has been quoted as £2,400,000 per MW [14]. With the utilisation efficiency of about 30% the actual carbon dioxide savings taken over 20 years and after allowance for fabrication is between 62,000 and 28,000 tonne giving a price of carbon dioxide equivalent to £40 (from coal) to £85 per tonne (from gas)!

Other green house gases such as **v**olatile **o**rganic **c**ompounds (VOCs) can be assessed against their green house effect. Methane has a value of 21 against CO_2 and other mixed hydrocarbons are less. A middle ground of £100 per tonne would be appropriate. It might be noted that this value is approaching that of a toxic which can cause premature deaths. It might be asked if this is appropriate.

The cost of oil pollution is definitely location, weather and oil nature specific. If the source of the pollution is some distance from the shore and may be altered or in the case of oil digested by organisms before it has any true environmental impact. Spills in deep and remote water are often broken up and dispersed by wave action and then digested biologically before they reach land. The blow out in 1977 on Ekofisk resulting on losses of some 30,000 Te oil had very little impact due to the dispersion of the oil by the release itself. The clean-up costs following the loss of the *Braer* in 1993 near to Sumburgh Head in the Shetlands with the release of some 80,000 tonnes of oil was $8 million but should have produced much higher clean-up cost if it were not for the weather [15]. (Compare the costs for the *Sea Empress* in Milford Sound, £100 million for a similar release [16].) The costs of clean up may also be compounded by litigation as was the case of the *Exxon Valdez* in Alaska. Clean up costs taken from [17] show a large scatter due to the location and loss of such businesses as Pearl and Fish Farms, however an averaging cost of £7,500 per tonne (2009 values) is appropriate.

VALUE OF LIFE

It is inevitable that there has to be an assessment of the value of life. The National Institute for Clinical Excellence (NICE) have an implied value of about £1 million per life extended beneficially. R^2P^2 [18] gives a value, in 2009 terms, of about £1.2 million. Such a sum would satisfy a substantial pension and a payment for the anguish following the loss of life. The concept of *As Low as is Reasonably Practicable* (ALARP) seems to be moving away from the concept of *grossly disproportionate* to *if it can be done, it is practicable and the cost is not an issue*. This is a strange attitude as one government body sets some implied value to life for Government purposes and another sets a much higher implied value for Industry, could this be a disincentive to production in the UK? This produces another dilemma. Is the value of life the same round the world? Should one nation impose its values on another? The answer to both questions must be in the affirmative or else the playing field will not be level. For the purposes of this paper it is appropriate to set a value of £5 million per life as that life may not be in the UK.

Summary of all values in the risk equation:

QUALITY CONTROL AND ASSURANCE

Safety is not only affected by the design of the equipment but also by the quality of both the manufacture and the quality of the materials used in the manufacture. Failure of the equipment will at best result in lost production but at worst could lead to a major incident with a significant impact on SHE. It is becoming clearer that products bought beyond the national shores may not have the same attention to QA and QC.

It is evident that on a global basis specifications, quality, quality control and materials specifications may suffer from local variations or interpretation. While there may be some form of assurance of the use of international specifications it is becoming evident that these are not necessarily being matched. A recent example of failure of the QA/QC is to be found in the purchase of materials for hanger rods for a bridge over the River Clyde. Either the quality was not specified completely or the quality of the steel was not adequate as the hanger rods failed inside 6 months of the bridge opening. It is not clear how much attention was paid by the Construction Contractor to Mill Certificates or if they had been available (or falsified). This information is not at present in the public forum. It is quite likely, as shown above and from allegorical stories that the Quality aspects may not be to international standards. How this is controlled is not for this paper but it is clear that some form of checks are carried out as the product, hardware or chemical, is produced to ensure that the desired standards are met. The only means of ensuring quality is the use of a detailed pre-bid audit of all potential manufactures. This must be done on site and not remotely and may take some time. The down side risks of a failure in the audit process may be extreme.

CONCLUSION

It is has been shown that it is easy to make an assessment of the total life cycle costs of Safety, Health and Environment at a very early stage in the development of any project. This also includes the purchase of bulk chemicals. The bid selection can either be based on given targets for SHE impact, global and local which should not be exceeded or the bidder should be asked to give an estimate of the SHE impact global and local that will be produced with the basis of that assurance. The bidder should also be made to make an assessment of the likely impact on the local environment and also the potential loss of life during the fabrication. The annualised cost of SHE can then be made.

It is becoming more and more important that the overall fuel efficiency of the process is maximised on a cost and environmental basis. This means that the unit cost of a power user or producer must be built into the overall bid assessment.

For a major fabrication project the bidder should be subjected to an Audit to ensure that there is the appropriate competence to ensure compliance with SHE standards. This is not all, it is necessary to assess the strict adherence by the producer to International Standards of Quality Control and Assurance and positive material identification. If this is not the case the items may not be "fit for purpose" and may result in a significant loss of availability, production and damage to the environment which would more than offset any financial savings.

The adage "*buy cheap, buy dear*" is as applicable in the 21st Century as at any time in the past.

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